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A hybrid approach to select the best sourcing policy using stochastic programming

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ABSTRACT

Supply contracts are known as the communication link among supply chain members. As sourcing of required goods is a challenging issue for supply chain members, different sourcing types for different market conditions have been presented in the literature. However, the uncertain price condition has not been much focused in the previous studies, and in the limited works on this issue the correlation between the periods has been ignored. In this paper, sourcing policies are analyzed in a multi-period system in which price and demand follow a Geometric Brownian Motion with drift. Wholesale contract, option contract, and purchase from the spot market are considered as the sourcing alternatives for the buyer. This paper applies the stochastic programming approach to model these three types of sourcing based upon price and demand uncertainties. Afterwards, a hybrid supply model of these sourcing types is developed. By a numerical example, the simulation results of the developed models reveal that each individual sourcing alternative can be selected as the best one in each price and demand behavior. The results also suggest that the proposed hybrid model dominates each of the individual sourcing types. Finally, the paper reports the effects of cost parameter alterations on the solution of the hybrid model through sensitivity analysis.

1. Introduction

Due to the increase in outsourcing to provide material for production, nowadays the purchasing cost plays a significant role in the cost of production. The share of procurement cost increases up to 50–90% of the total income of manufacturing companies. Outsourcing can result in lower production cost and higher quality, but it will be challenging to manage the supply chain as the system is less centralized, and has more supply uncertainty [1]. This uncertainty will be more challenging when the raw material demand is highly varied, and its market price is uncertain. Contracts are used as practical disciplines to manage these uncertainties.

Wholesale contract and spot sourcing are two main practical purchasing disciplines for manufacturers to provide their raw materials. Wholesale contracts bring about price stability while much less flexibility. Also, they are known as an operational risk hedging tool for high spot market price and material unavailability incidents. On the contrary, spot sourcing provides more flexibility but more risk of price increase and material unavailability. In order to utilize the advantages of both disciplines, simple wholesale contracts have been extended to several contract forms such as option, backup agreement, revenue sharing, return, and quantity flexibility (QF) contracts. Real option contracts are identified as highly efficient tools to hedge risk of uncertainty that provide flexibility in an uncertain demand and price environment [2]. These types of contracts, which are widely used in high-tech industries [1], are characterized by two parameters, the option price and the exercise price. The option price is an allowance paid by the manufacturer (buyer) to the supplier. Through paying this allowance, the buyer assumes the right to exercise his option in the future up to the committed quantity by the pre-defined exercise price. In uncertain demand sourcing, a widely used real option contract is Capacity Reservation contract, in which the buyer has only the long-term supplier and has no access to the spot market. Exercising option in Capacity Reservation contract merely depends on the demand situation. In the presence of a spot market with uncertain price the buyer exercises the option if an order is needed and the spot market price is also higher than the exercise price. This paper studies this type of real option contract under the name of the "Option Contract".

In this paper, wholesale contract, spot sourcing and option contracture studied from the buyer's viewpoint. A hybrid contract is also developed and its performance is compared with the

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Table 1
An overview of the related literature.

	Demand uncertainty	Price uncertainty	Time correlation	Multi-period	Capacity reservation	Wholesale contract	Option contract	Other sourcing types
Inderfurth et al. [13]	√	√		√	√		√	
Inderfurth and Kelle [2]	√	√		√	√		√	
Serel et al. [11]	√			√	√			
Serel [12]	√			√	√			
Van Delf and Vial [10]	√		√	√	√	√		
Barnes-Schuster et al. [14]	√		√	√	√			
Xu [1]	√	√			√			
Li et al. [9]	√	√				√	√	
Zhao et al. [3]	√				√	√		
Wang et al. [4]	√				√	√		
Boulaksil et al. [7]	√			√	√	√		
Jin and Wu [5]	√				√			
Mathur and Shah [6]	√				√			Price compliance contract
Gomez Padilla and Mishina [8]	√			√	√			
Our study	√	√	√	√	√	√	√	*Hybrid sourcing type*

individual wholesale contract, the spot sourcing and the option contract. The problem which is addressed here is a multi-period sourcing with time correlated uncertain demand and price, an issue which has not been investigated in the previous works. The researches that have utilized real option contracts can be divided into two subgroups. The first category investigates one period sourcing problem for non-storable goods. Most of these researches consider only demand uncertainty [3–8], and few researchers have studied the presence of price uncertainty [1,9]. The second category assumes that goods are storable for infinite time horizon and thus consider multi-period sourcing problem [2,10–14]. This paper only verifies the literature of this category from the perspective of the uncertain variables, uncertainty modeling and sourcing alternatives.

In a supply chain consisting of one buyer and one supplier, facing the uncertain demand in a Capacity Reservation contract, Serel et al. [11] have investigated the reactions of the supplier and the buyer to two different periodic review inventory policies, namely S and (S_L, S_U) policies. They assume that demand is the only uncertain variable and also independent identically distributed (IID) in each period. While Van Delft and Vial [10] consider the correlation of demands and assumed demand to be a stochastic process. They also incorporate wholesale contract to develop a hybrid contract of wholesale and capacity reservation contract. In their study the long-term supplier is the only sourcing alternative whereas in the problem in hand the buyer has an option to buy from the spot market. Having two supply alternatives, Inderfurth et al. [2,13] consider the option contract in the presence of the spot market with its infinite supply capacity and uncertain price to solve a multi-period sourcing problem via base stock inventory policy. They assume that the demand for needed materials and the spot market price are uncertain. Serel [12] studied an one price option contract and assumes that the availability of the needed items in the spot market is also uncertain; moreover, it is shown that as this uncertainty increases the usage of long-term contract increases. Studies that incorporate option contract model the demand and price of each period as IID random variables. In the real world this assumption is often inacceptable. To overcome this drawback, the identicality and independency assumptions for distribution of uncertain variables are flouted by taking into account the correlation of the demands in successive periods as well as the correlation of the prices in these periods. A comparative study of the major works has been provided in Table 1.

According to Table 1 few researches consider both the demand and the price uncertainties in a multi-period sourcing. Besides, none of them investigate time dependency of the demands and the prices simultaneously. Hence, this paper considers the option contract, the wholesale contract and the spot sourcing in a multi-period problem with time correlated uncertain demands and prices, and a new hybrid contract of them is proposed. Also, this paper uses the scenario based discretization technique for modeling uncertainty. Using this technique enables modeling of the problem via the Mixed Integer Linear Stochastic Programming (MILSP).

This article is organized as follows: first the assumptions and decision variables of the problem are described. Then, the notations and stochastic models are presented in Section 3. Modeling uncertainties including the demand and the price of goods is described in Section 4. Simulation based method is developed to evaluate the policies from different models in Section 5. Using numerical examples in Section 6, the cost performance of different sourcing types is analyzed and sensitivity of the decision variables to the problem parameters is investigated. Finally, the conclusion and the suggestions for future research are presented.

2. Problem definition

This paper investigates the four mentioned sourcing types, i.e. wholesale contract, option contract, spot market sourcing, and a combination of them in relation to a two-echelon supply chain consisting of one supplier and one buyer. The main assumptions underlying the studied supply chain are as follows:

- The supply chain consists of one supplier and one buyer.
- The supplier sells one commodity to the buyer with an uncertain demand.
- The buyer has access to a spot market with uncertain price.
- The spot market is perfect competition and big enough such that the demand of the buyer has no influence on it.
- Price and demand are independent and follow a Geometric Brownian stochastic process with drift.
- The problem is multi-periodic, and the periodic-review base stock inventory policy is applied.
- The shortage is allowed for the buyer's demand and is considered as back ordered that should be fulfilled in the next period.