Verification on the Integration of Buyback Contract and Revenue Sharing Contract
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Abstract. With the development of economy and the improvement of management methods, the supply chain management (SCM) has gradually been accepted by managers, and the supply chain contract has become one of the most important management methods. Meanwhile, e-business has been the main platform of business, which reduces the distance between the upstream members and the downstream members of the supply chain, and the electronic supply chain (E-SC) has become the hot spot of the SCM research. The paper will verify the integration between the buyback contract which is always used in the traditional supply chain and the revenue sharing contract which is much more used in the e-supply chain based on the research of the supply chain’s expected profit, analyze the relevance of the two contracts on the supply chain coordination effect, and find out the conditions that the two contracts make the same effect on supply chain coordination, and integrate the two contracts.

1. Introduction

Supply chain contract has become an important method to coordinate enterprises, integrate resources, improve quality, reduce costs, shorten delivery time and improve the level of service. Supply chain contract refers to reduce the opportunistic behavior of bilateral cooperation through the rational design contract, promote close cooperation between enterprises, ensure the effective completion of orders and the product quality, reduce supply chain costs, improve supply chain performance and the performance of each member [1]. Supply chain contract includes wholesale price contract, buy back contract, revenue sharing contract and quantity flexibility contract [2].

At the same time, due to the rapid development of information technology, e-commerce has been widely used. Compared with the buy back contract frequently used in traditional supply chain, revenue sharing contract is applied more in e-commerce, and become an important issue for scholars. The paper will discuss and verify the condition of the integration between them [3].

2. Symbol Meaning of Buyback Contract and Revenue Sharing Contract

2.1 Symbol meaning of buyback contract

Assume that the random market requirement of the commodities is $F(x)$, the density function is $f(x)$. $F(x)$ is a continuous, differentiable, and reversible strictly increasing function of $x$. Let $F(0) = 0, F(x) = 1 - F(x), \varepsilon = E(x) = \int_0^\infty xf(x)dx$. The supplier’s unit cost of production of goods is $c$, the retail price is $p$, and $c < p$. The quantities of goods the retailer ordered is $q$, the wholesale price of goods the supplier charged is $w$. At the end of the selling season, the salvage value of unsold goods is $v$, and $v < c$. In this point, the supplier will buyback the retailer’s unsold goods at the price of $b$ per unit, and $b < w$. As for the market demands of commodities have not been met, the out of shelf losses borne by the retailer is $g$. The expected sales volume is $S(q)$, the expected
remaining inventory is $I(q)$, the expected quantity shortage is $L(q)$. The transfer payment from the retailer to the supplier is $T$, the retailer’s expected profit is $\pi_r$, the supplier’s expected profit is $\pi_s$, the expected profit of the supply chain is $\pi$.

### 2.2 Symbol meaning of revenue sharing contract

The symbol meaning of the revenue sharing contract model is similar to the buyback contract model. It is assumed that the random market requirement of the commodities is $F(x)$, the density function is $f(x)$, $F(x)$ is a continuous, differentiable, and reversible strictly increasing function of $x$. Let $F(0) = 0, F(x) = 1 - F(x), E(x) = \int_0^x f(x)dx$. The supplier’s unit cost of production of goods is $c$, the retail price is $p$, and $c < p$. At the end of the selling season, the salvage value of unsold goods is $v$, $v < c$, and the salvage value of unsold goods is shared by two sides. As the market demand of commodities has not reached, the out of shelf losses borne by the retailer is $g$. The quantities of goods the retailer ordered is $q$, the wholesale price of goods the supplier charged is $w$, the proportion of sales revenue the retailer retained in the end of sales period is $\phi$, and the proportion of sales revenue given to supplier is $1 - \phi$. The expected sales volume is $S(q)$, the expected remaining inventory is $I(q)$, the expected quantity shortage is $L(q)$. The transfer payment from the retailer to the supplier is $T$, the retailer’s expected profit is $\pi_r$, the supplier’s expected profit is $\pi_s$, the expected profit of the supply chain is $\pi$.

### 3. Relevance Analysis Based on the Supply Chain Expected Profit and the Supply Chain utility

#### 3.1 Relevance analysis based on the supply chain expected profit

By comparing the expected profit function of the two models, the following conclusions are drawn:

1. Both of the contracts will coordinate supply chain, making the retailer and the supplier get their optimal profit without compromising the interests of each other under conditions of decentralized decision.
2. The $\gamma$ in the buyback contract and the $\lambda$ in the revenue sharing contract allot the whole expected profit between supplier and retailer arbitrarily. Values are between 0 and 1, the retailer’s profit increase with it, and the supplier’s profit decrease with it. Within the entire value range, the whole supply chain will maximize profits. The practical value, which is the profit sharing between the retailer and the supplier, depends on their bargaining power.

#### 3.2 Relevance analysis based on the supply chain utility

By comparing the optimal utility of the retailer, the supplier and the supply chain of the two models, the following conclusions are drawn:

1. Neither of the two contracts can achieve supply chain coordination in terms of utility. Retailer’s optimal order quantity is different from supplier’s optimal order quantity, and retailer’s optimal utility is different from supplier’s optimal utility.
2. The two supply chain contracts have the same general utility function, which make the two contract models has the same utility.

#### 3.3 The integration of buyback contract and revenue sharing contract

In the analysis of the supply chain expected profit, if the profit distribution coefficient of buyback contract $\gamma$ equals the profit distribution coefficient of revenue sharing contract $\lambda$, the equation will be:
\begin{align*}
p - b + g &= \phi (p - v) + g \\
\Rightarrow p - b &= \phi p - \phi v \\
\Rightarrow b &= (1 - \phi) p + \phi v \\
w_b - b &= w_r - \phi v
\end{align*}

(1)

Taking the buyback price \(b\) into (24), the equation will be:

\[w_b = w_r + (1 - \phi) p\]  

(3)

It means that when the buyback price of the buyback contract and the wholesale price of the revenue sharing contract meet the above conditions, revenue sharing contract is equal to buyback contract, and the two contracts are integrated.

Now look at the supply chain utility, if take \(b = (1 - \phi) p + \phi v\) and \(w_b = w_r + (1 - \phi) p\) into retailer’s optimal order quantity under buyback contract, the equation will be:

\[F(q^*_r) = \frac{2k_r(p-b)H_r(q) - \frac{p-w_b + g}{p-b + g}}{2k_r(p-b)H_r(q) + 2k_r g P_r(q) - 1}\]

\[= \frac{2k_r[p - (1 - \phi) p - \phi v]H_r(q) - \frac{p - w_r - (1 - \phi) p + g}{p - (1 - \phi) p - \phi v + g}}{2k_r[p - (1 - \phi) p - \phi v]H_r(q) + 2k_r g P_r(q) - 1}\]

\[= \frac{2k_r \phi (p - v) H_r(q) - \frac{\phi p - w_r + g}{\phi (p - v) + g}}{2k_r \phi (p - v) H_r(q) + 2k_r g P_r(q) - 1}\]

(4)

When the two conditions are satisfied, retailer’s optimal order quantity under buyback contract is equal to supplier’s optimal order quantity under revenue sharing contract. It means that the two contracts are integrated together.

4. The Verification of Integration

By genetic algorithm, the optimal ordering quantity and optimal utility of retailers, suppliers and the whole supply chain are solved respectively, and the solutions are compared.

The data in this paper comes from Wuhan Justeasy Agricultural Science & Technology Co. Ltd., which specializes in the distribution of fruit and cleaned vegetable. On the e-commerce platform, Justeasy constructs the circulation platform of agricultural products to distribute the fruit and cleaned vegetable to the consumer by Internet of things and e-commerce technology. This kind of supply contract is the revenue sharing contract under the e-supply chain. Look at “Kung Pao Chicken”, a kind of cleaned vegetable, as an example. Hereby, we take the data into the model and calculate the order quantity with days as unit, and the unit price is RMB.

Binary encoding is adopted in this paper, encoding length \(CL = 10\), coding accuracy \(\Delta x = (10 - 0)/(2^{10} - 1) = 0.01\), coded space cardinal number is \(2^{10} = 1024\), evolutionary algebra \(T = 100\). The independent variable is the order quantity \(q(q \in [0,10])\), suppose the distribution function of the random demand variable obeys the uniform distribution, that \(x \sim [0,10]\). Under the buyback contract, the retail price \(p = 10\), the wholesale price \(w_b = 4\), cost \(c = 2\), the salvage value of unsold goods \(v = 0.5\), the out of stock losses \(g = 1\), buy back price \(b = v + q \times 10%\). Because buy back contract and revenue sharing contract integrate on condition that \(b = (1 - \phi) p + \phi v\) and \(w_b = w_r + (1 - \phi) p\), follow the wholesale price \(w_r = 4 - \frac{10}{95} q\), the proportion of sales revenue the retailer retained in the end of sales period \(\phi = 1 - \frac{1}{95} q\). On account of \(w_r > 0\) and \(0 < \phi < 1\), the range of the order quantity is \(0 < q < 38\).
80 individuals were selected as the initial group by means of random selection. When solving the optimal order quantity and the optimal utility under buyback contract, the optimal utility function of the retailer, supplier and supply chain under the buy back contract is used as fitness function.

\[
U_r = (p-w_c)q-(p-b)H_1(q)-gP_1(q)
\]

\[
-k_1(p-b)^2H_2(q)-k_2g^2P_2(q)+k_1[(p-b)H_1(q)+gP_1(q)]^2
\]

\[
U_s = (w_s-c)q-(b-v)H_1(q)-k_1(b-v)^2[H_2(q)-H_1^2(q)]
\]

\[
U = (p-c)q-(p-v)H_1(q)-gP_1(q)
\]

\[
-k(p-v)^2H_2(q)-kg^2P_2(q)+k[(p-v)H_1(q)+gP_1(q)]^2
\]

When solving the optimal order quantity and the optimal utility under revenue sharing contract, the optimal utility function of the retailer, supplier and supply chain under the revenue sharing contract is used as fitness function.

\[
U_r = E[\pi_r]-k_1Var[\pi_r]
\]

\[
= (\phi p-w_c)q-(\phi p-v)H_1(q)-gP_1(q)
\]

\[
-k_1(\phi p-v)^2H_2(q)-k_2g^2P_2(q)+k_1[(\phi p-v)H_1(q)+gP_1(q)]^2
\]

\[
U_s = E[\pi_r]-k_2Var[\pi_r]
\]

\[
= [w_s+(1-\phi)p-c]q-[(1-\phi)(p-v)H_1(q)-k_1(1-\phi)^2(p-v)^2[H_2(q)-H_1^2(q)]
\]

\[
U = E[\pi]-kVar[\pi]
\]

\[
= (p-c)q-(p-v)H_1(q)-gP_1(q)
\]

\[
-k(p-v)^2H_2(q)-kg^2P_2(q)+k[(p-v)H_1(q)+gP_1(q)]^2
\]

When the population size is \( M = 80 \), the selection probability is calculated by using the fitness function ratio, and executed on the way of roulette. The cross probability is \( F = 0.6 \), and the cross method is single point crossover. The mutation probability is \( Bi = 0.01 \).

Evolutionary algebra is \( T = 100 \), performing 100 iterations with the above methods and operators. With the increase of iterations, the population gradually evolves into the neighborhood of the optimal solution of the fitness function, and remains stable on optimal solution.

According to the above program operation, the following calculation results are obtained by matlab7.0.

<p>| Table 1. The results of optimal utility of buyback contract and revenue sharing contract. |
|-------------------------------------------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>buyback contract</th>
<th>revenue sharing contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retailer’s optimal order quantity</td>
<td>3.7732</td>
<td>3.7439</td>
</tr>
<tr>
<td>Retailer’s optimal utility</td>
<td>9.9085</td>
<td>9.9074</td>
</tr>
<tr>
<td>Supplier’s optimal order quantity</td>
<td>10.0000</td>
<td>10.0000</td>
</tr>
<tr>
<td>Supplier’s optimal utility</td>
<td>14.5833</td>
<td>14.5670</td>
</tr>
<tr>
<td>Total optimal order quantity in supply chain</td>
<td>4.2815</td>
<td>4.2815</td>
</tr>
<tr>
<td>Total optimal utility in supply chain</td>
<td>17.1407</td>
<td>17.1407</td>
</tr>
</tbody>
</table>

Comparing the results of calculating the utility function under two contracts, we noticed that because the utility function of supply chain is exactly the same under the two contracts, the optimal order quantity and the optimal utility of supply chain are exactly the same under the two contracts. As shown in the table 1, total optimal order quantity in supply chain is 4.2815, and total optimal utility in supply chain is 17.1407, which is differ from retailer’s optimal order quantity and optimal utility and supplier’s optimal order quantity and optimal utility. It means that neither of these two contracts can coordinate the supply chain by utility. Although the utility function of retailers and suppliers is not the same under the two contracts, retailer’s optimal order quantity is almost same as supplier’s optimal order quantity, and retailer’s optimal utility is almost same as supplier’s optimal utility, which error is less than 0.1.
Comparing Figure 2 and Figure 3, retailer’s optimal utility and order quantity under two contracts are stabilized when iteration to about 10 generations. Comparing Figure 4 and Figure 5, supplier’s optimal utility and order quantity under two contracts are stabilized before iteration to about 40 generations. This proves the result of formula deduction, that is, the two contracts are integrated in the condition of \( b = (1 - \phi) p + \phi v \) and \( w_b = w_r + (1 - \phi) p \), which makes the supply chain achieve the same coordination effect both.

6. Conclusions

This shows that the buyback contract and the revenue sharing contract are different at environments, payment methods and mathematical models, but make the supply chain achieve the
same coordination effect on the distribution of profits. Neither of these two contracts can coordinate the supply chain by utility, but the two contracts’ profits are exactly the same, and the utility allocation ratio is basically the same on the integration point. It means there is a crossing point between the revenue sharing contract under the e-commerce supply chain and the buyback contract under the traditional supply chain in terms of coordinating supply chain profit ratio and realizing utility. At the crossing point, the achievements of the two contracts are basically the same, which can replace each other.

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References