Valuation on Flexibility in Daily Balancing Between Supply and Demand in Fresh Beverage Business: Based on Real Options Approach

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***Abstract*—This paper examines the possibility of flexible adjustments to more efficient lot size in supply chain management (SCM) for fresh beverage production using real option approach (ROA). For deterioration, it is necessary for a supplier to produce just the same amount to demand of a buyer. However, a daily demand is not necessarily the suitable amount for a supplier.**

In a real case study of beverage, a supplier divides the demand into batch capacity (a basic unit shows a carton piece per a batch), each batch is produced up to the maximum piece except for last batch. The pieces in the last batch may not meet the maximum. This may yield salvage and/or inefficient production to the supplier as producer. The authors considered the condition of the pieces in last batch as uncertainty. ROA allows the buyer and the supplier to permit supplier's option exercise to response to the demand uncertainty. In fact, the supplier was given the right to exercise options that can increase or decrease production pieces in last batch.

The authors simulated the flexibility of options using sensitivity analysis in one period. As a result, options can increase the pieces, reduce the salvage cost and improve cost per one piece. In a future next study, authors want to examine that the impact of the exercise of options in a multi-period.

I. INTRODUCTION

Price competition is more interested in Japan [5, 11, 13]. In the supply chain, if the same quality is assured, there is a movement to try to offer products more cheaply.

Supply chain management (SCM) is promoting the response with flexibility to accommodate uncertain demand. The flexibility in the supply chain is an important feature of production systems. Bertrand [2] has reviewed that the flexibility mainly stems from three sources. First is the variety of the manufacturing technologies. Second is the amount of capacity available for production. Third is timing and frequency of production. Authors consider that third stem contains the volume flexibility. According to Upton [18], definition of flexibility is that the ability to change or react with little penalty in time, effort, cost or performance.

Cachon[4] has reviewed more information about the agreement in SCM. Buyer and supplier had better to use the volume flexibility for the benefit of SCM.

Due to the high uncertainty in production process, methods to use the flexibility have increased [10]. One of the methods used in recent years is real options approach (ROA) [12]. ROA is derived from a conceptual extension of financial option theory and proposed to state that investment possibilities for commodity or real assets change through possible investments in the future [3, 15].

Many studies has been reviewed the ROA for investment in projects with irreversibility and uncertainties [6, 7, 14, 17]. Using ROA enables us to value the option to delay, expand or abandon an investment with uncertainties, when such decisions are made following an optimal condition.

In the case of SCM for beverages packed with carton, authors observed that made-to-order production is repeated every day because the expiration date of the product is short. The buyer orders the amount of demand to the supplier, and the supplier produces the beverage the next day. But the amount of demand is usually uncertain. The supplier modifies the uncertain using volume flexibility to protect product efficiency. The supplier divides the demand into batch capacity (a basic unit shows as a carton piece per batch), each batch is produced up to the maximum piece except for last batch. The pieces in last batch may not meet the maximum. This may yield salvage and/or inefficient production to supplier. There are some afford to decide the last batch using ROA and volume flexibility. The objective of this study is not to find simply the better demand along the batch size, but to analyze how ROA with volume flexibility enhances profits for a supplier.

II. RELATED WORK

In principle, it is necessary for supplier to produce just the same amount to daily demand of buyer. However, the demand is not necessarily the suitable amount for the supplier as producer.

Although ROA and supply chain has dealt with flexibility together, study on the flexibility has been limited. The studies of ROA in supply chain have just started and been introduced by classifying into three groups [20, 21]. First, there are studies on the call option that allows the buyer to adjust the order upwards. Second, there are studies on the put option that allows the buyer to adjust the order downwards. Third, there are studies on bidirectional option adjustments over the initial order.

In case of adjusting the order with the call option only, simply the initial order has been increased with the option. A two-stage model to explore the role of the call option shows significance which provides volume flexibility in response to market conditions [1]. Another two-stage model which buyer exercise call option to supplier have been presented [19].

In case of adjusting the order with the put option, simply the initial order has been decreased with the option. In this model, buyer orders to supplier in first stage, and buyer can have not an obligation but a right to exercise all or partial cancellation of the order with market uncertainty more cleared. The put option to return the ordered commodity has been analyzed between buyers and suppliers [8, 16].

In case of adjusting the order with the bidirectional option, the initial order has been increased with the call option or decreased with the put option. This case is most adjustable and easy to exercise in practice. A two-stage model to explore the role of the call option and/or the put option shows significance which provides volume flexibility [20, 21].

The results by Zhao et al. were unique in consideration of option price and exercise price[21]. The retailer purchases the option at unit price, which gives it the right but not the obligation to adjust its initial order either upwards or downwards.

However, these many previous studies have been pursuied from only a perspective of the buyer. To the best of our knowledge, few studies have been done from suppliers perspective. Then this study shows the monetary value of volume flexibility with three dimensional sensitivity analysis from supplier’s perspective.

III. MODELING

The supply chain consists of a single supplier and a single buyer. The supplier has volume flexibility in batch size capacity. The batch size capacity is expressed as pieces of product. The capacity of each batch is same.

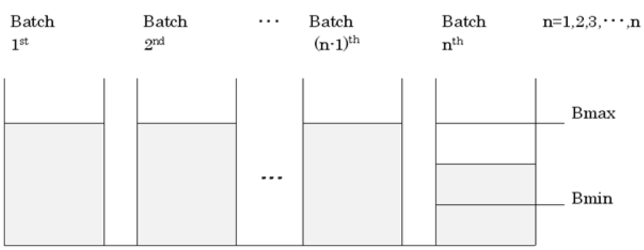

Fig.1. An illustration of formulation batches
$Bmax$: maximum pieces for batch, $Bmin$: minimum pieces for batch

Fig.1 shows an illustration of formulation batches. The supplier divides the demand into batch capacity (unit shows as piece per batch), each batch is up to the maximum piece except for last batch. The pieces in last batch may not meet the maximum, furthermore to make the matter worse, be less than the minimum. This may yield salvage and/or inefficient production to supplier. The authors considered the condition of the pieces in last batch as uncertainty.

The supplier has the options that can increase or decrease products in last batch. The options can regard as volume flexibility and lower the inefficiency in last batch.

The options consisted of call option and put option. The call option can exercise to increase the pieces, if the last batch does not reach the maximum pieces. The put option can exercise to decrease the pieces, if the last batch does not satisfy the minimum pieces and yields salvage. Though supplier would like to exercise the call option to increase profits, there is a case that exercises the put option to increase profits.

IV. CALCULATION

Fig.2 shows a decision tree to choose the options with respect to the condition of last batch.

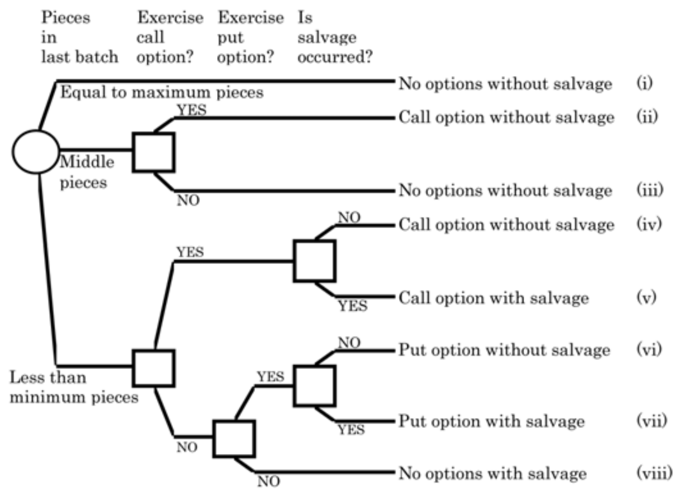

Fig.2. A decision tree to exercise options

A. Supplier maximize profits when there is no option

Behavior of the supplier who cannot exercise any option is just enough to meet the demand. The profits $\Pi(D)$ is assumed to be calculated by subtracting direct raw material costs, processing costs and the disposal expenses from sales.

$$\Pi(D) = \begin{cases} r \cdot D - n \cdot Fc - \{(n-1) \cdot Bmax + Blast\} \cdot Vc & if\ Blast \geq Bmin \\ r \cdot D - n \cdot Fc - \{(n-1) \cdot Bmax + Bmin\} \cdot Vc & \\ \quad -\{(n-1)Bmax + Bmin - D\}Sq & if\ Blast < Bmin \end{cases} \quad (1)$$

and

Π	=	the profits per period (JPY: Japanese Yen /period)
D	=	the number of demand per period (piece/period)
r	=	the sales price per piece (JPY/piece)
n	=	the batch number (group)
Fc	=	the processing cost per batch (JPY / group) which is treated as semi-fixed costs: a fixed cost per batch
B max	=	the maximum number of production in batch (pieces/group)
$Blast$	=	the production number only in the last batch before options exercised (pieces/group)
Vc	=	the direct material cost (JPY / piece) which is treated as variable costs
B min	=	the miniimum number of production in batch (pieces/group)
Sp	=	the salvage number per period (piece/period)
Sq	=	the salvage cost per piece(JPY/piece)

Equation (1) is the profits equation per period without any option and applied for (i), (iii) and (viii) in Fig.2. If $Blast \geq Bmin$, the first term is sales, the second term is the supplier's processing cost, and the last is the direct material cost. The sales are directly proportional to the multiplication of the unit price and pieces. The processing cost is directly proportional to the number of batches. Supplier can reduce the cost per unit piece by means of more production within the same number. The direct material cost is directly proportional to the pieces that are formulated. Pieces in each batch are Bmax until the one of before $Blast$, and pieces in last batch are not always $Bmax$. If $Blast < Bmin$, $Blast$ must increase up to $Bmin$ to produce and yields salvage cost. Therefore, if $Blast < Bmin$, $Blast$ turns to $Bmin$ and yields salvage pieces which are the difference between formulation and demand.

B. Supplier maximize profits when there are options

Behavior of the supplier who has the options is different from the condition in the last batch. That is, it can be divided into three cases; $Blast = Bmax$, $Bmin \leq Blast < Bmax$ or $Blast < Bmin$. For each case, the authors seek for the maximum profits function and the optimal last batch condition ($Blast^*$).

Case1. $Blast = Bmax$

In this case, there is no affording to exercise call options and it is applied for (i) in Fig.2. The optimized condition is not to exercise the option. The optimal last batch condition is $Blast^* = Bmax$. In addition, salvage cost is not occurred.

$$
\begin{aligned}
\Pi\,(D) &= \mathrm{r} \cdot D - n \cdot \mathrm{Fc} - \{(n-1) \cdot \mathrm{Bmax} + Blast\} \cdot Vc \\
&= \mathrm{r} \cdot D - n \cdot \mathrm{Fc} - \{(n-1) \cdot \mathrm{Bmax} + \mathrm{Bmax}\} \cdot Vc \\
&= \mathrm{r} \cdot D - n \cdot \mathrm{Fc} - n \cdot Bmax \cdot Vc \qquad (2)
\end{aligned}
$$

Equation (2) is the profits equation per period without any option.

Case2. $Bmin \leq Blast < Bmax$

In this case, there is affording to exercise call options. The optimized condition is to exercise the option. The optimal last batch condition is $Blast^* = Blast + di \cdot D$. In addition, salvage cost is not occurred. The optimized condition is subject to following formula.

$$
\begin{aligned}
\Pi\,(di, D) = r \cdot (1 + di) \cdot D - n \cdot \mathrm{Fc} - \{(n-1) \cdot \mathrm{Bmax} + Blast + di \cdot D\} \\
\cdot \mathrm{Vc} - \mathrm{Oc} \cdot Oq \quad (3)
\end{aligned}
$$

and

di = the increase (the call; $di > 0$) or decrease (the put; $di < 0$) in the ratio of demand for the option exercise. (in case of no option is $di = 0$)

Oc = the exercise cost of call option (JPY / piece)

= the exercise quantity of options (piece)

Case3. $Blast < Bmin$

In this case, supplier can select either call option or put option. More important matter is to reduce the salvage. Under these conditions, the supplier can choose either case3.1 or case3.2.

Case3.1. $Blast < Bmin$ and the exercise of call option

It is applied for (iv) and (v) in Fig.2. The optimal last batch condition has separate two results; $Blast^* = Blast + di \cdot D$ which is subject to $Bmin \leq Blast + di \cdot D \leq Bmax$ and $Blast^* = Blast + di \cdot D$ which is subject to $Blast + di \cdot D < Bmin$, respectively.

In addition, salvage cost is occurred in condition of not $Bmin \leq Blast + di \cdot D \leq Bmax$, but $Blast + di \cdot D < Bmin$.

The optimized condition is subject to following formula.

$$
\Pi\,(di, D) = \begin{cases}
r \cdot (1 + di) \cdot D - n \cdot \mathrm{Fc} - \{(n-1) \cdot \mathrm{Bmax} + Blast + di \cdot D\} \cdot \mathrm{Vc} \\
-\mathrm{Oc} \cdot Oq \\
if\ Blast + di \cdot D \geq \mathrm{Bmin} \\
r \cdot (1 + di) \cdot D - n \cdot Fc - \{(n-1) \cdot Bmax + Bmin\} \cdot Vc \\
-\{(n-1) \cdot Bmax + Bmin - (1 + di) \cdot D\} \cdot Sq - Oc \cdot Oq \\
if\ Blast + di \cdot D < Bmin
\end{cases} \qquad (4)
$$

Equation (4) is the profits equation per period with call option. The last represents exercised option cost.

Case3.2. $Blast < Bmin$ and the exercise of put option

In this case, supplier can exercise put option and meet production of the last batch to zero. It means that put option erase production in last batch at all. The put option should be exercised without shortage. The authors assume that put option can be exercised when in the previous period call option is exercised and the quantity is bigger than the quantity of put option to exercise in this period. This restriction is useful for supplier not to lower the buyer's demand within sequential two periods. If the restriction does not meet, supplier should choose case 3.1.

The optimal last batch condition is $Blast^* = Blast + di \cdot D = 0$. In addition, salvage cost is not occurred and processing cost of 1 group is saved and total batch number is (n-1). The optimized condition is subject to following formula.

$$
\begin{aligned}
\Pi\,(di, D) &= r \cdot (1 + di) \cdot D - (n-1) \cdot \mathrm{Fc} - \{(n-1) \cdot \mathrm{Bmax} + Blast + di \cdot D\} \cdot \mathrm{Vc} \\
&\quad -\{(n-1) \cdot \mathrm{Bmax} + Blast - (1 + di) \cdot D\} \cdot Sq - Op \cdot Oq \\
&= r \cdot (1 + di) \cdot D - (n-1) \cdot \mathrm{Fc} - (n-1) \cdot \mathrm{Bmax} \cdot \mathrm{Vc} - \mathrm{Op} \cdot Oq \qquad (5)
\end{aligned}
$$

and

Op = the exercise cost of put option (JPY / piece)

Equation (5) is the profits equation per period with put option and applied for (vi) and (vii) in Fig.2.

Summarized above 3 cases, the optimum conditions are as follows.

$$Blast^* = \begin{cases} Bmax & if\ Blast = Bmax \\ Blast + di \cdot D & if\ Bmin \le Blast < Bmax \\ Blast + di \cdot D & if\ Bmin \le Blast + di \cdot D \le Bmax,\ \ Blast < Bmin\ and\ di > 0 \\ Bmin & if\ Blast + di \cdot D < Bmin,\ \ \ \ Blast < Bmin\ and\ di > 0 \\ 0 & if\ Blast + di \cdot D < Bmin,\ \ \ \ Blast < Bmin,\ \ di < 0\ and \\ & \mathrm{Oc} \cdot Oq\ in\ previous\ period > \mathrm{Op} \cdot Oq\ in\ this\ period \end{cases} \quad (6)$$

V. SENSITIVITY ANALYSIS

A. Numerical conditions

The sensitivity analyses for profits in one period were simulated with reference to equation (6). Processing cost, salvage cost, exercised option cost and option value are also evaluated by sensitivity analysis. The values given are as follows:

di $\quad -0.10 \le di \le 0.10$
D = the number of demand per period (piece)
r = 60 (JPY/piece)
Fc = 30000 (JPY / group)
$B\max$ = 5000 (pieces)
$Blast$ $\quad 0 < Blast \le 5000$ (pieces)
Vc = 20(JPY/piece)
$B\min$ = 3000 (pieces)
Sp = the salvage number (piece)
Sq = 5(JPY/piece)
Oc = 1(JPY/piece)
Op = 0(JPY/piece)
Oq $\quad 0 < Oq \le di \ \ D \quad for \quad di > 0$ (pieces)
$\quad\quad 0 < Oq \le -di \ \ D \quad for \quad di < 0$
Oc･Oq in previous period =2000(JPY)

B. Sensitivity analysis for total profits

Fig.3 shows the result of sensitivity analysis in profits to uncertainties. Profits increase with demand regardless of the maximum value of *di*. Adjusting the demand with the bidirectional option, the profits with the call option increases until whichever in less of the Blast reaching Bmax or the *di* reaching upper limitation. As the put option had better not to exercise because of decrease in profits, *di* in negative number shows almost the same profits in same demand.

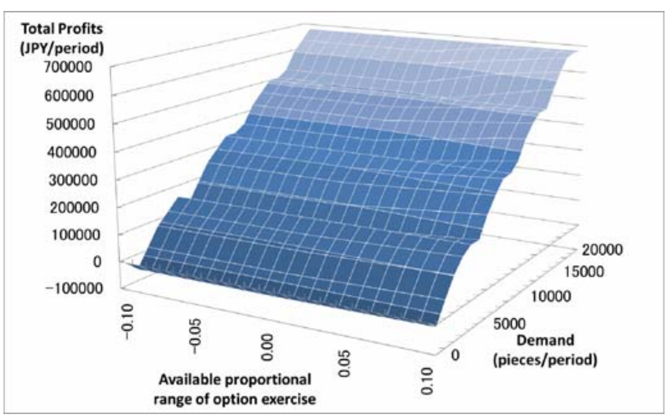

Fig.3.Sensitivity analysis for total profits per period

Profits slightly go down as demand with call option approaches the Bmax in demand such as 5000, 10,000, 15,000 and 20,000. Because there is little afford to exercise the option, additional profits derived from exercised the call option can slightly get.

C. Sensitivity analysis for total processing cost

Fig.4 shows the result of sensitivity analysis in total processing costs to uncertainties. The total processing costs are regarded as a semi-fixed cost that is proportional to the number of the batch. The total processing costs increases step by step with demand regardless of the value of *di*. The costs radically increase over the multiple of the upper of last batch pieces such as 5000, 10,000, 15,000 and 20,000. The total processing costs with the call option do not change with *di* and demand, because the costs are proportional to the number of batch and call option do not make additional number of batch, exercising within the same number. However, the total processing costs with the put option do not change with *di* and demand except for two areas. First is located in the area from -0.06 to -0.10 in *di* and 16,000 pieces in demand, second is -0.10 in *di* and 11,000 pieces. This means that production pieces are reduced in order to eliminate the total processing costs in the last batch.

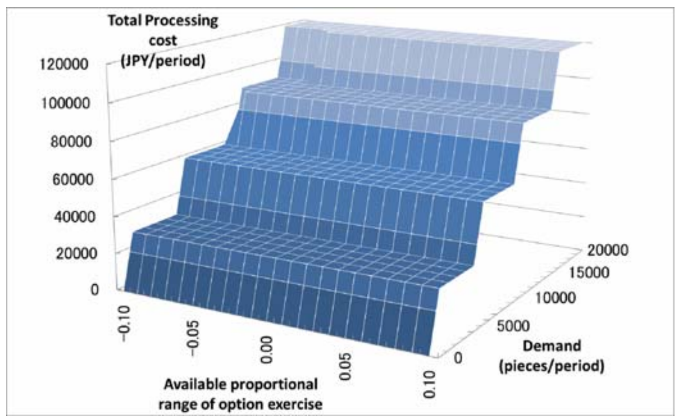

Fig.4.Sensitivity analysis for total processing cost per period

D. Sensitivity analysis for total salvage cost

Fig.5 shows the result of sensitivity analysis in salvage cost to uncertainties. The salvage cost yields from the pieces of a to last batch that is less than the pieces of the minimum required meet the required. The minimum required pieces in the last batch are 3,000.

The salvage cost yields between the multiples of the upper pieces in last batch such as 5000, 10,000, 15,000 and 20,000. However, call option gradually reduce the cost with the value of *di* in order to increase the production pieces. On the other hand, it is hard for put option to reduce the cost well.

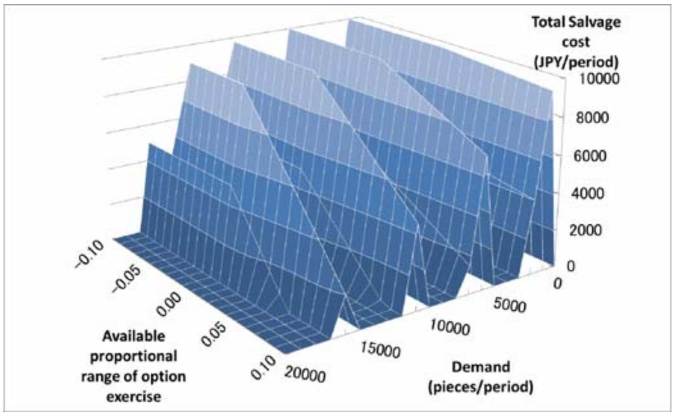

Fig.5.Sensitivity analysis for total salvage cost per period

E. Sensitivity analysis for total option exercised cost

Fig.6 shows the result of sensitivity analysis of option exercised cost to uncertainties. There is a clear asymmetry between positive *di* and negative due to the call option if the last batch turns fruits for supplier. The authors assume that the option exercised cost pays buyer for a compensation for the inventory cost increased. This cost occurs not for the put option that does not increase the inventory, but for the call option that increases.

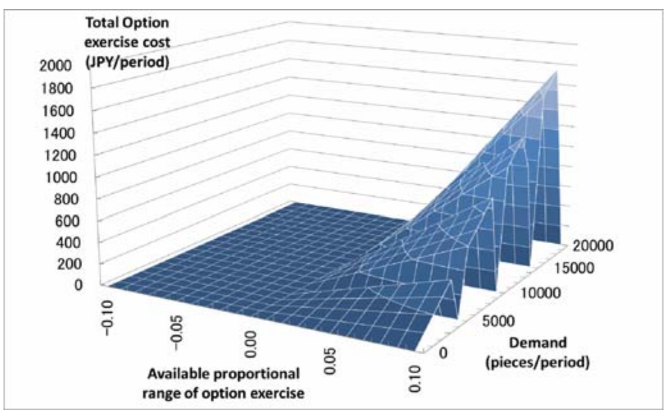

Fig.6.Sensitivity analysis for total option exercised cost per period

Demand increases in the option exercised cost with regard to the value of positive *di*. The cost radically decreases over multiples of the upper of last batch pieces such as 5000, 10,000, 15,000 and 20,000. There are little affords to exercise the call option around the multiples.

F. Sensitivity analysis for total option value

Fig.7 shows the result of sensitivity analysis of option value to uncertainties. The call option increases option value, but as in the case of the option exercise cost and the option exercised quantity. The put option also has increase of the option value in two cases. First is located in the area from -0.06 to -0.10 in *di* and 16,000 pieces in demand, second is -0.10 in *di* and 11,000 pieces. These results showed the cases reduction in the production pieces regardless of increase in profits. Moreover, volume flexibility in production can expressed as the amount of money in the option value by using ROA.

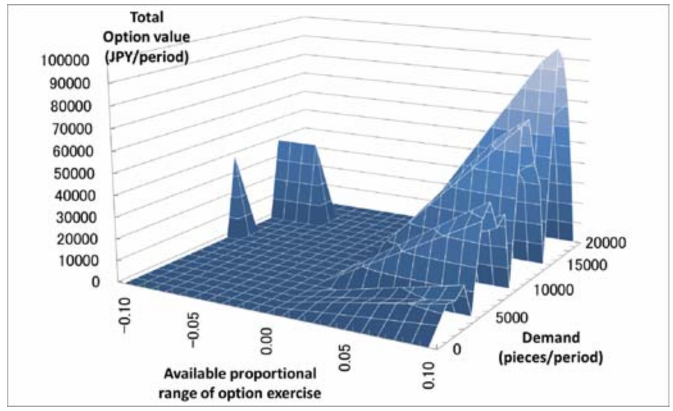

Fig.7.Sensitivity analysis for total option value per period

VI. CONCLUSION

The result of analysis reveals that profits can increase by reducing the salvage and processing costs even in the same sales.

Total option value is occasionally increased with options. Option value in one period rises, but this is due to the adjustment of the production volume. If supplier exercises options to adjust the amount of production in one period, the demand by the buyer should be changed. However, the buyer is able to change demand in next period according to changed volume information, demand by the buyer is not changed in the long run. In other word, if buyer got the information of suppliers' option exercise, buyer would change the demand in the next time. Therefore, adjusting the amount of demand in respect to amount of exercised option quantity, the buyer has a feedback system to adjust the demand.

If supplier increased the amount of production using the call option, the buyer would reduce the amount of demand next time. If supplier decreased the amount of production using the put option, the buyer would increase the amount of demand next time. In the long term, supplier raises profit not by simply increasing the production amount, but by improving the efficiency of production.

These results show that the sensitivity analysis is the valuation method on flexibility for irreversible production decision under uncertain demand. Soft drinks must be kept under cool condition produce daily. Even if soft drinks are produced repeated with a short interval, uncertainties in demand and the production of last batch will not disappear. In this view, ROA shows the significant to use volume flexibility of production and evaluate profits. Traditionally, flexibility has been regarded as free for supplier because of internal matter[2].

In principle of SCM, supplier produces just a number of demand, without exess or shortage. ROA can tell buyer and supplier the monetary flexibility as option value. Buyer and supplier can communicate the flexibility of production each other. The flexibility of production is not internal mater but external matter within supply chain.

From a perspective of ROA, a call option is seemed to be expand option and a put option is to be shrink option in volume flexibility of product. But, these option is called as timing option to approach for the optimal investment opportunity.

Buyer has a tendency to select the demand to meet their optimal stock point. The difference between demand and production prevents buyer from getting the optimal stock point, and makes buyer pay the extra cost. In case that the difference is within safety stock range, authors think that the extra cost is relatively equal to exercised option cost and supplier can pay as the compensation to buyer.

ROA leads cost reduction for supplier and is considered as an excellent tool to create a robust supply chain without disturbing the buyer.

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