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A Supply Chain Planning Model with Supplier Selection under Uncertain Demands and Asymmetric Information

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Abstract

In this paper, a supply chain planning model including a manufacturer, a retailer and multiple suppliers under demand uncertainty with asymmetric information is considered. The manufacturer determines production, estimated quantity of defective components and the selection of suppliers. Quantities and quality of components are decided by the selected suppliers. The negotiation between the manufacturer and the retailer is based on buyback contracts. Due to asymmetric information, the quality information of components purchased from suppliers is unknown for the manufacturer. Thus, two scenarios are investigated for the manufacturer to estimate uncertainty of risk. The problem is analysed by a Stackelberg game where the manufacturer is a leader and the suppliers are followers. An optimization approach is proposed to solve the problem under demand uncertainty. A Stackelberg equilibrium is obtained by the proposed solution approach. Computational experiments are conducted to illustrate the features of the proposed models with different parameters. The results show the validity of the proposed model.

Keywords: global supply chain, supply chain planning; supplier selection, demand uncertainty; asymmetric information; quality management; game theory

1. Introduction

Nowadays, the outsourcing from suppliers to countries such as China or India has become popular. Companies establish their factories globally to decrease costs. The increased outsourcing accelerates the competition on quality in the global market. In this paper, a game theoretic model for global supply chain planning with uncertain demands and the supplier selection is proposed in order to improve quality and obtain optimal profits.

In order to reduce costs and improve quality in global supply chain planning, the supplier selection becomes crucial. Many researchers consider a variety of supplier selection problems from different perspectives. Vanteddu et al. [1] presents a supplier selection problem as a supply chain configuration problem that competing suppliers at a stage differ only in terms of costs and responsiveness. Xu and Nozick [2] formulate a multi-period single product supply chain as a two-stage mixed-integer stochastic program to optimize the supplier selection to hedge against the loss of the production capability at supplier sites. Mendoza and Ventura [3] propose inventory planning models to select the best set if suppliers determine the proper allocation of order quantities while minimizing the annual ordering, inventory holding, and purchasing costs under suppliers' capacity and quality constraints.

The quality problem associating with defects from suppliers or in the production process is widely investigated [4, 5, 6]. Quality issues have been studied intensively in supply chain planning. However, incomplete quality information has not been studied. From more practical perspective, it is important to assume asymmetric information for supply chain members due to different business strategies

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in the global supply chain planning. Esmaeili and Zeephongsekul [7] introduce a seller-buyer supply chain model with an asymmetric information structure. They assume that only buyer knows the demand function and is aware of the seller's setup cost and purchasing cost. Lei et al. [8] investigates the impact of asymmetric information on disruption management when disruptions of demand and costs are private information. Most of works related to asymmetric information by applying game theory assume that demand information is asymmetric. There are rarely researches considering asymmetric quality information by applying game theoretic approaches. Tse and Tan [9] study the unclear information of quality risk and visibility in a multi-tier supply chain. They consider the situation of asymmetric information between a manufacturer and a supplier. They focus on the manufacturer's decision making to manage risk and visibility in supply chain planning. The coordination between the manufacturers and the supplier is not investigated. A game theoretic model for single manufacturer and suppliers has been presented by Yin et al. [10]. However, the supplier selection and the coordination with retailers have not been studied in the conventional works.

The objective of this paper is to study a three echelon supply chain model with the supplier selection and asymmetric quality information under demand uncertainty. The problem is solved by a game theoretical approach. It is assumed that the quality information between the manufacturer and suppliers is asymmetric. Thus, a worst case and an average case are analyzed to estimate uncertainty due to asymmetric information.

The rest of paper is organized as follows. The problem description and modeling are described in Section 2. The solution approach is provided in Section 3. Numerical examples are shown in Section 4. Finally, the concluding remarks are stated in Section 5 with the future work.

2. Problem description

2.1. The three echelon supply chain

The outline of the supply chain model is shown in Fig. 1.

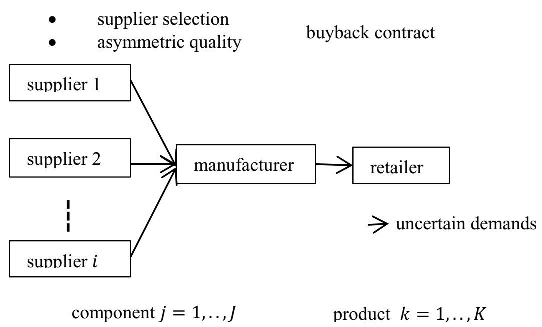

Fig. 1. The supply chain model.

In our model, a hierarchical supply chain consisting of one manufacturer which produces finished product k ($k = 1, \dots, K$), suppliers j ($j = 1,..,J$) as followers producing component i ($i = 1, \dots I$), and a retailer is addressed. In order to satisfy uncertain demands, the retailer orders finished products from the manufacturer. The manufacturer and the retailer are coordinated by buyback contracts. The retailer decides order quantities of finished products under demand uncertainty. The asymmetric quality information is considered between one manufacturer and suppliers in the paper. The manufacturer decides production and the selection of suppliers. Quality of components and quantity of components are determined by suppliers. The problem is formulated by a Stackelberg game where the manufacturer is the leader and both of the suppliers and the retailer are the followers.

2.2. Quality

Suppliers pay higher cost for producing one component if the reliability of the component increases. Thus, the production cost for one unit component i for supplier j depends on the reliability x_{ij} and the order quantity d_{ij} of component i for supplier j. The number of defective components is affected by reliability x_{ij}. If the reliability x_{ij} increases, the number of defective components decreases. The production cost is expressed by the cost function h_{ij}, such as $h_{ij} = A_{ij} + B_{ij}d_{ij} + C_{ij}x_{ij}$. A_{ij} is the fixed cost of production for one unit component i paid by supplier j. B_{ij} is the production cost responsiveness to the quantity of component i for supplier j. It indicates that if the order quantity d_{ij} is increased, production cost per one unit component increases. The increase of the order quantity of components causes the increase of production for the supplier. Thus, the supplier must pay more production costs such as machinery wearout costs or labor costs. C_{ij} is the production cost responsiveness to the reliability of component i for supplier j. It indicates that higher reliability drives the increase of the production cost. It is assumed that the number of defective component i for supplier j is normally distributed where μ_{ij} is mean value of number of defective component i for supplier, which is a constant known by both of the manufacturer and suppliers. However, the standard deviation of number of defective components δ_{ij} is a decision variable for suppliers which is unknown for the manufacturer. With the increase of the standard deviation δ_{ij}, the reliability of components will decrease. Therefore, there is an assumption in our paper such that reliability $x_{ij} = e^{-\frac{\delta_{ij}^2}{2}}$. The higher δ_{ij} reduces the reliability of components seen in Fig. 2. The negative sign of this assumption is that it becomes difficult to evaluate the quality of components if δ_{ij} is large, because x_{ij} tend to close to zero if δ_{ij} becomes large.

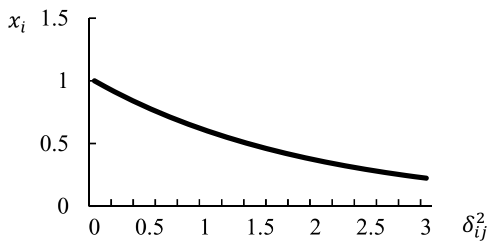

Fig. 2. Reliability and deviation.