CSCanada
Management Science and Engineering
Vol. 8, No. 3, 2014, pp. 1-7
DOI:10.3968/5591

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

The Price Decision of Order With Third-Prty Logistics Based on Incomplete Information Game

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Received 12 June 2014; accepted 26 August 2014
Published online 30 September 2014

Abstract

As the price is always a prime factor taken into consideration when a 3PL provides logistics service. With increasingly cases of logistics service providing to retailers rather than manufacturers nowadays, quantity may be not as an important factor. For retailers always have certain amounts of goods, they can hardly expand the scale at their will to obtain a quantity discount. To logistics companies, most of them are medium-sized and small enterprises, under limitations of its fields and capability. They can neither provide enough warehousing area for retailers. This paper builds the price decision model in expectation of utility obtaining by service contract instead of the whole revenueof pricemultiplying quantity, and would be more suitable for 3PL to apply when working for a retailer. Besides, this paper sets the opponent's acceptable price as uncertain information, which is more realistic than the usual complete and perfect information assumption. Based on the incomplete information game and introducing variables of service capability and service level, this paper will give the best decision of pricing order and a specific amount in quotingthe price stage. Further discussion will quantify the benefits of pricing first and factors affect the benefits which aremore conducive to the third -party logisticsenterprises to provide services for external companies.

Key words: Pricing order; Incompleteinformation game; Quoting decision

LIU Fangtong (2014). The Price Decision of Order With Third-Party Logistics Based on Incomplete Information Game. *Management Science and Engineering*, *8*(3), 1-7. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/5591
DOI: http://dx.doi.org/10.3968/5591

INTRODUCTION

It is never too much to have discussions about how to make a better quoting price decision it is a key point when two parties of supply chain consider collaborating. As we know, price is always the most pivotal factor no matter a manufacturer or a retailer finds logistics company. When our group did field research in Jingliang City Logistics Department for the Undergraduates Innovative Project, a manager of this company's client told us that he would choose logistics company with the feasible quoting price in a certain level of service, and he always has a range of acceptable price in advance. Jingliang City Logistics Department mainly provides warehousing service for retailers, such as Yansha Outlets, Dazhong Household Appliances and some other retailers. Before getting a long-term contract, both parties would make deal in price (about 1-2 RMB per square meter). In this way, how to make the most beneficial price with a certain degree of service level is worth a discussion: whether quoting price first would get a benefit and what is the specific price should be quoted. The factor of quantity may be not as crucial to a retailer as to a manufacture, so we will not take the traditional utility function of price multiplies quantity. Instead, based on the dynamic game of incomplete information, the final decision will be evaluated by the expectation of contract's agreement utility in this paper. A strategy of pricing order and specific quoting price will be given. Beyond that, we will have a further discussion of factors that influence the benefits of quoting price and the compensation of cost when you have to pay in order to get the initiative.

1. REVIEW OF LITERATURES

There is never short of researches about pricing strategies. However, from the classic Bertrand Model, decision about price always takes quantity as an indispensable factor into consideration. Literatures concerning third-party logistics service pricing is not scarce, however, most of them focus on qualitative analysis instead of quantitative analysis. As Xie and Li (2010) published several research in methods and factors should be considered or applied in the pricing decision. These provide useful information to build up specific quantitative model. Instead specific quoting price decision, existed literatures prefer to investigate the benefit of cooperation or competition in bidding process and the times of quoting's benefits, like several articles of TianDagangand XueHao. In BaiYanhuaand YanhuaYing's research, the model based on complete information static game gives basic analysis between cost and revenue. Although they apply the game theory to the pricing mechanism of the third partylogistics enterprises in standard logistics service and core logistics services, the cost is not described in a detailed expression and decisions of 3PL and client are made at the same time which is not realistic.

As many consider the situation of a manufacture and a logistics server who provide service always in terms of transport, packaging and warehousing, quantity does take as an important role. The manufacture's production will be affected by the price of its total cost which includes the expense of logistics operation. Nowadays, the form of providing warehouse for retailer is more common for 3PL especially the city logistics server with medium or small scale.This model's assumption and standard of evaluation will fit for logistics service provided to retailers much more.

2. THE MODELING FRAMEWORK

According to background mentioned in Chapter 1, this paper would consider the simple but effective service model that consists of one retailer and one third-party logistics server. When talks about the comprehensive capacity of these two decision maker, no one is so powerful that has ability to take a leading position in the whole decision process. In this way, the decision model of these two participants could be considered to have the same reaction function. Basic assumptions are that both parties are entirely rational and pursue profit maximization. As we do not take quantity variable into consideration, the traditional profit presentation of $u=p*q$ (price multiplies quantity) will not be available. In this paper, the final profits of both retailerand third-party logistics server would be present as the expectation of dealing contracts, which are denoted as$u_l$and u_r.

Focusing on the price order of two participants, we will discuss the two different order cases respectively.

Let $e_l$and e_r denote the cost of logistics service provided for the third-party logistics server and retailer, respectively. To better describe the cost of logistics service, we would invite specific variables of logistics service level denoted as l, and conversion coefficient denoted as k to indicate the cost$e=k*l^2$. The coefficient is service level's conversion to service cost, which reflects the ability of providing logistics service. Of course, $e_l$and e_r would be respectively expressed as $e_l=k_l*l^2$ and $e_r=k_r*l^2$. To third-party logistics server, e_l just shows the cost of service it provides; however, $e_r$would be conceived as the cost of logistics operation if the retailer deals with by its own ability. We also assume that k_l is always smaller thank_r. This would provide motivations for the retailer to find a third-party logistics server.

In two cases of different participants fixing price first, p_l and p_r represents bidding price of the third-party logistics server and the retailer respectively. As we are particular interested in warehousing service providing, we would point each price as the storage unit(per square meter) price. In this way, if contract is signed in each participant own bidding process, the benefit per unit of their process would be indicated as p_l - e_l and p_r -e_r. Let s_l and s_r denote the benefits obtained by the third-party logistics server and the retailer if an agreement is not reached. Now, we only need the probability of contract agreement to work out the final benefit expectation. Let αdenote the probability of contract agreement with the third-party logistics server bidding process, and β denote the retailer's one.

Here, we have finished the expression of final benefit expectations to both parties:

$$\begin{aligned} u_l &= \alpha(p_l - e_l) + (1-\alpha)s_l \\ u_r &= \beta(e_r - p_r) + (1-\beta)s_r \end{aligned} \quad . \tag{1}$$

For this model, we set conditions based on incomplete information. To be specific, both parties cannot get the exact information of the opposite's acceptable price. The only thing there now is just the range of possible price to each of the parties. And we set $\overline{v}_l$and $\underline{v}_l$ to indicate the highest and lowest price thoseare acceptable to the third-party logistics server known by the retailer; $\overline{v}_r$ and $\underline{v}_r$ mean the same to the logistics server.Further, we assume that

$$e_l \in X_l = \left|\underline{v}_l, \overline{v}_l\right|,\ e_r \in X_r = \left|\underline{v}_r, \overline{v}_r\right|.$$

X_l and X_r are the random variable, which has CDF (cumulative distribution function)F.

$$F_l(v_l \mid \delta_l),\ F_r(v_r \mid \delta_r),$$

Where,δis the cumulative probability; uniformly distributed,strictly monotone increasing and derivable in interval $[\underline{v}, \overline{v}]$. In this way, wehave $F(\underline{v}|\delta)=0$, $F(\overline{v} \mid \delta)=1$. These assumptions are common knowledge to both parties.

3. QUOTING PRICE DECISION

The key point we care about is whether fixing price first would bring abundant benefits and if it is true, what exact price should be fixed to obtain the highest benefits. So, we just consider situations that the deal will be made. As we have assumed in Chapter 2 that k_l is always smaller than k_r; it is also meaningful to get a contract signed: e_l is always smaller than e_r in the same logistics service level. And this is the basic condition of price decision.

3.1 Third-Party Logistics' Quoting First

Assuming the only thing both parties care about is the price offered by the other, the probability of reaching agreement or not will be influenced by it. So, when the logistics server fix price first, the probability of dealing with the retailer is

$$\alpha=\frac{\overline{v}_r-P_l}{\overline{v}_r-\underline{v}_r}{}^2. \quad (2)$$

It makes sense that when the price is much profitable for the other, he will be more willing to accept. Bringαto Equation(1), we have the logistics server price decision function:

$$u_l(p_l)=\frac{\overline{v}_r-p_l}{\overline{v}_r-\underline{v}_r}(p_l-k_l l^2)+\frac{p_l-\underline{v}_r}{\overline{v}_r-\underline{v}_r}s_l\,. \quad (3)$$

At present, we do not take the cost of pricing first into consideration, which may include the expenses of information collection, marketing survey, data analyzing, etc. However, in Chapter5, we will further discuss the max cost the party who price first could afford.

For better analyze final solution of the function, we firstly assume the value of not obtaining contract is nothing, expressed as s_l=0.And the meaningful price given by logistics server has limitations: $p_l\in\left[\max(\underline{v}_r,e_l),\overline{v}_r\right]$. The giving price will not be higher than estimated retailer's highest price. And as logistics server should find the most beneficial price, on the condition of getting profits ($p_l>e_l$), he will not give a price lower than estimated retailer's lowest price. We should find the best response of p_l to this function to make the most benefits, that is

$$u_l(P_l^*)=\max\left\{\frac{\overline{v}_r-p_l^*}{\overline{v}_r-\underline{v}_r}(p_l^*-k_l l^2)|\,p_l\left[\max(\underline{v}_r,e_l),\overline{v}_r\right]\right\}. \quad (4)$$

Firstly, we would calculate its second derivative of p_l to find whether there is a value to realize the maximization of utility. And we get $\frac{\partial^2 u}{\partial p_l^2}=-\frac{2}{\overline{v}_r-\underline{v}_r}<0$, which means that the function is concave with maximum. Than we figure out the first derivative of p_l as the optimal solution as:

$$P_l^*=\frac{\overline{v}_r+k_l l^2}{2}\,. \quad (5)$$

To simplify the expression, we denote $\Delta_1=\overline{v}_r-\underline{v}_r$. Bringing P_l^* back to function, we would get the final max utility expressed as:

$$u_l(P_l^*)=\frac{(\overline{v}_r-k_l l^2)^2}{4\Delta_1} \quad (6)$$

To retailer, his utility in 3PL quoting first stage would be measured as his expense of finishing logistics operation himself minus the quoting price of 3PL. So the expression of retailer's utility when he accepts 3PL's quoting price is

$$u_r(P_l^*)=k_r l^2-\frac{\overline{v}_r+k_l l^2}{2}\,. \quad (7)$$

And if retailer deny this price, neither party would get a utility, expressedasu_l=u_r=0. However, as we have set the condition that $p_l\in\left[\max(\underline{v}_r,e_l),\overline{v}_r\right]$, we should examine whether the best response of 3PL's quoting price meets this requirement.For assumption that e_l is always smaller than $e_r$has been made, that e_l is always lower than $\overline{v}_r$ is established either. P_l^* would always satisfies the condition that $e_l\le P_l^*\le\overline{v}_r$, and we should only discuss that whether $P_l^*\ge\underline{v}_r$.

① If it is true that $P_l^*\ge\underline{v}_r$, best response of 3PL's quoting price would not change. Both utilities of 3PL and retailer would be remained as expressions above.

② If $P_l^*<\underline{v}_r$, 3PL would quoting price of $\underline{v}_r$ instead of P_l^* to get more profits. In this way, utility of 3PL would be expressed as:

$$u_l^{'}=\underline{v}_r-k_l l^2\,. \quad (8)$$

And if retailer accepts this quoting price, his utility would be:

$$u_r^{'}=k_r l^2-\underline{v}_r\,. \quad (9)$$

If not, both parties would not get utility at all.

So far, we get the integrate expressions of two parties utilities when 3PL quoting a price first. That is also our **proposition1**:

When 3PL pricing first and retailer accept the price:

$$\text{If } p_l^*\ge\underline{v}_r,\ P_l^*=\frac{\overline{v}_r+k_l l^2}{2},\ u_l=\frac{(\overline{v}_r-k_l l^2)^2}{4\Delta_1}\text{ and }u_r=k_r l^2-\frac{\overline{v}_r+k_l l^2}{2}$$

$$\text{If } P_l^*<\underline{v}_r,\ P_l^{*'}=\underline{v}_r,\ u_l^{'}=\underline{v}_r-k_l l^2\text{ and }u_r^{'}=k_r l^2-\underline{v}_r\,.$$

3.2 Retailer's Quoting First

Giving the same restrictive conditions as the third-party logistics server's that price influence the decision probability, when retailer quoting a price first the probability of dealing can be expressed as:

$$\beta=\frac{p_r-\underline{v}_l}{\overline{v}_l-\underline{v}_l}. \tag{10}$$

It makes sense that 3PL prefer higher service price with the same service level, so the higher t price afforded by retailer, the more possibility 3PL would contract. And bring β to function 1, we have the retailer's price decision function

$$u_r(p_r)=\frac{p_r-\underline{v}_l}{\overline{v}_l-\underline{v}_l}(k_r l^2-p_r)+\frac{\overline{v}_l-p_r}{\overline{v}_l-\underline{v}_l}s_r. \tag{11}$$

Also same as 3PL, we assume the value of not obtaining contract is nothing, expressed as s_r=0. The meaningful price given by logistics server also has limitations: $p_r\in[\underline{v}_l,\min(\overline{v}_l,e_r)]$. The retailer's giving price will not lower than estimated 3PL's lowest price, otherwise 3PL will definitely not accept. And as retailer should find the most beneficial price, on the condition of getting profits ($p_l<p_r$), he will not give a price lower than estimated 3PL's highest price. We should find the best response of p_r to this function to make the most benefits. In this way, we can equally get the retailer's deciding function,

$$u_r(P_r^*)=\max\left\{\frac{p_r^*-\underline{v}_l}{\overline{v}_l-\underline{v}_l}(k_r l^2-p_r^*)|\ p_r\in[\underline{v}_l,\min(\overline{v}_l,e_r)]\right\}. \tag{12}$$

When retailer quotes a price first, the best response of price and corresponding utility would be figured out in exactly the same way as 3PL's function. Equally, we get retailer's best quoting price as

$$P_r^*=\frac{\underline{v}_l+k_r l^2}{2}. \tag{13}$$

Under this condition, the utility of 3PL would be considered as retailer's quoting price minus logistics company service cost, if 3PL accepts this price. The utility expression would be

$$u_l=\frac{\underline{v}_l+k_r l^2}{2}-k_l l^2. \tag{14}$$

Also too simplify the expression, we denote $\Delta_2=\overline{v}_l-\underline{v}_l$. And bringing P_r^* back to retailer's utility function, we get retailer's max utility expressed as

$$u_r=\frac{(k_r l^2-\underline{v}_l)^2}{4\Delta_2} \tag{15}$$

The best response of retailer's quoting price should also be examined to see whether satisfy the restrictive limitations that $P_r^*\in[\underline{v}_l,\min(\overline{v}_l,e_r)]$. According to previous assumptions, we can easily get the conclusion that $\underline{v}_l\le P_r^*\le e_r$ is constant satisfied. And only should we discuss different situations of relationships between P_r^* and $\overline{v}_l$.

① If it is true that $P_r^*\le\overline{v}_l$, best response of retailer's quoting price would not change. Both utilities of 3PL and retailer would be remained as expressions above.

② If $P_r^*>\overline{v}_l$, retailer is not necessary to give the higher price, and $\overline{v}_l$ would be set as his quoting price. If 3PLaccepts this price, his utility would be expressed as:

$$u_l'=\overline{v}_l-k_l l^2. \tag{16}$$

And retailer's utility would be

$$u_r'=k_r l^2-\overline{v}_l. \tag{17}$$

No matter in which situation, no utility would both parties get if 3PL refuse retailer's quoting price.

Here, we get our **proposition2**:

When rerailer pricing first and 3PL accept the price:

$$\text{If } P_r^*\le\overline{v}_l,\ P_r^*=\frac{\underline{v}_l+k_r l^2}{2},\ u_l=\frac{\underline{v}_l+k_r l^2}{2}-k_l l^2 \text{ and } u_r=\frac{(k_r l^2-\underline{v}_l)^2}{4\Delta_2}$$

$$\text{If } P_r^*>\overline{v}_l,\ P_l^{*'}=\overline{v}_l,\ u_l'=\overline{v}_l-k_l l^2 \text{ and } u_r'=k_r l^2-\overline{v}_l.$$

4. RESULT ANALYSIS

In chapter 3, we have figured out the specific price and utility of both parties in different pricing order. The 3PL would provide the most profitable quoting price if he has chance to quote first. And he can also work out the utility when the opposite price first through this model. However, the purpose of this paper is to compare the different situations utility, which could help 3PL to decide whether or not should he strive for quoting first. And we would also like to get the benefits or loss of quoting order. Further, to see which the factors would influence the benefits (or loss) and how can we make use of these information is also meaningful and important.

For there are different situations with best response of price and corresponding utility, it is hard to get a clear conclusion under all these cases. So we would set a few more limits to simplify the final result in the two different order ways.

We'd like to let both situations quoting price meets the restrictions, in this way we would have $\frac{\overline{v}_r+k_l l^2}{2}\ge\underline{v}_r$ when 3PL price first, and $\frac{\underline{v}_l+k_r l^2}{2}\le\overline{v}_l$ when retailer price first.

Let these two inequalities always be met and further we have

$$\begin{cases} k_l l^2 \geq \underline{v}_r\text{-}\Delta_2 \\ k_r l^2 \leq \overline{v}_l + \Delta_1 \end{cases}. \tag{18}$$

We just take the value when both functions get equations

$$\begin{cases} \underline{v}_l = \underline{v}_r\text{-}\Delta_2 \\ \overline{v}_r = \overline{v}_l + \Delta_1 \end{cases} \Rightarrow \Delta_1 = \Delta_2, \overline{v}_l = \underline{v}_r. \tag{19}$$

$\Delta_1 = \Delta_2, \overline{v}_l = \underline{v}_r$ are the two additional restrictions for a better discussionofthe results. And these two are not too ridiculous to realize. For those just means both parties have the same price range and 3PL's cost would always lower than retailer's.

As we concern more about the benefits (or loss), we suppose that both parties would accept the opposite's quoting price as long as it meets the basic restrictions. As a result, we would have just one result in two pricing order:

When 3PL price first, $u_l = \dfrac{(\overline{v}_r - k_l l^2)^2}{4\Delta_1}$ and $u_r = k_r l^2 - \dfrac{\overline{v}_r + k_l l^2}{2}$.

When retailer price first, $u_l = \dfrac{\underline{v}_l + k_r l^2}{2} - k_l l^2$ and $u_r = \dfrac{(k_r l^2 - \underline{v}_l)^2}{4\Delta_2}$.

The difference of 3PL's utility would be

$$\Delta u_l = \frac{(\overline{v}_r - k_l l^2)^2}{4\Delta_1} - \frac{\underline{v}_l + k_r l^2}{2} + k_l l^2. \tag{20}$$

However, we can find that this Δu_l is always a positive number. The detailed calculative process will be present in appendix. And several factors would be analyzed in the following part to quantify their influence.According to warehousing cost of 3PL we know about, we would like to set the range of 3PL's acceptable price range as [0.5, 1.5]. Because the further restrictions have limited retailer's acceptable price has the same length of range and always higher than 3PL's, his price range would be [1.5, 2.5]. When we discuss the influence of price range, we would set it changing from 0.5 to 1. To give a meaningful level of service provided, we could figure out that $l \in [1, 2]$, and when we do not take it as a variable, it is set as 1.5. The 3PL's service capability is higher than retailer's, so let k_l=0.5, k_r=0.9. When discuss impact of 3PL's service capability, it would be set from 0 to 0.7, which also satisfies higher than retailer's capability. And to have a better value, we would multiply quantity instead of unit profit to show the final benefits. Set quantity=5000. Giving these parameters above, we can get figures of benefit affected by these factors.

And the red line represents 3PL's utility when he quoting a price first, the blue line represents his utility when accepts the opposite's quoting price.

4.1 ServiceLevel(*l*)

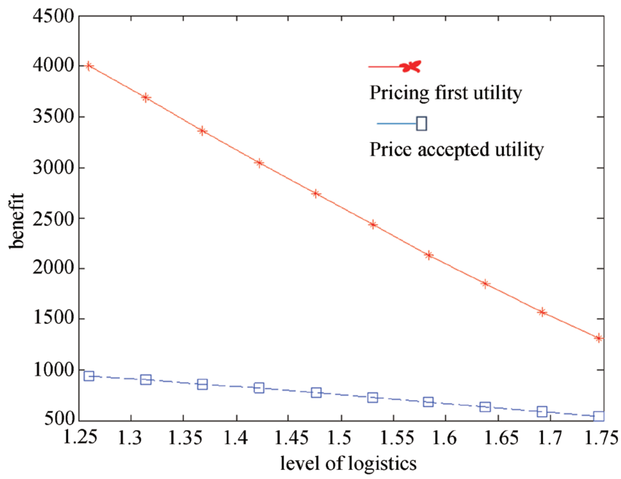

Figure 1
Impact of Service Level

From Figure 1, we can easily find that when 3PL quoting the price first, he would always get benefits. The benefits decrease in service level. This means if the logistics service 3PL provides is not high-level, just like low requirements warehousing service, much more benefits would 3PL get from fixing to price first. In this way, 3PL do has motivation to price first.

4.2 Price Range(Δ)

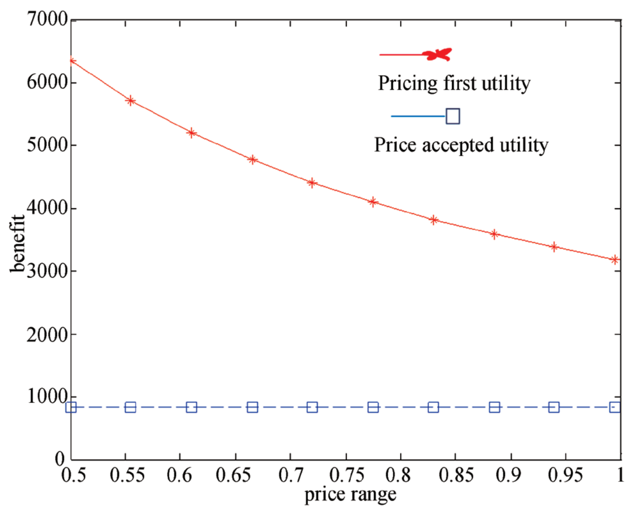

Figure 2
Impact of Price Range

The second figure also testifies the conclusion that quoting first always has benefits. Andthe bigger price range is, the smaller profits will 3PL get. That means the benefits are increasing when 3PL gets more accurate range of retailer's acceptable price.It is easy to understand that when one can know the exact cost of the other one, he would give the most profitable price to deal a contract. However, when making efforts to find the opposite's price range, 3PL would also pay out and this expense has not been considered into his cost. But we still get the point that 3PL should be motivated to find the opposite's accurate price range.

4.3 ServiceCapability(k_l)

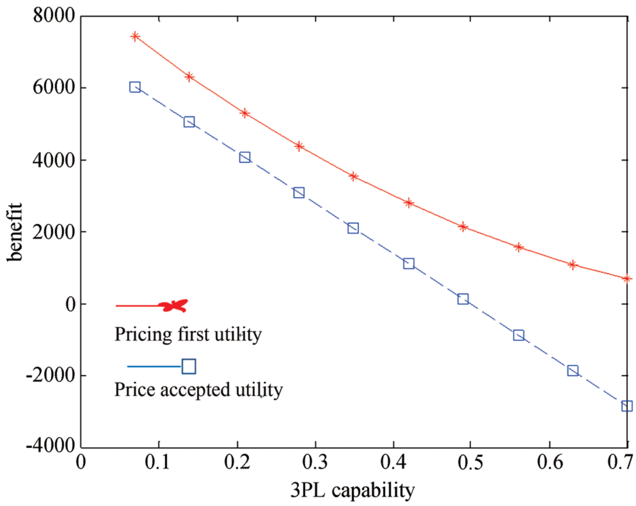

Figure 3
Impact of Service Capability

When taking 3PL's service capability as a variable, the result is a little bit confused to get a clear conclusion. Though we can see that quoting price first is still profitable, the trend is not as expected. While 3PL would not agree on a contract which is deficient, we may just ignore the right part when benefit has a minus value. Just focus on the positive part, we find the improvement in capability does not bring more difference to 3PL's benefits in this model. It can be explained by that no other capability related factors have been taken into consideration. However, we can still use this formula to work out the least service capability of 3PL to guarantee a benefit.

5. MANAGERIAL INSIGHT

According to analyses in Chapter 4, some managerial insights have been obtained. First in the process of making a price, quoting first would always get benefits. Serving for retailer, 3PL should try his best to get the first price chance. For example, 3PL could give some of benefits he would get from it to obtain this chance. Secondly when 3PL provide an easy work, much more benefits would he get from quoting first. Though it is hard to define a high level service, those logistics operations involving fewer techniques could be considered as less complicated and a low level service. So in these cases, 3PL would even sacrifice some profits in price to get the quoting chance. Third, 3PL should balance the cost and profit of acquiring the opposite's acceptable price range. He should make sure that the increased benefits from accurate price rangewould compensate the extra cost of getting these informations. And if 3PL itself has advantages in attaining information, for example he has a great team or many channels, 3PL should exploit his advantages to the full as possible. Forth, when we take the cost of quoting first into consideration, the Δu_l could be cognized as the compensation. As we know $\Delta u_l = \frac{(\overline{v}_r - k_l l^2)^2}{4\Delta_1} - \frac{\underline{v}_l + k_r l^2}{2} + k_l l^2$, we can figure out the highest cost of information acquisition. And making use of this value, 3PL could decide his devotion to retailer's company messages in advance.

CONCLUSION

In this paper, the model based on incomplete information game gives the conclusion that in pricing decision process, active strategy brings benefits which are quantified as $\Delta u_l = \frac{(\overline{v}_r - k_l l^2)^2}{4\Delta_1} - \frac{\underline{v}_l + k_r l^2}{2} + k_l l^2$. And 3PL should set his price equals to $P_l^* = \frac{\overline{v}_r + k_l l^2}{2}$ as best response price. Here he would get the utility of $u_l = \frac{(\overline{v}_r - k_l l^2)^2}{4\Delta_1}$ which is the maximum value. If 3PL wants to get a more beneficial position, he would try the best to get the chance of fixing the price first. Especially when 3PL provides a relatively low level service, he would be more motivated to get the chance for more benefits. And more accurate information can 3PL obtain, more profits would he achieve. In this way, find a balanced point between expenses and benefits are crucial. 3PL also needs to figure out the lowest rank of service capability to assure his revenue.

FURTHER DISCUSSION

As the cost of information retrieval has been mentioned times in this paper, it is a point worth further discussion. Though this model does not take it into consideration, later papers could add this variable in to utility function to find a new best response price. What's more, though this model sets the cost by expression of service level and service capability, these two factors donot be taken as variables. We just make sensitive analysis of these two,further study could set relevant variables to investigate the best response value of them. Of course, more relevant factors should be added into the decision formula. And it would turn into a multi-staged dynamic game with both price and service level decision.

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APPENDIX

Denotes $\overline{v_l} = \underline{v_r} = v,\ \Delta_1 = \Delta_2 = \Delta$

$$U_{l1} - U_{l2} = \Delta u_l = \frac{(\overline{v}_r - k_l l^2)^2}{4\Delta_1} - \frac{\underline{v_l} + k_r l^2}{2} + k_l l^2$$

$$= \frac{r^2 + \Delta^2 + (k_l l^2)^2 - 2\Delta k_l l^2 - 2v k_l l^2 + 2\Delta v - 2\Delta v + 2\Delta^2 - 2\Delta v_r + 4\Delta k_l l^2}{4\Delta}$$

$$= \frac{(k_l l^2 - v + \Delta)^2}{4\Delta} + \frac{\Delta + v - v_r}{2}$$

We have that $\frac{(-v_r + v + \Delta)^2}{4\Delta} + \frac{\Delta - v + v_l}{2} \geq 0$ always set up, when and only when $e_l = \underline{v_l}$, $e_r = \overline{v}_r$.

