# A TWO-ECHELON FUZZY GAME APPROACH TO OPTIMAL SUPPLY CHAIN DECISION IN SMALL OR MEDIUM ENTERPRISES 

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#### Abstract

In this paper, we will analyze the behaviors of enterprises and customers, and help them make best decision for geting optimal profits. Today small and medium enterprises play an important role in our economy. When enterprises are small or medium, they need to find an effective way to reach decisions. In the paper, we will employ game theory to analyze it. Also, as relationship of the manufacturer and retailers can be taken as Stackelberg behaviors, we will build models based on Stackelberg behaviors. In order to make optimal decisions for the chain members, we use crisp numbers and fuzzy numbers in expressing the market demand. After that, we will analyze which is more accurate to the real situation and which is better to gain more profit for the members on the supply chain. Finally, we can get conclusions for the members on the supply chain. We clarify the advantage and disadvantage about this model of supply chain taken by small and medium enterprises.


## Index terms

Game theory, fuzzy game, small and medium enterprises, two-echelon model, supply chairn, stackelberg, optimal decision.

## 1. Introduction

In the development of the society, the trading way is always changing. Except the complex supply chain (SC) in large enterprises, now new trading patterns in the SC continuously appear in many small and medium enterprises which play a pivotal role in economical decision. These enterprises don't have the complex SC, but they need a high efficient operation model.

### 1.1. Background

The SC of small and medium enterprises is always formulated by the manufacturer, retailers and customers. In this model, as the manufacturer supplies the goods directly, the model can save a lot of unnecessary overhead. Also, according to the direct contact between the manufacturer and retailers, the manufacturer can master the market demand

[^0]more clearly. So the manufacturer will get more reliable market data to analyze the situation and consider the future development of the enterprise.

This model is benefit for the retailers and the manufacturer. But the problem is how to decide the order quantity and sale price of goods for retailers and how to decide the wholesale price and total quantity for the manufacturer. They all want to maximize their profit.

In this paper, we will analyze the SC in the model mentioned above and solve the problems for enterprises. Let us consider an enterprise of new mobile phone. This model is in heavy competition to sale goods and needs to decide the quantity and price for themselves. They face complex economic environment. Scientific decisionmaking is important in the economic activity to adapt an optimal decision in a invincible position. Scientific decision-making can be decided after considering several aspects. For example, considering the order quantity, the cost, the profit and so on. In order to make a intuitive impression for enterprises, statistics and Mathematical model are always used to deal with these problems. Enterprises will have accurate and useful statistical information by doing these analysis. In the two-echelon SC problem, we need make decision on the basis of some mathematical models.

SC is a network organization connected by manufacturers and sectors. If enterprises have effective SC, it can quickly response to the market demand. The SC includes all of planning, decision making, demand forecasting, inventory planning, resource allocation, equipment management, channel optimization, production planning, material requirements and procurement plans. In the whole SC, the core enterprise as a leader needs to take measures for making all involved enterprises to be active effectively, and optimize the resources of the whole SC. To produce better products with the lowest cost and the fastest speed to satisfy the customers' requirements. Enterprises should consider many factors which effect the final profit and make a optimal decision. Game theory [1], [2], and Bilevel-programming [3], [4] are used to solve these problems.

Market demand can be decided by investigating the demand in the past and analysing the factors that affect market demand. Using the rule of change of market demand enables us to predict the future market demand. Let us consider factors that affect market demand. After knowing the market demand in the past, we can analyze how the market demand will be in the industry, which factors will affect the development of market demand and how to affect the market demand in the future. It is benefit for us to predict the market demand.
In each industry, we can find out some relevant factors. For example, the market demand of baby cars is closely related to the baby's birth rate; the market demand of gasoline is closely related to the quantity of cars. Generally speaking, we often use population, export volume and gross domestic product to analyze the market demand. These data are more authoritative. Using these factors can be more accurate to predict other products. Although market demand can be analyzed by these methods, it is also affected by many factors and it is always uncertain. To make our model more near to
the real situation and make the result more accurately, we will apply fuzzy numbers to express the market demand.

### 1.2. Existing Research Works

Nowadays, Game theory plays a pivotal role in the SC management which becomes more and more important in optimizing the profit of whole SC. Game theory is one of the vital analyzing tool in economics on the incentive structure by studying interaction between supplier and retailer. As a mathematical theory and method, game theory deals with corovides an efficient and effective means in the SC management consists of the whole process from raw materials procurement to the final goods consumption including the various relations, information, logistics management, etc. Game theory enables us to improve the customer service and increase the economic value of the process. Game theory is widely used in the decision-making, production/price settled and SC network equilibrium problem. Actually, every part of SC can focus on their own core competitiveness, on the other hand, they always ignore the win-win cooperation of SC. Therefore, it is necessary to consider the coordination though game theory to maximize the profit. Ilham Slimani [5] introduces the model which explains the coordination between the supplier and retailers through sharing information. In order to achieve a win-win situation, HuilinChen [6] makes a full-return coordination mechanism in twoechelon SC, so as to incentive the ordered quantity of retailers. In a real situation, the market demand used to be uncertain. There is a selling season when selling the products to customers. Cai Jian-hu [7] consider this situation and gives a chance to make retailer order product before the selling season by providing price incentives. Competitive can make the participate individual get more profit. But, coordination can bring more profit for the whole SC. From this perspective, the supplier offers a different type of scheme for a better result.

It is also important to ensure and enlarge the market demand so as to get more profit. B.C. Giri [8] consider the sales' effort and retail price as two important factors which affect the market demand. Therefore, he analyses the two-echelon SC effected by retail price and promotional effort. Some researchers focus on Quality Control to get the optimal decision. Hong Jiang-tao [9] studies the quality control of two-echelon SC and he compared the different profit about whether the supplier and retailer select coordination or not. Dajun Yue [10] gets the optimal quantity and decision by game theory and proposes a bilevel programming model and generalized Nash equilibrium.

On the two-echelon SC model, inventory and transportation problem also needs to be concerned to get the maximum profit. Seyed Mohsen Mousavi [11] studies the location of warehouse so as to minimize the transportation and holding cost. Hung-Chi Chang [12] fed sight on the integrated production inventory problem on two-echelon SC to determine the delivery time of procedure to minimize the total cost. Kwangyeol Ryu [13] explains a major problem on two-echelon SC inventory management and presents a fractal-based approach to minimize costs of inventory. H. Hishamuddin [14] proposed a
recovery model and analysis the optimal quantity so as to make sure that the disruption come from transportation to the smallest. So the total relevant cost can be minimized and bring the supplier and retailers maximum profit. Amanda J. Schmitt [15] also analysis the problem of disruption and explains the effect on reducing SC risk based on uncertain market demand. Brojeswar Pal [16] builds a model for multi-echelon SCS and discuss the supply disruption for saving the whole cost. From these research works, the effect of disruption on SC can be well recognized. J Watada et al. apply fuzzy game model to real option problems [3], hotel yeald management [3], [4].

In recent years, the research works on two-echelon SC are not only about the optimal price, order quantity, inventory, transportation, disruption, but also about the trade credit and markdown allowance. Chang Hwan Lee [17] study the trade-credit and markdown allowance from the perspective of supplier. His research explained to get a maximized joint profit. The supplier should take trade-credit and markdown allowance. Ruo Du [18] studies the coordination on two-echelon SCs and analyses trade-credit and wholesale price discount. The purpose of his research is to develop the model to make the individual members get maximum profit. Se-Jik Kim [19] explained the interactions of incentives as the sustainability of production chain is important. J Watada et al. applied two-echelon model in decision making [20].

In order to solve two-echelon SC problems, many research works use crisp numbers to describe market demand. However, the market demand is always uncertain. They are always affected by many factors, so we will use fuzzy numbers to describe them in our model in order to enable our model nearer to the real situation. Similarly, Haiyu Yu and J Watada built bi-level model based theoretical neural network model to solve winary management problem [21], [22].

### 1.3. Research Objective

Our purpose is to provide methodologies for making decisions in small and medium enterprises. we analyze their behaviors and use game theory to build model. On their SC, each chain member wants to maximize their profits. But they should not only consider their own situation, but also consider the others' decision to making an optimal decision as in win-win relation. The study on analyzing the information obtained from the others and make an accurate strategic decision is our main purpose.

We will apply fuzzy numbers to describe the market demand and compare the result between using fuzzy number and crisp number. So we can know the difference between them will be clarified. Using fuzzy numbers make market demand nearer to the real situation.

The remaining of the paper consists of 5 sections. Sections 2 and 3 explain briefly game theory and fuzzy sets, fuzzy variables based on [21] and [22]. In the Section 4, we will build a two-echelon SC model, and finally Section 5 provides the decisions way for enterprises and make conclusions. Finally Section 6 draws the conclusions.

## 2. Game Theory

In this section 2, we will introduce game theory and explain how to use game theory in building our model.

### 2.1. The Definition

Game theory refers to the study of multiple individuals or teams under certain restrictive conditions making strategy according to the related information. It is a theory which study the struggle or competition and it is also included in applied mathematics, modern mathematics which are an important subject of operational research.

Game theory is widely applied to biology, economics, computer science, politics, international relations, military strategy and many other disciplines.

### 2.2. The Types of Game

Game theory consists $6 f$ layers, strategies, orders, payoffs, and equilibrium. In the following, we will discuss the types of game theory.
2.2.1. Cooperative and Non-cooperative Games: Game theory discuss the game mainly from the perspective of cooperative or non-cooperative feature.

The difference between cooperative and non-cooperative features is whether the players are interactive among them to reach an agreement. If it is interactive, the game is called a cooperative game, if it is not, it is a non-cooperative game.
2.2.2. Dynamic Game and Static Game: Static game is whether all participants take action at the same time or not in the game, the participant who takes action later does not know the action that the first participant takes.

Dynamic game refers to the participants take action in order. And the participant who takes action later can observe the action that the first participant takes.

For example, "prisoner's dilemma" belongs to static game. It is because the participants take action in the same time.

And board game belongs to the dynamic game, it is because the participants make decision and take action in sequence.
2.2.3. Complete Information and Incomplete Information: When required information is given completely, it means that every participant in the game knows the accurate information about other participants' such as characteristics, the strategies and profit functions.

On the other hand, in incomplete information game, the participant does not know accurately about other participants' information, strategies and profit functions. In these situations the game is the incomplete information game.

### 2.3. Stackelberg Competition

The Stackelberg Competition is a strategic game in economics, in which a leader participant takes first an action and then the follower participant responses sequentially the the leader paticipant's action.

The German economist Heinrich Freiherr von Stackelberg (1905-1946) published Market Structure and Equilibrium in 1934 which described the model [23].

In game theory jargons, the players consist of a leader and a follower(s) and they compete on quantity. The Stackelberg leader is sometimes called a Market Leader.

A Stackelberg Approach From, we have,

$$
\pi_{i}=\left(p_{i}-c_{i}\right)\left(D_{i}-c p_{i}+\frac{d}{2 c} D_{j}+\frac{d^{2}}{2 c} p_{i}+\frac{d}{2} c_{j}\right)
$$

For any $c$ set by the shippers, the forwarder $i$ who acts as the leader can obtain his optimal retail freight by setting $d \pi_{i} / d p_{i}=0$.

$$
\begin{align*}
\pi_{i}= & D_{i}-c p_{i}^{2}+\frac{d}{2 c} D_{j} p_{i}+\frac{d^{2}}{2 c} p_{i}^{2}+\frac{d}{2} c_{j} p_{i}+c_{i} D_{i} \\
& -c_{i} c p_{i}+\frac{d c_{i}}{2 c} D_{j}+\frac{d^{2} c_{i}}{2 c} p_{i}+\frac{d c_{i}}{2} c_{j} \tag{1}
\end{align*}
$$

Then we have the following relation:

$$
\begin{equation*}
p_{i}^{*}=\frac{2 c D_{i}+d D_{j}+c d c_{j}-2 c^{2} c_{i}+d^{2} c_{i}}{2 d^{2}+4 c^{2}} \tag{2}
\end{equation*}
$$

### 2.4. Cournot Competition

Cournot competition is an economic model employed in describing an industry structure where companies compete on the amount of output they will produce. Paticipants decide the amount independently of each other at the same time.

Antoine Augustin Cournot [5] (1801-1877) was inspired by observing competition in a spring water duopoly. This type of game is named a Cournote game after his name. It has the following features:

In Cournot competition, companies produce homogeneous product. And they compete independently.

Companies will affect with each other. In other words, each company's product will affect sale price in the market.

The most important feature is the companies compete in quantities, and they decide quantities at the same time.

Of course, all the companies want to maximize their profit and make a strategic decision.

Let us give the calculation of the optimum solution of prices in a Cournot circumstance. The other situations: Collusion and Stackellberg circumstances are in the same way. These calculations are left to readers.

Let us calculate the optimal prices $p_{i}^{*}$ and $p_{j}^{*}$ in the Cournot approach,

$$
\begin{align*}
& \pi_{i}=\left(p_{i}-c_{i}\right) Q_{i}=\left(p_{i}-c_{i}\right)\left(D_{i}-c p_{i}+d p_{j}\right)  \tag{3}\\
& \pi_{j}=\left(p_{j}-c_{j}\right) Q_{j}=\left(p_{j}-c_{j}\right)\left(D_{j}-c p_{j}+d p_{i}\right) \tag{4}
\end{align*}
$$

Setting $d \pi_{i} / d p_{i}=0$ and $d \pi_{j} / d p_{j}=0$, we obtain the respective optimal solutions $p_{i}^{*}, p_{j}^{*}$ as follows:

$$
\begin{align*}
& D_{i}-2 c p_{i}+d p_{j}+c c_{i}=0  \tag{5}\\
& D_{j}-2 c p_{j}+d p_{i}+c c_{j}=0 \tag{6}
\end{align*}
$$

Solving both the equations (5) and (6), we can obtain the optimal $p_{i}^{*}$ and $p_{j}^{*}$ as follows:

$$
\begin{align*}
& p_{i}^{*}=\frac{d D_{j}+2 c D_{i}+d c c_{j}+2 c^{2} c_{i}}{4 c^{2}-d^{2}}  \tag{7}\\
& p_{j}^{*}=\frac{d D_{i}+2 c D_{j}+d c c_{i}+2 c^{2} c_{j}}{4 c^{2}-d^{2}} \tag{8}
\end{align*}
$$

Input (6.10) and (6.11) in (6.8) and (6.9), respectively, we have the optimal $Q_{i}^{*}$ and $Q_{j}^{*}$.

### 2.5. Collusion Competition

Collusion Competition is a special competition which has an agreement between two or more companies.

Companies will make an agreement to limit open competition or to obtain an objective forbidden and gain an fair market advantage.

In this game, an agreement is supposed among companies to divide a market, limit production, set prices, or limit opportunities.

In economics, market competition and collusion used to provide that rival companies cooperate for their mutual benefit.

### 2.6. Problem Analysis

We have knew the definition of game theory and it's types. Now we will analyse the problem we will face and decide which type of game theory we will use.

In our case, we will assume two retailers. One retailer make it's decision first and it's information is known by other retailers.

The other retailer will make decision after getting the information of the first retailer.
So in our case, we will use Stackelberg competition to analyze our model. It is because the two retailers compete independently. And the follower know the accurate information of the first one.

Of course, they will compete on quantities. According to these analysis, both the retailers and the manufacturer will gain their maximum profits and make appropriate strategic decision for themselves.

## 3. Fuzzy Sets and Fuzzy Variables

In this section 3, we will introduce fuzzy theory simplified. And also we will explain why we use fuzzy theory in our problem and what advantage it has.

### 3.1. Definition

Fuzzy theory refers to the theory that has basic concepts of fuzzy set or continuous membership function [21], [22].

It can be classified into five branch. They are fuzzy mathematics, fuzzy system, uncertainty and information, fuzzy decision, fuzzy logic and artificial intelligence. They are not completely independent, there is close relationship between them.

For example, fuzzy control will use the concept of fuzzy mathematics and fuzzy logic. In a real situation, the application of fuzzy theory is mostly in fuzzy systems. Especially focus on fuzzy control. There are also some fuzzy system applied in medical diagnosis and decision support.

When we take about fuzzy, it is always refers to the uncertainty. If thing does not have a definite boundary, it will express fuzzy concept. Of course, when we use fuzzy theory to represent things, we have to know our mind is subjectivity. That is to say, everyone has different fuzzy boundaries about the same things. For example, 100 people say the age range of "young people", we will get 100 different answers. Even so, when we use the fuzzy theory to analysis the problem, the age range of young people has some regularity.
Actually, fuzzy is very usefully when we deal with the real life problem. For example, many people are in a room and we need to look for a tall and old man, it is not difficult to do it. "old" and "tall" are fuzzy concept, but as as long analysis, we can quickly find the man in the crowd.

### 3.2. Fuzzy variable

In this part, we will introduce fuzzy variable in order to make preparation for building our model. The conditions of possibility measure should be:
(1) $\operatorname{Pos}\{\emptyset\}=0$
(2) $\operatorname{Pos}\{\Theta\}=1$

$$
\begin{equation*}
\operatorname{Pos}\left\{\bigcup_{i=1}^{m} A_{i}\right\}=\sup _{i \leq i \leq m} \operatorname{Pos}\left\{A_{i}\right\} \tag{3}
\end{equation*}
$$

When $D=(a, b, c)$, we will get the membership function:

$$
\mu(x) \begin{cases}\frac{x-a}{b-a} & ; a \leq x \leq b  \tag{9}\\ \frac{x-a}{b-a} & ; b \leq x \leq c \\ 0: & ; \text { otherwise }\end{cases}
$$

So we can get the necessity measure of $A$ :

$$
\begin{equation*}
\operatorname{Nec}(A)=1-\operatorname{Pos}\left(A^{c}\right) \tag{10}
\end{equation*}
$$

Also, we can get the credibility measure denoted $C r$, is defined as:

$$
\begin{equation*}
\operatorname{Cr}\{A\}=\frac{1}{2}\left[1+\operatorname{Pos}(A)-\operatorname{Pos}\left(A^{c}\right), \quad A \in A\right. \tag{11}
\end{equation*}
$$

where $A^{c}$ is the complement of $A$.
Of course, according to the definition above, we can get:

$$
\begin{equation*}
\operatorname{Cr}\{A\}=\frac{1}{2}[\operatorname{Pos}(A)+N e c(A), \quad A \in A, \tag{12}
\end{equation*}
$$

The properties of credibility measure are as follows:
(1) $\quad C r(\emptyset)=0$ and $C r(\Theta)=1$;
(2) Monotonicity: $\operatorname{Cr}(A) \leq \operatorname{Cr}(B)$ for all $A, B \subset \Theta$ with $A \subset B$;
(3) Self-duality: $\operatorname{Cr}(A)+\operatorname{Cr}\left(A^{c}\right)=1$ for all $A \subset \Theta$;
(4) Subadditivity: $C r(A \cup B) \leq C r(A)+C r(B)$ for all $A, B \subset \Theta$.

After knowing these knowledge, we will introduce the expected value.
Let $X$ be a fuzzy variable, the expected value of $X$ is defined as

$$
\begin{equation*}
E[X]=\int_{0}^{\infty} C r\{X \geq r\} d r-\int_{-\infty}^{0} C r\{X \leq r\} d r \tag{13}
\end{equation*}
$$

## 4. Fuzzy Two-echelon SC Model

In this section 4, we will introduce the model.

### 4.1. Model Assumption and Notations

This paper will consider the behaviors between a manufacture and two retailers. We can know the assumptions as follows:
$c$ : unit manufacturing cost;
$w$ : manufacturer's wholesale price ;
$p_{i}$ : retailer $i$ 's sale price ( $i=1,2$ );
$D_{i}$ : retailer $i$ 's market demand $(i=1,2)$.
$\Pi_{i}$ : the profit of retailer $i(i=1,2)$;
$\Pi_{M}$ : the profit of manufacturer;
$\Pi_{i}^{*}$ : the optimal profit of retailer $i(i=1,2)$;
$\Pi_{M}^{*}$ : optimal profit of manufacturer.
The demand function is:

$$
\begin{equation*}
Q_{i}=\left(D_{i}-p_{i}+\theta p_{j}\right) \quad(i, j=1,2) \tag{14}
\end{equation*}
$$

### 4.2. Building the model by Stackelberg game

This part will build the model. We can get the profit of retailer 1 and retailer 2 :

$$
\begin{align*}
& \Pi_{r 1}=\left(p_{1}-w\right) Q_{1}=\left(p_{1}-w\right)\left(D_{1}-p_{1}+\theta p_{2}\right)  \tag{15}\\
& \Pi_{r 2}=\left(p_{2}-w\right) Q_{2}=\left(p_{2}-w\right)\left(D_{2}-p_{2}+\theta p_{1}\right) \tag{16}
\end{align*}
$$

The reaction function of the retailer 2 will be given as follows:

$$
\begin{gather*}
\frac{d \Pi_{r 2}}{d p_{2}}=0  \tag{17}\\
p_{2}=\frac{\left(D_{2}+w+\theta p_{1}\right)}{2}=0 \tag{18}
\end{gather*}
$$

Then we can get the profit of retailer 1 as follows:

$$
\begin{equation*}
\Pi_{r 2}=\frac{\left(p_{1}-w\right)\left(2 D_{1}+\theta D_{2}-2 p_{1}+\theta^{2} p_{1}+\theta w\right)}{2} \tag{19}
\end{equation*}
$$

by setting:

$$
\begin{equation*}
\frac{d \Pi_{r 1}}{d p_{1}}=0 \tag{20}
\end{equation*}
$$

The function can be given as follows:

$$
\begin{equation*}
p_{1}^{*}=\frac{\left(2 D_{1}+\theta D_{2}+2 w+\theta w-\theta^{2} w\right)}{\left(2-\theta^{2}\right)} \tag{21}
\end{equation*}
$$

The maximum profit of retailer 1 can be given as

$$
\begin{equation*}
\Pi_{r 1}^{*}=\frac{\left(2 D_{1}+\theta D_{2}+\theta w-\theta^{2} w-2 w\right)^{2}}{8\left(2-\theta^{2}\right)} \tag{22}
\end{equation*}
$$

So, we can get the retailer 2 ' results as follows.

$$
\begin{align*}
p_{2}^{*} & =\frac{\left(2 \theta D_{1}+4 D_{2}-\theta^{2} D_{2}+4 w+2 \theta w-\theta^{2} w-\theta^{3} w\right)}{4\left(2-\theta^{2}\right)}  \tag{23}\\
\Pi_{r 2}^{*} & =\frac{\left(\theta^{2} D_{2}-2 \theta D_{1}-4 D_{2}+4 w-2 \theta w-3 \theta^{2} w-\theta^{3} w\right)^{2}}{16\left(2-\theta^{2}\right)^{2}} \tag{24}
\end{align*}
$$

We can get the profit function of manufacturer:

$$
\begin{gather*}
\Pi_{M}=(w-c)\left(Q_{1}^{*}+Q_{2}^{*}\right)  \tag{25}\\
\Pi_{M}=(w-c)\left[D_{1}+D_{2}-\left(p_{1}^{*}+p_{2}^{*}\right)+\theta\left(p_{1}^{*}+p_{2}^{*}\right)\right] \tag{26}
\end{gather*}
$$

by setting

$$
\begin{equation*}
\frac{d \Pi_{M}}{d w}=0 \tag{27}
\end{equation*}
$$

We can get the optimal wholesale price:

$$
\begin{gather*}
w^{*}=\frac{c}{2}+\frac{A}{2 R}  \tag{28}\\
A=2\left[\theta+2\left(D_{1} D_{2}\right)\right]-\theta\left[-2 D_{1}+\theta^{2} D_{2}+\theta\left(2 D_{1}+D_{2}\right)\right]  \tag{29}\\
R=\left(8-4 \theta-7 \theta^{2}+2 \theta^{3}+\theta^{4}\right) \tag{30}
\end{gather*}
$$

We can get the maximum profit of the manufacturer:

$$
\begin{equation*}
\Pi_{M}^{*}=\frac{\left(8+4 \theta+3 \theta^{2}-\theta^{3}\right)\left(c-c \theta-D_{1} D_{2}\right)}{16(\theta-1)\left(2-\theta^{2}\right)} \tag{31}
\end{equation*}
$$

## 5. Solving Problems and Making Decisions for Enterprises

In this Section 5, we will explain how to solve real life problem based on our model.
Nowadays, as the development of the economy, many small and medium enterprises are set up. They don't have complex SC and also they don't have complete management system.

How to decide the quantity and price of the goods is the most important and common problem for them. Also, they face another problem that is how to make the whole SC get optimal profit. The reason is that as they are small company, there are not so many
retailers would like to sale goods for them. They have to make their goods satisfy the customers' needs and they also need to master the market demand clearly.

For these enterprises, the relationship between them and retailers are not only competitive but also dependent.

So, in our paper, we will make decisions for them. We will decide the order quantity, sale price, wholesale price based on the models mentioned in Section 3. Then, we will do some comparison in order to clarify which method can describe the market demand more accurately. Of course, after getting these results, we will make a summarize in part 5.4.6 (strategic decision-making).

### 5.1. Calculate the Difference between Expected Value of Fuzzy Number and Crisp Number

In order to know the difference clearly, we will use the function as follows:

$$
\begin{equation*}
M A P D R-F D=\frac{100 \%}{n} \sum_{k=1}^{n}\left|\frac{\pi_{k}^{l}-\pi_{F k}^{l}}{\pi_{k}^{l}}\right| \tag{32}
\end{equation*}
$$

where $\pi_{k}^{l}$ is the non-fuzzy value and $\pi_{F k}^{l}$ is the expected value of fuzzy number. Where $l=i, j, M$ and $k=1,2, \cdots, n$.

### 5.2. Numerical Example

In this part, we will introduce the numerical example.
Table 1. Assumed parameters

| $c$ | $\theta$ |
| :---: | :---: |
| 2 | 0.5 |

The market demand of retailer 1 supposed to be $X_{D_{1}} . D_{1}=(9,19,32)$
The market demand of retailer 2 supposed to be $X_{D_{2}} . D_{2}=(7,18,28)$
Then, we can get the possibility distribution of the triangular fuzzy variable:

$$
\mu_{D_{1}}(x)= \begin{cases}\frac{x-9}{10} & ; 9 \leq x \leq 19  \tag{33}\\ \frac{32-x}{13} & ; 19 \leq x \leq 32 \\ 0 & ; \text { otherwise }\end{cases}
$$

$$
\mu_{D_{2}}(x)= \begin{cases}\frac{x-7}{11} & ; 7 \leq x \leq 18  \tag{34}\\ \frac{28-x}{10} & ; 18 \leq x \leq 28 \\ 0 & ; \text { otherwise }\end{cases}
$$

Then, we can get the expected value.

$$
\begin{equation*}
E\left[D_{1}\right]=\int_{0}^{\infty} C r\left\{D_{1} \geq r\right\} d r-\int_{-\infty}^{0} C r\left\{D_{1} \leq r\right\} d r \tag{35}
\end{equation*}
$$

The expected value using example of triangular fuzzy variable $\xi_{i}=(a, b, c)$ can be calculated as:

$$
\begin{equation*}
E[\xi]=\frac{a+2 b+c}{4} \tag{36}
\end{equation*}
$$

Table 2. Retailer 1 and 2's market demand when in a fuzzy environment

|  | Fuzzy Triangular | Expected Value |
| :---: | :---: | :---: |
| $D_{1}$ | $(9,19,32)$ | 19.75 |
| $D_{2}$ | $(7,18,28)$ | 17.75 |

### 5.3. Compare the Results between Using the Value of the Fuzzy Number and NonFuzzy Number

Table 3. The difference of the result between using the expected value of fuzzy number and the crisp number.

|  | Expected value <br> $\left(\times 10^{2}\right)$ | Crisp number <br> $\left(\times 10^{2}\right)$ | MAPRD-FD <br> $(\%)$ |
| :---: | :---: | :---: | :---: |
| $\Pi_{r 1}^{*}$ | 0.68 | 0.66 | 3.03 |
| $\Pi_{r 2}^{*}$ | 0.45 | 0.42 | 7.14 |
| $\Pi_{M}^{*}$ | 3.42 | 3.15 | 8.57 |
| $P_{1}^{*}$ | 0.29 | 0.31 | 6.45 |
| $P_{2}^{*}$ | 0.26 | 0.29 | 10.34 |
| $Q_{1}^{*}$ | 0.09 | 0.08 | 12.5 |
| $Q_{2}^{*}$ | 0.09 | 0.07 | 28.57 |

From Tables 2 and 3, we can get the conclusions as follows:
From table 3, we can get conclusions that

1) By using the expected value to calculate the result, we can see that the profit of retailer $1,2, \mathrm{M}$ is higher than the result using crisp number. We can know the reason from table 2. It is because when we use the expected value to calculate the result, the expected value is higher than the crisp number. Of course, the expected value can describe the market more accurately.
2) We can also see that by using expected value, the price of 1,2 is lower than using crisp number. The quantity of 1,2 by using expected value is higher than using crisp number. This explain that the more the quantity is, the lower the sale price will be. Of course, this also explain that the more the quantity is, the lower the wholesale price will be. However, we can know that even though the sale price will be lower, as the quantity is more, the profit will not reduce.
3) From table 3, we can know that whether the result calculated by the expected value or calculated by crisp number, the profit of manufacturer gain the most profit in the SC. From this point, we can get a conclusion that in the SC, the manufacturer have a important position. The manufacturer will gain the most profit of the SC. If the retailers would like to gain more profit in the SC, they would better compete with the manufacturer according to some contract.
4) We will analyze the Mean Absolute Percentage Difference Rate of the Fuzzy Demand in table 3. We can see that by using the expected value and crisp number the results are different. Although the difference between the expected value and crisp number is not large, but the results calculated by them are different. So we can get a conclusion that the market demand have a heavy effect on the results. We need to explain the market demand more clearly considering many factors in order to make optimal decision.

### 5.4. Real life problem and strategic decision-making

In this part, we will introduce the real life problem and make decision for enterprises by using the two-echelon SC model.

In our problem, there are two retailers and one manufacturer in the SC. They both face problems that how to make a decision for themselves and how to gain the maximum profit in the SC. So in order to solve them, we will use two-echelon SC model.
5.4.1. Problem Description: In our problem, there is a manufacturer which sales mobile phone. As this mobile phone is a new type, so the manufacturer need to find retailers. Of course, in order to make the retailers try their best to sale the mobile phone and gain the maximum profit for itself, there are only two retailers in one market.

One reason is that when two retailers share the market, the manufacturer can know the market demand more clearly and also, when the two retailers compete with each other, the manufacturer will benefit more.

The other reason is that if the manufacturer find many retailers to sale the mobile phone, there will be a worse competition between the retailers. Finally, the brand value of the mobile phone will be decrease and the profit in the whole SC will also decrease.
5.4.2. Solving Method: When we know what the problem is, we need to make decision for enterprises. We will use the two-echelon SC model and the fuzzy variable to solve this problem.

We regard the manufacturer and the two retailers as the members in the two-echelon SC.

The manufacturer want to gain the maximum profit. Of course, the retailers also want to gain more profit. So, from this point, we can see that they have to know the market demand and satisfy the custom's need.

In our research, we would like to consider the market demand as the triangle fuzzy number instead of crisp number.

The reason is market demand is always effect by many factors. The weather, the festival and a variety of factors are effect the market demand. So, if we regard the market demand as crisp number, perhaps there is a big difference between the forecast value and the real value. In order to decrease the difference, in this research, we would like to consider the market demand as triangle fuzzy number.

So, in our calculation, we will use the expected value of triangle fuzzy number to calculate the result. We will also compare the result between using the expected value and using the crisp number. Then we can see which result is more near to the real situation and why the result is.
Finally, we will help the enterprises make decisions about the wholesale price, order quantity and sale price by using our two-echelon SC model.
5.4.3. The Expected Value of Market Demand: In order to solve this problem, we need to get the expected value of the market demand.
First, we need to how to estimate the desired range. For example, the arithmetic average:

$$
\begin{equation*}
E=\frac{x_{1}+\cdots+x_{n}}{n} \tag{37}
\end{equation*}
$$

is a monotonically increasing function of each of its $n$ variables $x_{1}+\cdots+x_{n}$. So,

- The smallest possible value $\underline{E}$ of the average $E$ is attained when each value $x_{i}$ is the smallest possible ( $x_{i}=\underline{x_{i}}$ ), and
- The largest possible value $\bar{E}$ of the average $E$ is attained when ( $x_{i}=\overline{x_{i}}$ ) for all $i$.

In other words, the range $E$ of $E$ is equal to $\left[E\left(\underline{x_{i}}, \cdots, \underline{x_{n}}\right), E\left(\overline{x_{i}}, \cdots, \overline{x_{n}}\right)\right]$, where

$$
\begin{equation*}
\underline{E}=\frac{1}{n}\left(\underline{x_{1}}+\cdots+\underline{x_{n}}\right) \tag{38}
\end{equation*}
$$

and

$$
\begin{equation*}
\bar{E}=\frac{1}{n}\left(\overline{x_{1}}+\cdots+\overline{x_{n}}\right) \tag{39}
\end{equation*}
$$

In our problem, we would like to make the problem simply. We also need to make the market demand as fuzzy variable. As the market demand need to decide according to it's own situation, so we will gather the real data to decided the inaccuracy $\delta$.

We will gather the sales data and analyze the data in the recently 3 years. Then, we will assume the data as the triangle fuzzy number. So, by the calculate function. We can get the expected value of the triangle fuzzy number.

Next, we will gather the data of a kind of mobile phone sales in China and solving the problem.
5.4.4. Problem solving: In table 4, we can get the data of a kind of mobile phone sales in China.

Table 4. The Data of a kind of Mobile Phone Sales in China

| D1 | E (D1) | D2 | E (D2) | C(CNY) |
| :---: | :---: | :---: | :---: | :---: |
| 1100 | 1010 | 1100 | 1170 | 1230 |
| 1050 | 1140 | 1200 | 1350 | 1230 |
| 1310 | 1165 | 900 | 1225 | 1230 |
| 1150 | 1345 | 1200 | 1075 | 1230 |
| 1610 | 1465 | 1000 | 1000 | 1230 |
| 1550 | 1528 | 1320 | 975 | 1230 |
| 1400 | 1363 | 1400 | 1175 | 1230 |
| 1100 | 1250 | 1300 | 1025 | 1230 |
| 1250 | 1133 | 1080 | 1450 | 1230 |
| 1080 | 1200 | 1030 | 1250 | 1230 |
| 1340 | 1025 | 1120 | 1425 | 1230 |
| 1100 | 1225 | 1310 | 1350 | 1230 |
| 900 | 1100 | 1100 | 1150 | 1230 |
| 1000 | 1025 | 1100 | 1075 | 1230 |
| 1200 | 1050 | 1300 | 1125 | 1230 |
| 1050 | 1320 | 1200 | 1375 | 1230 |
| 1320 | 1220 | 1060 | 1525 | 1230 |
| 1000 | 1410 | 1250 | 1075 | 1230 |
| 1100 | 1325 | 1100 | 1025 | 1230 |
| 1380 | 1300 | 950 | 1175 | 1230 |
| 1400 | 1125 | 1400 | 1200 | 1230 |

After we get these data, we will analyze for enterprise. Firstly, we would like to calculate the profit of retailer 1, retailer 2 and the manufacturer by using the expected value and the crisp number.

Of course, we consider the retailers and the manufacturer as the members in the SC. So we assume retailer 1 make his decision first. As the information is know by the manufacturer and the retailer 2, so retailer 2 will make his decision according to retailer 1 .

Then, we can also get the profit of the manufacturer. By two-echelon SC model mentioned above, we will get table 5 .

When we get these result in the table 5 . We will do some comparison and make decisions for enterprises. Of course, we will gather the real data and help enterprises gain maximum profit in the real situation.
5.4.5. Result Analyzing: The difference between the results by using the expected value and crisp number.

From Figs. 1, 2, 3, we can see that by using the expected value to calculate the result, we can get the result nearer to the real situation. The profit of retailers and manufacturer is changing along the time. It will be effected by the weather, advertisement, and hobby.

Table 5. The profit of retailers and manufacturer

| Profit of retailer 1 (CNY) | Profit of retailer 2 (CNY) | Profit of manufacturer (CNY) | Profit of retailer 1 (fuzzy)(CNY) | Profit of retailer 2 (fuzzy)(CNY) | Profit of manufacturer (fuzzy)(CNY) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 40910.22 | 42195.97 | 917836.83 | 28576.99 | 55546.58 | 896359.15 |
| 33806.58 | 60876.99 | 955783.26 | 47211.67 | 92824.11 | 1167524.33 |
| 78249.94 | 14422.49 | 894310.04 | 51262.56 | 64486.92 | 1082619.20 |
| 48771.59 | 59675.87 | 1046854.69 | 85751.82 | 35872.43 | 1096849.11 |
| 152689.59 | 23362.54 | 1221408.26 | 113662.14 | 24459.41 | 1111363.62 |
| 136058.95 | 79870.25 | 1552301.12 | 129896.04 | 20975.94 | 1130185.04 |
| 98262.85 | 101351.11 | 1487033.26 | 89749.10 | 52465.20 | 1214976.34 |
| 40984.31 | 81568.79 | 1084801.12 | 66388.66 | 29473.20 | 971910.49 |
| 66414.61 | 37530.82 | 1024086.83 | 46132.85 | 118979.94 | 1246339.06 |
| 37948.30 | 31627.33 | 843765.40 | 57301.49 | 69226.78 | 1137926.12 |
| 84696.39 | 43082.95 | 1138533.26 | 30564.58 | 113942.25 | 1108043.30 |
| 40988.01 | 83874.99 | 1093149.33 | 61858.22 | 91561.46 | 1254611.38 |
| 16463.01 | 44229.86 | 750872.54 | 40928.74 | 50833.59 | 959577.90 |
| 27319.30 | 43206.93 | 834354.69 | 30452.67 | 38898.88 | 835777.68 |
| 57323.40 | 80177.50 | 1183461.83 | 33781.34 | 46942.82 | 896017.63 |
| 33806.58 | 60876.99 | 955783.26 | 80578.99 | 96280.26 | 1376988.62 |
| 80415.39 | 33855.19 | 1061426.12 | 61021.07 | 139036.68 | 1411519.87 |
| 27364.71 | 71825.18 | 948193.97 | 100406.17 | 35272.66 | 1149879.24 |
| 40910.22 | 42195.97 | 917836.83 | 81449.11 | 28846.63 | 1030253.13 |
| 93429.10 | 19162.27 | 994488.62 | 76333.89 | 53173.56 | 1158796.65 |
| 98262.85 | 101351.11 | 1487033.26 | 44773.97 | 59975.03 | 1024086.83 |
| 68449.06 | 83930.26 | 1261783.26 | 66523.15 | 81763.12 | 1242278.79 |
| 48848.43 | 102696.57 | 1212680.58 | 33796.49 | 55086.32 | 931877.01 |
| 21576.21 | 62090.08 | 864711.83 | 44014.15 | 70260.40 | 1062033.26 |
| 53836.81 | 80454.80 | 1163729.69 | 27295.10 | 30901.56 | 773640.40 |

In order to explain the difference clearer, in the next portion, we will use Root Mean Square Error (RMSE) to calculate the result.

$$
\begin{array}{r}
R M S E=\sqrt{\frac{\sum_{i=1}^{M}\left(t_{f u z z y}^{i}-t_{r e a l}^{i}\right)^{2}}{M}} \\
R M S E=\sqrt{\frac{\sum_{i=1}^{M}\left(t_{n o n-f u z z y}^{i}-t_{\text {real }}^{i}\right)^{2}}{M}} \tag{41}
\end{array}
$$

From table 6, we can know clearly that by using the expected value to describe the market demand can obtain the result nearer to the real situation.


Fig. 1. The profit of retailer 1


Fig. 2. The profit of retailer 2
5.4.6. Strategic Decision-making: After knowing the information mentioned above, we can get a conclusion that by using the expected value, we can make a more accurate decision for enterprises. So, in this problem, the retailer 1 and retailer 2 can make their decision by using the two-echelon SC model as follows:

From figures 4 and 5, we can know the sale price and order quantity of retailer 1 and 2. Of course, when they making decision like this, they can gain the maximum profit and decrease the waste.
The purpose of the two-echelon SC problem is to gain the maximum profit successfully in the economic activity. The most important problem is the market demand forecast. As the retailers need to reserve the products and the manufacturer need to produce the products based on market demand forecast, the market demand need to be considered in a most reasonable situation.

So, in our problem, as we take an advantage reservation, we need to decide the market demand. From the previous data, we can know that even though in the same time of


Fig. 3. The profit of manufacturer


Fig. 4. The sale price of retailer 1 and 2
the past 3 years, the sales volumes are not the same. So it explained that if we just take a crisp number as our market demand, it will not predict clearly.

For this reason, we consider the market demand as a triangle fuzzy number in our research. We calculate the expected value of the triangle fuzzy number and find that the result is actually near to the real situation. So this explained that we need to considered the market demand in a real situation. We would better gather the data as more as well. The more data we have gathered, the results are more nearer to the real situation. In our problem, the two-echelon SC is based on the prediction of the market demand. We need to predict the market demand, order the products in advance. The most advantage of this model is that it can satisfy the customers' need immediately and give the customer well impression. This model is good for those products which are new type or sales volumes are not so good.

On the other hand, as it is based on the market demand forecast, the waste is easily happen. If we can not predict the market demand clearly, there will be a waste on


Fig. 5. The order quantity of retailer 1 and 2
Table 6. Root Mean Square Error

| The profit of <br> retailer <br> (RMSE) |  |
| ---: | ---: |
| fuzzy ; <br> real | Non-fuzzy; <br> real |
| 3806.36 | 4914.55 |
| 3416.51 | 6062.32 |
| 6302.75 | 12780.21 |
| 9483.59 | 16665.38 |
| 11460.69 | 16135.89 |
| 2300.89 | 2460.98 |
| 2269.18 | 8289.31 |
| 5076.08 | 12887.51 |
| 2851.66 | 17193.02 |
| 5615.48 | 8069.29 |
| 7555.73 | 30721.24 |
| 8158.75 | 8976.36 |
| 7034.82 | 10265.06 |
| 942.34 | 1273.29 |
| 6313.51 | 10333.23 |
| 7558.26 | 25514.83 |
| 1450.33 | 15164.18 |
| 13736.37 | 37911.74 |
| 7423.99 | 21241.33 |
| 4033.26 | 16121.40 |
| 11643.24 | 26179.11 |
| 344.25 | 1017.57 |
| 3912.78 | 6730.55 |
| 2159.61 | 13706.41 |
| 4571.37 | 14196.45 |
| 4651.26 | 13358.34 |
| 3029.10 | 11636.47 |
| 1970.47 | 4523.27 |


| The profit of <br> retailer 2(RMSE) |  |
| ---: | ---: |
| fuzzy ; <br> real | Non-fuzzy ; <br> real |
| 3673.83 | 5766.47 |
| 3241.46 | 19348.57 |
| 10682.21 | 24718.69 |
| 3081.26 | 13750.31 |
| 317.78 | 457.82 |
| 14311.18 | 27333.39 |
| 3666.49 | 38234.05 |
| 8186.04 | 28651.11 |
| 6830.61 | 50762.62 |
| 11325.58 | 15261.25 |
| 22240.10 | 27864.99 |
| 1132.40 | 4302.75 |
| 10321.22 | 14990.77 |
| 883.09 | 3929.34 |
| 9080.79 | 14419.67 |
| 10786.39 | 14247.50 |
| 11686.13 | 62688.42 |
| 2984.46 | 28830.99 |
| 3042.24 | 6397.18 |
| 6387.69 | 17661.92 |
| 7809.97 | 21447.34 |
| 315.99 | 1216.41 |
| 10623.35 | 23042.19 |
| 3602.43 | 9379.71 |
| 12984.91 | 22054.52 |
| 4555.22 | 39719.01 |
| 12876.61 | 28261.86 |
| 2844.83 | 3635.85 |


| The profit of <br> Manufacturer (RMSE) |  |
| ---: | ---: |
| fuzzy ; <br> real | Non-fuzzy ; <br> real |
| 29740.31 | 44927.32 |
| 48666.15 | 101057.40 |
| 63829.96 | 69324.72 |
| 10991.34 | 24360.05 |
| 24279.49 | 53533.82 |
| 89459.58 | 209021.55 |
| 58741.95 | 133631.34 |
| 5882.78 | 73942.95 |
| 45042.04 | 112114.02 |
| 98447.73 | 109555.31 |
| 13112.10 | 34671.75 |
| 32740.02 | 81430.89 |
| 124289.64 | 271866.62 |
| 4334.79 | 5341.00 |
| 43184.68 | 160069.06 |
| 111219.85 | 186617.32 |
| 56158.33 | 191395.34 |
| 35835.64 | 106777.39 |
| 28176.88 | 51313.44 |
| 48222.31 | 67961.01 |
| 113612.38 | 213740.18 |
| 5579.22 | 8212.52 |
| 24446.10 | 223004.21 |
| 57861.32 | 81666.00 |
| 18730.97 | 257103.80 |
| 39005.64 | 109739.72 |
| 26070.11 | 38815.40 |
| 7569.93 | 16713.19 |
|  |  |

the inventory. Also there will be an other disadvantage. That is a limit money will be waste on the inventory and the retailers cannot react to the customers' need as soon as possible.

So, not only for the retailers, but also for the manufacturer, the data of the past year is very important to make a decision of market demand.

## 6. Conclusions

As the small and medium enterprises become more and more, there are heavy competitive with them. This paper analyzes their behaviors and make decisions for them.

Manufacturer, retailers and customer consist the SC. The benefit of the two-echelon SC is as manufacturer contact with the retailer directly, he can master the market demand more clearly. It is very useful for small and medium enterprises considering they need to follow the change of the market demand.

Then, we can see that the discussion above explains that we provided an accurate decision when using fuzzy variables and applying a game approach. Also by using credibility measure to calculate the expected value is benefit for evaluating market demand. So the profit of SC will be nearer to the real situation and enterprises can save their resources. It is necessary for enterprises to save the money. Especially for small and medium enterprises, use the money effectively is important.

Of course, we know whether in the fuzzy case or in the non-fuzzy case, the manufacturer gains the most profits of the SC, but the retailers only gain a small part of profits. If the retailers want to gain more profits in the two-echelon SC, they would better make themselves get a more important position in the SC so as to deal with the manufacturer.

In this paper, we discussed how to make decisions for chain members and help them gain the optimal profit. In the future, our task is to master the market demand more accurately, so that we can satisfy the customer's needs better. In order to achieve this, we would better gather more data and analyze the data in the real situation.

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# PHƯƠNG PHÁP TIẾP CẬN TRÒ CHƠI MỜ HAI TẦNG CHO BÀI TOÁN TỐI UUU CHUỖI CUNG ỨNG VỚI CÁC DOANH NGHIỆP VỪA HOẶC NHỎ 

Junzo Watada, Chen Xiang

## Tóm tắt

Trong bài báo này, chúng tôi sẽ phân tích hành vi của doanh nghiệp và khách hàng, giúp họ đưa ra quyết định để đạt được lợi nhuận tối ưu. Ngày nay các doanh nghiệp vừa và nhỏ đóng một vai trò quan trọng trong nền kinh tế. Khi doanh nghiệp có quy mô vừa và nhỏ, họ cần phải tìm ra cách thức hiệu quả để đưa ra quyết định. Trong bài báo, chúng tôi sẽ sử dụng lý thuyết trò chơi để phân tích nó. Ngoài ra, vì mối quan hệ của nhà sản xuất và nhà bán lẻ có thể được coi là hành vi của Stackelberg, chúng tôi sẽ xây dựng các mô hình dựa trên hành vi của Stackelberg. Để đưa ra quyết định tối ưu cho các thành viên trong chuồi, chúng tôi sử dụng số rõ nét và số mờ để thể hiện nhu cầu thị trường. Sau đó, chúng tôi sẽ phân tích cái nào chính xác hơn với tình hình thực tế và cái nào tốt hơn để thu được nhiều lợi nhuận hơn cho các thành viên trong chuỗi cung ứng. Cuối cùng, chúng tôi đưa ra kết luận cho các thành viên trong chuô̂i cung ứng. Chúng tôi làm rõ lợi thê và bât lợi của mô hình chuỗi cung ứng được thực hiện bởi các doanh nghiệp vừa và nhỏ.


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