



An option contract pricing model of relief material supply chain

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ABSTRACT

Relief material management which aims to reduce the impact of disaster and maintain social stability is of great importance for nonprofit organization (NPO) such as government, department of civil affair or Red Cross. However, the research of efficiency and performance on this field has long been ignored. In order to improve the efficiency and performance of the relief material management, we apply the supply chain management method into this field. Considering the relief material management system as a supply chain with one buyer and one supplier, we introduce the option contract mechanism into relief material supply chain management. With reasonable assumptions, we design an option contract with two delivery steps, and build an option pricing model with binominal lattice to estimate the different values of the same option contract for both members of supply chain. Furthermore, we analyze the impacts of the different parameters (such as the ratio of inventory, subjective probability of disaster, etc.), on the supply chain and its members in detail. The numerical example presented at last demonstrates that, with two delivery steps, there is a feasible price range of option contract which makes both members of relief material supply chain profitable and willing to conduct the transaction with option contract.

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1. Introduction

Relief material supply chain management differs from the traditional supply chain management. According to Beamon's [1] study, these differences include nonprofit identity of the buyer, high stakes (often life-and-death), unreliability, incomplete prior information and demand pattern. For these features do not fit the profit-maximization assumption of traditional supply chain management, we cannot duplicate its methodology and put into practical use. Therefore, a new tool which more effectively suits relief material supply chain management is needed to improve the performance of relief material supply chain.

Option is a kind of derivatives, and for a long time it has been used as an effective tool to avoid risks and reduce uncertainty in finance. Many scholars had introduced the option as a kind of contract into real assets field and studied option contract in supply chain management. Essentially, option is a special right of choice: by pre-paying premium, the buyer gets the right to purchase (or sell) goods at fixed price before expiry date. This right of choice endows the buyer with the power to control large amount of materials with small amount of funds, reduce risk and delay decision. These three powers can cope with the problems of

different demand pattern, high stakes and lack of prior information, respectively. Therefore, we believe the option contract can fit the specialties of relief material supply chain. However, the literatures on combining option contract with relief material supply chain can hardly be found. Our work would venture into this gap.

The purpose of this paper is to build an option contract pricing model in relief material supply chain and to find a feasible range of prices within which both the buyer and supplier are profitable and willing to conduct the transaction with option contract instead of wholesale price mechanism. To achieve this aim, firstly we design an option contract with two steps delivery process and present the conditions, which the pricing model must satisfy. Secondly, we build an alternative binomial option pricing model to estimate the value of option contract for different members of supply chain. The option pricing model presented in this paper is more accurate and consists with reality for it takes account of the price fluctuation of relief material and subjective probability of disasters. The numerical example demonstrated at last shows that the feasible range exists as long as the option pricing model subjects to the given conditions.

The paper is organized as follows: In Section 2, related work from literature is reviewed. In Section 3, we design the option contract with two steps delivery and introduce conditions under which both the buyer and supplier are profitable and willing to conduct the transaction with option contract. Section 4 introduces

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the option pricing model and capital leverage index. Section 5 analyses the parameters in detail. The simulations results are presented in Section 6. Section 7 concludes the paper and presents perspectives for further work.

2. Literature review

In this section, we briefly review the literature in two areas, management of relief material and option contract in supply chain management.

Relief material management, as a kind of emergency management responses to unconventional disasters can reduce the impact of unexpected events and maintain social stability. Whybark [2] studied the management of disaster relief material inventories, divided the management process into three stages including acquisition, storage and distribution, and analyzed the similarities and differences between traditional commercial materials and relief material inventory. He presented a definition that relief materials management is a form of “social” management which serves broad social objectives as opposed to being used for the benefit of an individual enterprise, and has big differences from “strategic” materials management and “defense” materials management, which, respectively, aim to maintain national and regional economic stability and territorial security. Given the importance of relief material management, it is surprising to note that very little literature is available in this area. Scholars have long studied the relationship between commercial material management and economic behavior. However, research on disaster relief material is very limited. One exception can be found in the area of medical community that Bechtel et al. [3] studied the management of stockpiles of medicines, blood, and medical supplies and some of its approaches could serve as models for the management of other disaster relief material. Using stochastic programming, Barbarosoglu and Arda [4] built a disaster response model in an urban environment and explicitly studied the impact of uncertainty. Using a two-stage approach the authors first solved the response problem with stochastic estimates of transportation capacities, supply availabilities and demand based on various disaster scenarios. Beamon [1] considered humanitarian relief material supply process as a supply chain. By comparing and contrasting the commercial supply chain and the humanitarian relief chain, he pointed out several specific characteristics of relief material supply chains which differentiate them from traditional commercial supply chains, including: zero (or approximately zero) lead times, high stakes, unreliable, incomplete or non-existent prior information and different demand pattern. Lately Beamon and Balcik [5] presented a framework which can be used as basis for a performance measurement system in the relief material management field. Present researches on relief material management focus on logistic and operation research (see for example, [6–11]). But still, the risk management methods and models of contracts which are commonly used in supply chain management (see [12–14]), are rarely introduced into relief material management.

Cachon [15] generalized supply chain contract theory in 2003. Since then, scholars had done a lot of researches on supply chain contract and made great progress in this area, see relevant studies in [16–23]. The major supply chain contract can be divided into the following four main types: the wholesale price contract, the buyback contracts, the revenue sharing contract, and the quantity-flexibility contracts. Besides the four kinds of contract models mentioned above, there are quantity discount contract, number committed contracts, options contracts, delay compensation contracts, futures contracts, and punishment feedback contracts model. Among all these contract models, option contract, which

origins from financial derivatives, is a potential one. Kleindorfer and Saad [13] proposed the idea that the price of the contract should include two parts, reserve fee and executive fee. This idea introduced the concept of real option into contract pricing. Burnetas and Ritchken [19] used the case of supply chain with downward-sloping demand curve to study the option pricing problem and its impact to the supply chain. They are the first ones to analysis real option contract in supply chain from option pricing prospective. The value of option of service and non-storage commodity with cost and demand uncertainty was studied by Spinler and Huchzermeier [24]. Cucchiella and Gastaldi [25] hold the idea that supply chain under uncertainty requires flexibility. Since real option can increase the degree of flexibility, he implied real options method to supply chain management as a risk management instrument. Fang and Whinston [26], using option contracts as a price distinguishing tool, measured the demand type of enterprise and get the conclusion that even if demand type of buyers cannot be distinguished, option contract can still guarantee manufacturer the same profit. Wang and Liu [27] gave two necessary conditions of coordination on retailer-led supply chain. One is that the executive price must negatively correlate with premium price. Two is the obligations of manufactures must not be greater than the optimal yield under centralized system. Zhao et al. [28], taking wholesale price as a benchmark, studied the efficiency of options contracts in supply chain coordination. In the scenario analysis, individual risk preferences and bargaining power were taken in account. Guo's study [29] found that options contract is an effective risk management tool to overcome the problem of double marginalization, improve the performance and efficiency of supply chain and coordinate the behavior of members of the supply chain so as to achieve a win-win situation. All these studies, however, still revolve around optimize and coordinate problems of commercial supply chain. Few literatures can be found involving the combination of option contract and relief material management.

In this paper, we design an option contract for relief material supply chain and try to find out a feasible range of prices, which can be accepted by both members of chain. Compared with the literature presented above, our study is different in a few ways. First, our paper employs option contract as a risk management tool to cope with the issues of inaccurate demand forecasting and overstock in relief material management. Second, we provide conditions under which both the buyer and supplier will prefer option contract to wholesale contract in relief material management. Third, we take into account of price fluctuation and risk-free interest rate in option pricing model which makes the pricing process more reasonable and practical. Different from the existing binominal option pricing model proposed by Cox et al. [30], the contract trigger condition of our pricing model is the occurrence of disaster instead of material's price. The objective of this paper is to provide the feasible price range rather than finding the optimization point of profit sharing. Therefore, the bargain power and risk preference are not considered.

3. Problem description and conditions

3.1. Description

We consider the relief material management system as a single-buyer, single-supplier supply chain, in which the buyer stands for Nonprofit Organization (such as department of civil affair, FEMA or Red Cross) while the supplier stands for cooperation (such as manufactory or supermarket), with one kind of relief material, i.e., food, drinking water or daily necessity. In this model, we assume that if the disaster does not happen, the buyer

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