Coordination Mechanism of Three-level Supply Chain with Joint Revenue Sharing and Price Reduction Contract

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Abstract. Based on the cooperative game theory of supply chain profit distribution strategy model. Analyze the actual situation and find out the influencing factors that affect the profit distribution of supply chain nodes. Shapley value of the distribution of benefits given is amended to effectively address the rational distribution of benefits in the supply chain. Establishing a Mechanism to Realize the Strategy of Joint Benefit - sharing Contract and Price-cut Contract Shapley value of the distribution of benefits given is amended to effectively address the rational distribution of benefits in the supply chain. By choosing a reasonable revenue sharing factor and price cut. To achieve practical application of supply chain reasonable allocation policy interests in cooperative game theory.

Introduction
Supply chain cooperation game the interests of enterprises fair, Reasonable distribution, In the actual situation Supply chain through the establishment of a joint revenue sharing contract and price reduction contract to achieve business cooperation. By setting up different revenue sharing efficient and price cut price, cooperative game enterprise maximizes the overall interests of the supply chain, maximizes the profit of the node enterprise, and determines the reasonable order quantity and the sales price. So theoretically and practically, we can find the theoretical parameters of the contract to maximize the theoretical interests, the theoretical structure to achieve the actual application.

Three - level Supply Chain Profit Distribution under Cooperative Game
In the cooperative game of supply chain members, the main problem is to find the equilibrium point of the game. So that participants through consultations to adopt a strategy favorable to all the Union, the establishment of an agreement to be achieved after the cooperation of the interests of the distribution, that is, the distribution agreement that the proportion of the distribution of the interests of cooperation. Suppose there are n companies forming a supply chain alliance \( N = (x_1, x_2, \ldots, x_n) \), The total benefits of a centralized decision are \( v(N) \), use Shapley Value method for business i the share of profits is
\[
\phi_i(v) = \frac{1}{n!} \sum_{S \in \Pi_N} (n-|S|)!|S|!(|S|-1)! [v(S) - v(S \setminus \{i\})] \quad i = 1, 2, \ldots, n
\]
share of profits is, however, this method has some limitations. It does not take into account the risk factors, investment and contribution of each node in centralized decision-making, therefore, the combination of these factors leads to a correction factor affecting the overall distribution of benefits, into the Shapley value model, get an improved model.
Therefore, the revised distribution of the interests of enterprises as follows:
\[
\phi_i^*(v) = \phi_i(v) + \Delta \phi \frac{1}{n!} \sum_{S \in \Pi_N} (n-|S|)!|S|!(|S|-1)! [v(S) - v(S \setminus \{i\})] + v(N) \times \Delta \rho
\]
Based on $\phi^i(v)$, we can find out the revised profit distribution of each node in the supply chain, so that the distribution result is more reasonable, scientific, fair, node enterprises to work together for the long-term effective alliance so that the implementation of centralized decision-making more extensive and effective.

**Coordination of Three Levels of Supply Chain with Revenue Sharing and Price Reduction Contracts**

**Description of the Joint Contract Mechanism**

Commonly used supply chain coordination of many strategies, revenue sharing contract refers to the supplier to the retailer a lower wholesale price, and get part of the retailer’s sales revenue, thus improving the performance of supply chain coordination to improve the overall performance of the supply chain. It considers the different risks, contributions and inputs undertaken by the supply chain enterprises, reaches the share ratio, and achieves the rational distribution of the common interests of the supply chain among the node enterprises. At the same time, the price cut contract is a more widely used contractual means. At the end of the sales season, the supplier compensates the seller for not selling the product at a price less than the wholesale price. Therefore, the transfer profit of the contract is calculated on the basis of the profits from the wholesale price contract, Product repurchase value. The supplier can share the retailer's remaining risk of the goods, eliminating the return of the remaining goods and at the same time properly encouraging the retailer's order volume to increase. After considering the risk, income and contribution that their own supply chain enterprises, through the cooperation game, they reach an agreement to form a stable supply chain alliance, and the performance of the agreement is the contract, combined with the revenue sharing contract, with the characteristics of the price cut contract, the two contracts unite. At the end of the sales cycle, the retailer receives its own sales revenue and the manufacturer compensates for the price of the remaining product $d$, the manufacturer's revenue is: own wholesale to retailers income, net of retailers after the discount income multiplied by the sharing factor $\phi$; Share of revenue.

**Basic Assumptions and Symbols**

The research object is one by a single provider, a single manufacturer and a single vendor composed of three supply chain cooperation problems, the supply chain to run a single product, and the short life cycle, affected by the seasons. From top to bottom is followed by a supplier, manufacturer and retailer. The information among suppliers, manufacturers and retailers is symmetrical. The amount is equal. The manufacturer then orders the raw materials or parts for production from the supplier according to the ordering status of the sales merchant, Assuming a perfectly competitive market, no one has an absolute advantage. The traded product is a short-lived, perishable product that takes into account only one sales cycle, placing orders prior to the sales season, placing orders only once, disposing of the remaining products at the end of the sales season. The cost of producing products in various enterprises is fixed, that is, there is no scale economy. Revenue sharing contracts are used between suppliers and manufacturers, That is, the manufacturer distributes a portion of the profit to the supplier. At the same time, manufacturers and retailers use the price cut contract, namely: after the sales cycle, the manufacturer of retailers to give the remaining product a certain discount compensation. $\omega_{i=m,r}$: unit price; $C_{i=m,r}$: unit cost; $g_{i=m,r}$: out of stock caused by the loss of stock out of stock; $Q_{i}$: before sales, the seller ordered the manufacturer's order quantity or production volume; $h$: unit inventory costs for unsold goods; $\pi_{i=m,r}$: represents the total profit of the supply chain; $Q'$: indicates the best order quantity; $x$: market demand random variable; $\phi$: the share factor of manufacturer revenue sharing to
suppliers; \( \hat{\lambda} \): the manufacturer's retailer to the remaining price of the product; \( f(x) \): probability density function of demand \( x \); \( F(x) \): the distribution function of demand \( x \); \( S(Q) \): expected sales, \( S(Q) = E[\min(Q, x)] = Q - \int_0^Q F(x)dx \); \( I(Q) \): the expected remaining amount, \( I(Q) = Q - S(Q) \); \( L(Q) \): expect sales loss, \( L(Q) = E(x) - S(Q) = \mu - S(Q) \).

### Joint Revenue Sharing and Price Reduction Contract Three Supply Chain Coordination Mechanism

The benefits of retailers, manufacturers, suppliers and supply chains under the Revenue Sharing and Price Reduction Compact are. Under the revenue sharing and contract reduction mechanism, the expected returns of retailers, manufacturers, suppliers and the supply chain as a whole are as follows:

\[
E(\pi_r) = (\omega_r + g_r - C_r - \omega_m)Q - (\omega_r - \hat{\lambda} + h + g_r) \int_0^\infty F(x)dx - g_r \mu
\]

(1)

\[
E(\pi_m) = (\phi \omega_m + g_m - C_m - \omega_r)Q - (g_m + \phi \hat{\lambda}) \int_0^\infty F(x)dx - g_m \mu
\]

(2)

\[
E(\pi_s) = [\omega_s + (1 - \phi) \omega_m + g_s - C_s]Q - [g_s + (1 - \phi) \hat{\lambda}] \int_0^\infty F(x)dx - g_s \mu
\]

(3)

\[
E(\pi_t) = (\omega_t + g - C)Q - (\omega_t + h + g) \int_0^\infty F(x)dx - g \mu
\]

(4)

The following gives the revenue sharing and price reduction contract mechanism, the retailer's order volume 

\[
\bar{Q}_r = F^{-1}(\frac{\omega_r + g_r - C_r - \omega_m}{\omega_r - \hat{\lambda} + h + g_r}) \quad \bar{Q}_m = F^{-1}(\frac{\phi \omega_m + g_m - C_m - \omega_r}{g_m + \phi \hat{\lambda}})
\]

\[
Q_r^* = F^{-1}(\frac{\omega_r + (1 - \phi) \omega_m + g_s - C_s}{g_s + (1 - \phi) \hat{\lambda}}) \quad Q_t^* = F^{-1}(\frac{\omega_t + g - C}{\omega_t + h + g})
\]

Revenue sharing and price reduction contract mechanism to achieve coordination of the supply chain to benefit all parties and the overall benefits of the supply chain to achieve the best must meet: \( Q_r^* = Q_s^* = Q_m^* = Q_t^* = \beta \).

\[
\omega_r^* = \omega_r + g_r - C_r - \beta (\omega_r - \hat{\lambda} + h + g_r)
\]

(5)

\[
\omega_m^* = \phi \omega_m - C_m + g_m - \beta (g_m + \phi \hat{\lambda})
\]

(6)

\[
\omega_s^* = \beta (g_m + \phi \hat{\lambda}) + C_m + \omega_s - g_m
\]

\[
\omega_t^* = \beta [g_s + (1 - \phi) \hat{\lambda}] - (1 - \phi) \omega_m + C_s - g_s
\]

(7)

\[
(e) = (g) \text{and}(f) = (h) \text{income sharing and price reduction contract under the two mechanisms to achieve coordination of the supply chain to benefit all parties to achieve the maximum profit when the overall supply chain parameters } \phi, \beta \text{ the relationship is } \omega_r, \omega_m, \omega_s \text{ as follows:}
\]

\[
\phi = \frac{\beta g_m + C_m + \omega_s - g_m}{\omega_r + g_r - C_r - \beta \omega_r - \beta h - \beta g_r} \quad \lambda = \omega_t + h - g + \frac{\omega_t - \omega_r - g_r + C}{\beta}
\]

(8)
Examples Analysis

Reference to the relevant literature, the following gives specific examples to illustrate: Suppose that the supply chain of a short-lived product consists of a single supplier, a single manufacturer and a single retailer that form a three-level supply chain, and the supplier is the unit cost of the raw materials provided by the manufacturer to produce the product $C_s = 5, C_m = 7, C_r = 8$. When the order quantity is less than the market demand, the loss of the unit out of stock caused by the shortage of suppliers is $g$, the same $g_m, g_r$; the unit inventory cost for unsold goods at the end of the sales season is $h$. Market demand function is $Q = 200 - 4\alpha$. That is, parameters $D = 200, \alpha = 4, \Delta C_i = 0, i = 1, 2, 3, 4$. Under the revenue sharing and contract reduction mechanism, the overall interests of retailers, manufacturers, suppliers and supply chains are as follows:

The interests of the supply chain and the interests of the node enterprises:

- The supply chain interest: $\pi_s(Q) = \pi_s(Q) + \pi_m(Q) + \pi_r(Q) = \omega_s S(Q) - CQ - hI(Q) - gL(Q) = 900$
- The supplier interest: $\pi_s(Q) = \omega_s Q + (1 - \varphi)[\omega_m Q - \lambda I(Q)] - C_s Q - g_s L(Q) = 397.35$
- The manufacturer interest: $\pi_m(Q) = \varphi \omega_m Q - C_m Q - g_m L(Q) - \omega_r Q - \varphi \lambda I(Q) = 275.175$
- The retailer interest: $\pi_r(Q) = \omega_r S(Q) - C_r Q - \omega_m Q + \lambda I(Q) - hI(Q) - g_r L(Q) = 227.475$

When correcting the distribution of benefits, find the approximate value of the revenue sharing factor and the price cut that match the actual situation. Solve the following relationship:

\[
\begin{align*}
g - h &= 35 \\
\omega_s \cdot 60 - g_s \cdot 140 + (1 - \varphi) [\omega_m \cdot 60 + 140\lambda] &= 697.35 \\
\varphi (\omega_m \cdot 60 + \lambda \cdot 140) - g_m \cdot 140 - \omega_r \cdot 60 &= 695.175 \\
\omega_m \cdot 60 + (g_r + \lambda - h) \cdot 140 &= 6292.225
\end{align*}
\]

We can intuitively see the revenue sharing parameters $\varphi$ With the price cut $\lambda$. From the above analysis we can see that by adjusting the contract parameters, different distributions of the supply chain benefits among the participating parties can be achieved. By adjusting the contractual parameters, different distributions of the supply chain benefits can be realized among the participating parties. When the order quantity is less than the market demand, the loss of the unit out of stock caused by the shortage of suppliers is $g_s = 10, g_m = 17, g_r = 18$, at the same time, revenue sharing coefficient is:0.2452; The price of the retail is: 15. At this point, we focus on the decision-making, the interests of enterprises in the nodes of the supply chain, and the value of interest is equal to the value of the revised profit distribution strategy: Supplier: 397.3043; Manufacturer: 270.7777; Retailer: 231.9180. In the contract to achieve supply chain coordination, the joint revenue sharing contract and price reduction contract, to achieve the optimal distribution of supply chain profit strategy, you can find the actual situation of the revenue sharing factor and price cut prices. That is to say, the practical application of the theoretical method, to provide guidance for the distribution of profits of supply chain enterprises, to achieve the coordination of the supply chain.

Conclusion

Propose the realization of the distribution strategy of supply chain benefits correction under the cooperative game theory, and give the realization mechanism of the joint revenue sharing contract and the price reduction contract in the three-level supply chain, and find out the revenue sharing coefficient and price cut price in line with the actual situation. In addition, this paper also gives a specific example to analyze the overall benefit of the supply chain in the centralized decision-making of the supply chain, and then modify the profit distribution strategy of Shapley law under the input, contribution and risk factors. Finally, Under the joint contract, the revenue sharing
coefficient and the price-cutting price have reached a fairly fair and reasonable distribution of the interests of the supply chain and promoted the efficient and stable operation of the supply chain.

References

