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Research on Risk-averse Suppliers' Supplying Behavior Based on Consignment Sale Model

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Abstract: Owing to the existence of risk-averse suppliers, this research constructed a newsvendor model of supply chain on the basis of consignment sale model. Through theoretical analysis, this research proved the correlation between suppliers' risk coefficient, the distributional proportion of retailers' interests and suppliers' supplies was negative while the correlation between shared coefficient of retailers' cost and suppliers' supplies was positive. Finally, the conclusion was proved to be correct through a numerical illustration. The conclusion set a guidance to formulate a effective supplying contract for predominant retailers.

Key words: Consignment sale model, the newsvendor model, risk-averseness, supply chain

INTRODUCTION

With the more rapid development of competitive market and updating of products, there formed a commercial entity which had different influences on supplying channel in market. Various small-scale suppliers may propagate themselves through some famous large-scale virtual and real markets (for instance, Amazon, Carrefour, Wal-Mart Stores and etc.). The sale model both sides often used was consignment sale model. In this model, suppliers should pay for their access to retailers' market. Through consignment sale model, suppliers could make full use of retailers' channels to gain better publicity and improve sales.

In virtue of the popularity of consignment sale model, many experts researched its inherent mechanism. Hackett (1993) researched the contract of consignment sale systematically. Then, Gerchak *et al.* (2003) researched suppliers sought for maximal profits when they had no way to know retailers' sales report in the environment of consignment sale. Wang *et al.* (2004) systematically researched the influence of venture sharing contract had on each participant on supply chain in consignment sale model, then analyzed the influence coefficient of price flexibility and composition of cost had on the coefficient of venture contract and suppliers' and retailers' profits. On this basis, they got meaningful conclusion. Chen *et al.* (2008) researched the consignment sale model in which predominant manufacturers and retailers respectively bore the maintaining charge of stocking, they got the conclusion that manufacturers could coordinate supply chain and guaranteed more profits in consignment sale model than that in traditional sale models through setting down the admitting charge and proper distribution of interests. On the basis of literature Wang *et al.* (2004) and Li *et al.* (2009) further researched consignment sale model by Game Theory and proved that more profits than that in literature (Wang *et al.* 2004) could be got through NASH negotiation, then gave guidance for win-win strategy in consignment sale model. Wang (2010) compared the interests of manufacturers and retailers in two different consignment sale models i.e., RMVI (Retailer Managed Consignment Inventory) and VMRI (Vendor Managed Consignment Inventory), then concluded that more interests could be got in RVMI than in MVMI. They proved the reason why RMVI model is widely used from the theoretical angle. Zhang *et al.* (2010) applied to a new revenue sharing contract to realize the coordination of supply chain in consignment sale model, subsequently, they found this model can realize Pareto improvement to improve each participant on supply chain and coordinate under special condition. The above discussions only focused on the consignment sale model of single supplier and single retailer. Adida *et al.* (2011) discussed the consignment sale model in which there might exist competition between a supplier and various retailers. However, all the above conclusions were drawn under the condition that participants were neutral to risks.

In reality, participants of different position in consignment sale model hold different attitudes towards

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risks which thereby affected participants' action. Therefore, various experts systematically researched the channel of supply chain which was not neutral to risks. Gan *et al.* (2005) firstly established the model of supply chain which was composed of risk neutral suppliers and risk-averse retailers. Wang and Webster (2007) put forward a venture and risks sharing contract and finally they found out the condition under which supply chain contract could be coordinated. Shi and Xiao (2008) researched the coordinated effects on supply chain of buyback contract and price subsidized contract. Xiao and Yang (2008) found there existed competition of price and service among different supply chains, further, they researched the influence retailers' averseness to risks had on different supply chains under this condition. Wang *et al.* (2009) researched risk-averse newsvendor model and got the relation between price and the degree of risk averseness. Hsieh and Lu (2010) researched the model of supply chain composed of a manufacturer and two risk-averse retailers and change of participants' interests under the guidance of buyback strategy.

At present, the researches on consignment sale model neglected the effects of the participants' risk preference on supply chain, furthermore, the researches on risk preference just focused on retailers' attitudes towards risks. Actually, various suppliers who were direct owners of commodity, were sure to have risk preference as units which were far away from market in that they were uncertain about demands. Therefore, it is exactly necessary to research suppliers' risk preference. This paper will study the ordering of suppliers who are risk preferred under the consignment sale model, then set the foundation for further researches. Systematical analysis on the effects of risk preference on orderers' order will give guidance for predominant retailers to draw up effective supplying contract.

PARAMETER SETTING

The supplying chains discuss here is composed of a supplier and a retailer. Prior to selling season, supplier decide to exhibit their merchandises in retailer's market. As the dominant on supply chain, the proportion of sale profits retailers get from suppliers is r. Later, suppliers ascertain supply q of commodity according to retailers' deducting proportion. For objectivity, suppose there are commodity which are unsold or unsatisfactory in sale season, the salvage value and shortage cost can be ignored. In order to establish a model, Table 1 shows the relevant parameters.

Table 1: Table of Parameters

Parameter	Description
p	Sales of merchandises which is decided by competition in market, is a fixed value
c	The sum of retailer and supplier's cost
r	The deducting proportion of retailer's interests which is decided by retailer
α	Retailers' distributive proportion of total cost
λ	Suppliers' risk coefficient, represents the degree of suppliers' risk averseness
$q^*_{\lambda-1}$	If suppliers' risk coefficient is λ, suppliers ascertain the optimal supply according to the function of their revenue
q^*_0	The optimal supply under the condition that suppliers are neutral to risks
q^*_c	The optimal supply under the supply chain on which centralized decision are made
$f(\bullet)$	The Probability density function of Parameter "$\bullet$"
$F(\bullet)$	the distribution function of parameter "$\bullet$"

MODEL CONSTRUCTION

Centralized decision making of supply chain: The function of expected profits under the centralized decision of supply chain is as follow:

$$E[\pi_c(q)] = pE[\min\{q,X\}] - cq,\ E[\min\{q,X\}] = \int_0^q xf(x)dx + \int_q^\infty qf(x)dx = q - \int_0^q F(x)dx$$

Therefore:

$$E[\pi_c(q)] = pE[\min\{q,X\}] - cq = (p-c)q - p\int_0^q F(x)dx$$

then:

$$\frac{\partial E[\pi_c(q)]}{\partial q} = p - c - pF(q)$$

$$\frac{\partial^2 E[\pi_c(q)]}{\partial q^2} = -pf(q) < 0$$

Therefore, the function of expected profits on the whole supply chain is a Concave function of supply q, then, there exist a unique optimal supply q^*_c which maximize the interests of supply chain.

Let-be:

$$\frac{\partial E[\pi_c(q)]}{\partial q} = 0$$

the optimal supply is:

$$q_c^* = F^{-1}\left(\frac{p-c}{p}\right) \quad (1)$$

Decentralized decision making of supply chain: Under the condition of uncertain demands, suppliers are usually

averse to risks. Suppliers' attitude towards risks affects the whole supply chain. This paper chooses a typical model from various risk evasion, i.e.:

$$U(W)=\begin{cases} W-W_0 & W>W_0 \\ \lambda(W-W_0) & W\le W_0 \end{cases}$$

For objectivity, take $W_0 = 0$. Accordingly, function of suppliers' expected profits is:

$$E[\pi_m(q)]=\int_0^q[p(1-r)x-c(1-\alpha)q]f(x)dx+\int_q^{\infty}[p(1-r)-c(1-\alpha)]qf(x)dx$$

Based on the expression of risk averseness, function of risk averse suppliers' expected profits is:

$$E[U(\pi_m(q))]=(\lambda-1)\int_0^{q_e}[p(1-r)x-c(1-\alpha)q]f(x)dx+E[\pi_m(q)]$$

Within the above expression:

$$q_e=\frac{(1-\alpha)c}{(1-r)p}q$$

represents the equilibrium between suppliers' profit and loss. When $\lambda = 1$, then suppliers are neutral to risks. When $\lambda>1$, then suppliers are averse to risks. If $x<q$, then suppliers are under deficit; if $x>q_e$, then suppliers make profits.

Correspondently:

$$\frac{dE[U(\pi_m(q))]}{dq}=-(1-\alpha)(\lambda-1)cF(q_e)+[p(1-r)-c(1-\alpha)]-F(q)(1-r)p$$

$$\frac{d^2E[U(\pi_m(q))]}{dq^2}=-\frac{(\lambda-1)(1-\alpha)^2c^2}{p(1-r)}f(q_e)-f(q)(1-r)p$$

Considering $\lambda>1$, $r<1$ and the probability density function $f(\bullet)>0$, therefore:

$$\frac{d^2E[U(\pi_m(q))]}{dq^2}<0$$

represents the function of risk averse suppliers' respected profits is the concave function of supply q. Then there exist the single optimal supply $q^*_{\lambda-1}$, the value of function of expected profit is maximal. Let:

$$\frac{dE[U(\pi_m(q))]}{dq}=0$$

then there can get the value $q^*_{\lambda-1}$:

$$-(1-\alpha)(\lambda-1)cF(qe(q^*_{\lambda-1}))+[p(1-r)-c(1-\alpha)]-F(q^*_{\lambda-1})(1-r)p=0 \quad (2)$$

The exponent of $q^*_{\lambda-1}$ is ascertained by Eq. 2. When $\lambda = 1$, suppliers are neutral to risks, the above expression is replaced by the following:

$$[p(1-r)-c(1-\alpha)]-F(q^*_{\lambda-1})(1-r)p=0$$

Therefore, the optimal supply under the condition of neutral risks is:

$$q_0^*=F^{-1}(\frac{p(1-r)-c(1-\alpha)}{p(1-r)}) \quad (3)$$

Comparing q^*_0 and q^*_c, it is easy to get when and only when $r = \alpha$, $q^*_0 = q^*_c$, the supply chain can be coordinated. In normal case, as predominant on supply chain, retailers let $r>\alpha$, correspondently, $q^*_0<q^*_c$. It is verified that on risk neutral supply chain where decision making are decentralized, the optimal supply can not maximize the profits. It means that it is necessary to realize the coordination on supply chain through profits distributing in consignment sale model.

Considering suppliers are risk-averse, it is necessary to analyze the influence risk averseness have on suppliers' decision of supplying. Through judging the relationship between $dq^*_{\lambda-1}/d\lambda$ and 0, it is easy to make sure the influence risk averseness have on suppliers' decision of supplying.

Through expression 2, it is ascertained that:

$$\frac{dq^*_{\lambda-1}}{d\lambda}=-\frac{c(1-\alpha)F(q_e)}{\frac{(\lambda-1)(1-\alpha)^2}{p(1-r)}+p(1-r)f(q^*_{\lambda-1})} \quad (4)$$

Considering $\lambda>1$, $r<1$ and $\alpha<1$ and the probability density function is $f(q^*_{\lambda-1})>0$ and $F(q_e)>0$, thus, $dq^*_{\lambda-1}/d\lambda<0$, then when $\lambda>1, q^*_{\lambda-1}<q^*_0=q^*_c$. Hence, the optimal supply $q^*_{\lambda-1}$ is a monotonous decreasing function of risk coefficient λ. The higher degree of suppliers' risk averseness is, the less supplying batches for retailers are.

Considering the suppliers' decision of supplying is ascertained according to the deducting proportion of retailers' profits, then it is necessary to analyze the influence deducting proportion have on suppliers' decision of supplying. Through judging the relationship between $dq^*_{\lambda-1}/dr$ and 0, it is easy to make sure the influence retailers' deducting proportion have on suppliers' decision of supplying.

Through expression 2, it is ascertained that:

$$\frac{dq^*_{\lambda-1}}{dr}=-\frac{p[1-F(q^*_{\lambda-1})]}{\frac{(\lambda-1)(1-\alpha)^2c^2}{p(1-r)}f(q_e)+p(1-r)f(q^*_{\lambda-1})} \quad (5)$$

Considering $\lambda>1$, $r<1$ and $\alpha<1$ and the probability density function $F(q^*_{\lambda-1})$ and$(q^*_{\lambda-1})<1$, hence, $dq^*_{\lambda-1}/dr<0$. Thus, the optimal supply $q^*_{\lambda-1}$ is a monotonous decreasing function of retailers' deducting proportion r. The more retailers' deducting proportion is, the less supplying batches for retailers are.

Furthermore, cost on the whole supply chain is apportioned by retailers and suppliers, it is necessary to analyze the influence risk averseness have on suppliers' decision of supplying. Through judging the relationship between $dq^*_{\lambda-1}/d\alpha$ and 0, it is easy to determinate the distributive proportion of retailers' cost to suppliers' supply. Through expression 2, it is ascertained that:

$$\frac{dq^*_{\lambda-1}}{d\alpha}=\frac{q[1+(\lambda-1)F(q_e)]}{\frac{(\lambda-1)(1-\alpha)c^2}{p(1-r)}f(q_e)+p(1-r)f(q^*_{\lambda-1})} \quad (6)$$

Concerning, $\lambda>1$, $r<1$ and $\alpha<1$, the function of probability density is $F(q^*_{\lambda-1})>0$ and $f(q_e)>0$, therefore, $dq^*_{\lambda-1}/d\alpha>0$. Therefore, the optimal supply $q^*_{\lambda-1}$ is a monotonous decreasing function of retailers' distributive proportion α. It represents that the more distributive proportion of retailers' cost is, the more supply of suppliers' supply is.

ANALYSIS ON VALUES

This study chose a series of values to verify the conclusion. It is supposed that the distribution of suppliers' needs is even i.e., $X\sim U(\mu-\sqrt{3}\sigma,\mu+\sqrt{3}\sigma)$. Generally speaking, if the anticipated needs is smaller than $\mu-\sqrt{3}\sigma$, represents participated error is too large, it is necessary to participate again. In sale season, the value after needs are met is among the interval $(\mu-\sqrt{3}\sigma,\mu+\sqrt{3}\sigma)$. Let p = 200, c = 100, r = 0.5, v, μ = 80, σ = 20 as basic parameter.

From Fig. 1, the larger the extent of suppliers' risk averseness is, the less the supply is. In Fig. 2, risk coefficient is defined, hence the more retailers' distributive proportion is, the more suppliers' supply is. In this way, the less suppliers' cost is, the more profits they will make through enlarge supply. Meanwhile, in Fig. 3, the more retailers' deducting proportion is, suppliers are more difficult to make profits, it is inevitable that suppliers are unwilling to supply more commodities. Accordingly, this graph indirectly indicates the influence risk coefficients have on supply.

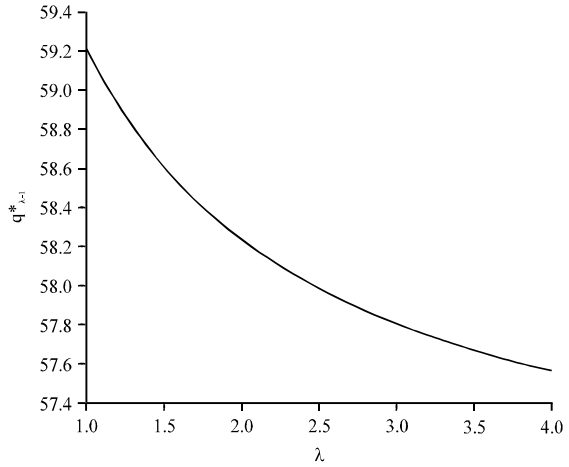

Fig. 1: Relation between suppliers' risk coefficient λ and supply $q^*_{\lambda-1}$

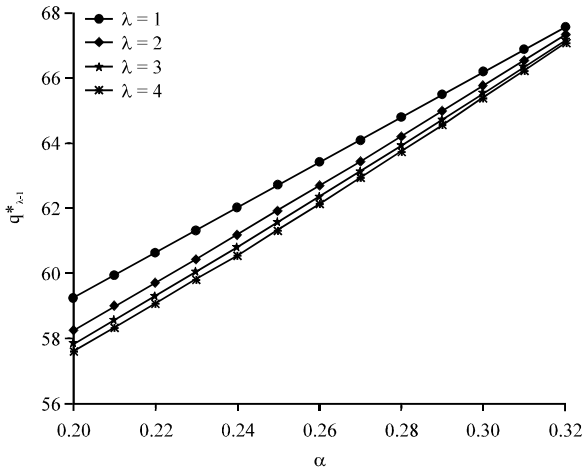

Fig. 2: Relation between the distributive coefficient of retailers' cost α and supply $q^*_{\lambda-1}$

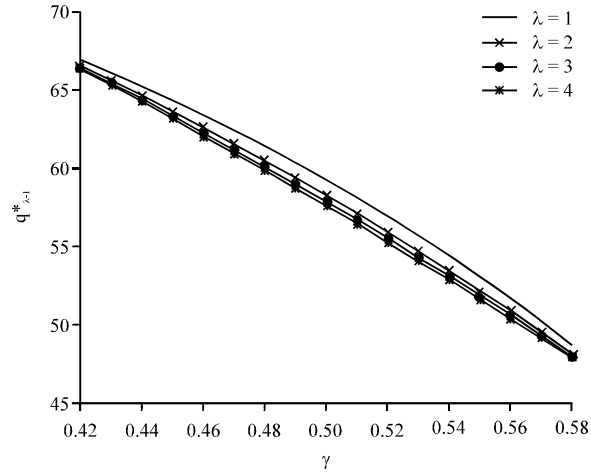

Fig. 3: Relation between the distributive coefficient of retailers' profit r and supply $q^*_{\lambda-1}$

CONCLUSION

This study constructs a newsvendor model of supply chain in which suppliers are averse to risks while retailers are neutral to risks. In this study, it is analyzed that the influence distributive proportion have on suppliers' decision of supplying. Finally the conclusion that the higher degree of suppliers' risk averseness is, the less supplying batches are; the higher of retailers' distributive proportion is, the more supplying batches are; the higher of retailers' deducting proportion is, the less supplying batches are.

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