Applied Mathematical Modelling 37 (2013) 8796–8812

Contents lists available at SciVerse ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Coordination mechanism for capacity reservation by considering production time, production rate and order quantity

Yahya Pezeshki [a,b], Mohammad R. Akbari Jokar [b], Armand Baboli [a,*], Jean-Pierre Campagne [a]

[a] INSA-Lyon, DISP Laboratory, Villeurbanne F-69621, France
[b] Department of Industrial Engineering, Sharif University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 16 September 2011
Received in revised form 25 March 2013
Accepted 6 April 2013
Available online 26 April 2013

Keywords:
Supply chain coordination
Contracts
Capacity reservation
Inventory cost
Information updating

ABSTRACT

In this paper we study the coordination of a dyadic supply chain producing a high-tech product by contracts. The product has a short life cycle and the buyer faces stochastic demands during the selling period. We consider the production time, which causes the inventory costs on supplier's side. As the supplier builds production capacity in advance, the production rate is limited to the capacity created during the production time. In addition, we take into account the inventory cost and operational cost for the buyer. We examine the model under both full information and partial information updating situations, and propose a coordinating contract for each case. Our analysis includes the study of members' decisions under both forced and voluntary compliance regimes. Numerical results are presented to provide more insights into the models developed and the mechanisms proposed.

1. Introduction

In centralized supply chains (hereafter SC), information is shared among all the members and a credible information flow is well established. A central planner makes all the decisions optimally and creates integrity among the members. In contrast, a decentralized supply chain is based on the members' individual rational decisions. The behaviors of the members result in double marginalization which degrades the efficiency of the total supply chain. Double marginalization was first introduced in the economics literature by Spengler [1]. Although self-interested decisions seem to be optimal from the member's point of view, they can damage the entire performance and credible information sharing in SC. Creating a partnership among the members and sharing information credibly throughout the SC can improve efficiency. A well-designed contract can coordinate the decisions of the self-interested individual parties to achieve the maximum profit of centralized SC. In complex SCs, achieving the maximum efficiency is idealistic, but the efficiency can improve significantly with well-designed contracts. In this study, coordination of members' decisions in the context of a Capacity Procurement problem, also known as a Capacity Reservation problem, is investigated.

We start by introducing the Capacity Procurement problem as defined in the existing literature [2–7], among others. The Capacity Procurement problem, hereafter referred to as CP, concerns production capacity determination in a newsvendor model comprising a supplier (he) and a buyer (she). The buyer faces stochastic demands and both members have the same

* Corresponding author. Address: Building Jules Verne, 19 avenue Jean Capelle, 69621 Villeurbanne Cedex, France. Tel.: +33 472436201; fax: +33 472438538.
E-mail address: armand.baboli@insa-lyon.fr (A. Baboli).

0307-904X/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.apm.2013.04.007

knowledge of demand distribution. As capacity building has a long lead time and is expensive, the supplier should decide on the capacity level well before the selling season. The buyer therefore places her initial but costless and nonbinding order well in advance of the selling season. This can be considered as demand forecast information sharing. Regarding his own costs and profits, and the buyer's initial order quantity, the supplier determines his capacity level and builds the amount of capacity decided upon before the selling season. When she starts the selling season, the buyer observes the actual demand and places her final order regarding the realized demand, with the restriction that the final order cannot be greater than the initial order. The supplier incurs capacity building and production costs and should decide on capacity level, whereas the buyer has no explicit cost and determines her initial order quantity. Moreover, in the literature price is mostly assumed to be exogenous.

In this paper, in order to coordinate the main decisions concerning the Capacity Procurement problem, a dyadic SC is considered with stochastic demand, exogenous prices and various types of costs. In the existent models in this field, formulating capacity as a quantity of products leads to some unreasonable results. More precisely, the supplier is implicitly assumed to have infinite capacity rate, which results in the interpretation that he can postpone the production phase until the demand is observed and the buyer places her final order. The supplier then produces goods with the infinite rate. As a result, the supplier never has leftovers, and if sufficient capacity is at hand, he also does not have shortages. As it is clear that these possibilities and consequences differ substantially from a realist model, capacity is redefined in this study as a production rate. This new formulation of capacity resolves both unrealistic consequences and incorporate production time as a new decision variable in the model, thereby taking into account inventory holding costs on the supplier side. The supplier thus decides on the production rate and production time simultaneously. The buyer incurs purchase costs according to the terms of the contract. Furthermore, various types of costs such as operational cost per product unit, inventory holding cost and lost sales cost are included in the model.

In this paper the coordination of decisions is examined under both forced and voluntary regimes. The model also includes analysis of decisions in both full and partial information updating. In situations with full information, the buyer observes actual demand just before the selling starts, and can place her final order after resolving all demand uncertainties. But with regard to the situation with partial information updating, stochastic demand is modeled as the sum of two independent stochastic parameters. At a specific time which both the supplier and the buyer are aware of, the value of the first stochastic parameter is observed by the buyer, but the value of other parameters remains uncertain. In this situation, the buyer should place her final order, considering the observed value and remaining uncertainty. Coordination of the supply chain is investigated under both compliance regimes and in both information updating situations, and proper mechanisms are developed and proposed for each situation. Non-concavity of profit functions of the centralized SC, the supplier and in some cases the buyer, along with the complexity of objective functions are the most important challenges in profit maximization of the model.

From the applicability point of view, this model is suitable for high-tech industries such as semiconductors, telecommunications, and optoelectronics [3,4,8,9]. In these industries, manufacturers face capital-intensive production equipment and almost continuous technological innovation. Capacity building lead time is long and products have short life-cycles with highly uncertain demand in high-tech industries. Manufacturers should determine their capacity level well in advance of the selling season. Exogenous prices are also a common assumption in this context because it is argued that either the price can be assumed to be constant or it is determined in a completely different way than capacity level and order quantity. This model is also appropriate for those groups of fashion products with highly reputed brands, where managers do not allow price reduction for demand promotion because they believe that this would deteriorate their brand names [10]. As a consequence, price can be assumed to be exogenous for such products.

The remainder of this paper is organized as follows. A literature review is presented in Section 2. Notations and assumptions are categorized in Section 3. Individual self-interested decisions of the supplier and the buyer, as well as optimal decisions of centralized supply chains under wholesale price contracts are examined in Section 4. The objective of this section is to provide insights into the performance of famous wholesale price contract in this context, along with the potential for improvement. In Section 5, a coordination mechanism called the PARD contract is proposed to coordinate decisions in the decentralized SC in a full information updating situation. In Section 6, an RCRS contract is designed and proposed to coordinate decisions in the decentralized SC, in a partial information updating situation. Section 7 provides numerical results to provide a better understating of the models and proposed mechanisms. Finally, findings and directions for future research are summarized in Conclusion.

2. Literature review

Supply chain coordination and capacity reservation problems have received a great deal of attention in the recent years. In a centralized supply chain, the information sharing is well-established and there is a central planner who makes all decisions and aligns all actions. On the other hand, in a decentralized supply chain, the firms decide based on their own interests leading to an inefficient supply chain. In order to improve supply chain performance, the firms can design a coordination mechanism by employing an appropriate contract. In a capacity reservation problem, the supplier bears the risk of building high capacity and the buyer takes the risk of large numbers of leftovers at the end of the selling period in a newsvendor setting. Considering inventory holding cost and operational cost for entities makes the problem more realistic