A Study on Supply Chain Trade-in Decision Making of Retailer with Considering New and Old Customers

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Abstract. From the perspective of supply chain, the decision making of retailer which carries out Trade-in is studied. The impact of market segmentation and depreciation of old product on decision making and supply chain efficiency are analyzed. It is found that product price and supply chain efficiencies are affected by the old customer proportion, the old product loss degree and offset price by returning old goods. The offset price in the trade-in model can attract more old customers for the retailer, but retailer’s profit is reduced as the old customer proportion of the market increases. When the old customer proportion increases, in order to win the market, retailer will reduce the price to attract more old customers. When the depreciation of old product increases, retailer will raise price to take more profit. The conclusion of this paper has certain theoretical significance for enterprises to implement the trade-in policy in the supply chain environment.

Introduction

The economic development and social progress over the recent years have made more people become concerned about ecological civilization and sustainability issues. As a result, environment-friendly consumption methods have gained increasing support from consumers (Lee and Shin, 2010). Moreover, the adoption of the trade-in scheme by retailer does not only protect the environment, but also expands and stimulates market demand.

Trade-in is often investigated in articles about remanufacturing and reverse logistic that consider the subsidy policies of the government. Focusing on the auto industry, Huang et al. (2014) investigated whether manufacturers should apply for government subsidies to adopt trade-in strategy when such subsidies place a restriction on sales price, as well as analyzed the influence of strategy selection on retailers. Hong and Ke (2011) presented a Stackelberg-type model to determine the advanced recycling fees and socially optimal subsidy fees from the government in decentralized reverse supply chains. Wang et al. (2014) investigated the effects of four subsidy policies on the development of the recycling and remanufacturing industry in China by using the system dynamics methodology. Ma et al. (2013) analyzed the influence of a consumption-subsidy program on a dual-channel closed-loop supply chain and the decisions of channel members before and after the introduction of such program. The above articles have taken the government intervention into account. However, as the 2008 global financial crisis eased, the trade-in policies that were implemented by the government to stimulate domestic demand and promote consumption gradually faded from public interest. In contrast, the autonomous trade-in strategies of different industries are widely used, and the existing studies on government subsidy policy cannot satisfy the strategy demand of enterprises. In this case, corresponding studies on trade-in policy which is carried out by enterprises themselves must be conducted.

In view of the lack of research, this article studies the decision making of retailer which carries out Trade-in. Moreover, it analyzes the impact of market segmentation and depreciation of old products on decision making and supply chain efficiency.
Model Descriptions

The Symbols that will be mentioned below are described in table 1.

<table>
<thead>
<tr>
<th>Symbols</th>
<th>descriptions</th>
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<tbody>
<tr>
<td>$c$</td>
<td>unit production cost of the manufacturer</td>
</tr>
<tr>
<td>$w$</td>
<td>wholesale price that the manufacturer sells to the retailer</td>
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<tr>
<td>$p_r$</td>
<td>retail price</td>
</tr>
<tr>
<td>$p_o$</td>
<td>offset price by returning old goods</td>
</tr>
<tr>
<td>$s$</td>
<td>unit revenue that the retailer resells an old product</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>the old customer proportion (OCP)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>the old product loss degree (OLD)</td>
</tr>
<tr>
<td>$D_i$</td>
<td>the demand function of $i$</td>
</tr>
<tr>
<td>$\Pi_f$</td>
<td>the profit function of the manufacturer</td>
</tr>
<tr>
<td>$\Pi_s$</td>
<td>the profit function of the retailer</td>
</tr>
<tr>
<td>$\Pi_{mi}$</td>
<td>the profit that is contributed by $i$ customers</td>
</tr>
<tr>
<td>$\Pi_{ni}$</td>
<td>the profit that is contributed by $i$ customers for retailer</td>
</tr>
</tbody>
</table>

This paper considers that a two-stage supply chain comprises a manufacturer and a retailer who are both individual decision makers. The manufacturer is considered as the dominant player, whereas the retailer is the follower. The second case is a differentiated trade-in marketing approach for new and old customers (Figure 1) in which the retailer sets the retail price $p_r$ and subsidizes old customers with an offset price $p_o$ if they return old products. The retailer can obtain unit revenue $s$ by dealing with an old product, such as reselling the old goods to a third party.

![Figure 1. Supply chain model with trade-in implemented by the retailer.](image)

The above mentioned model divides the market into old customers and new customers. We define the total market to be 1 and assume that the old customers occupy $\alpha(0 \leq \alpha \leq 1)$. So the new customers account for $1-\alpha$. By using economic theory of consumer utility to determine the function of market demand (Choudhary, 2005), we assume that those customers are willing to pay $v$ which follows a uniform distribution $[0,1]$. Therefore, the utility that is gained by customers is a function of their willingness to pay and the retail price of the product. However, for the old customers, the product loss will increase after a certain period using, which will drive old customers to consider the surplus value when buying new products. We assume OLD is $\gamma(0 < \gamma < 1)$. Hence, the loss estimate $\gamma v$ is equivalent to the willingness of old customers to pay for a new product. From an economic point of view, to develop a reasonable and accurate model, the parameters must satisfy $c < \gamma + s < 1$. Therefore, we can conclude the following.

With a trade-in policy, old customers can have an offset price $p_o$ by returning old products. The purchasing utility of new customers is $U_n = v - p_r$ and that of old customers is $U_o = \gamma v - (p_r - p_o)$. We can conclude that the demand functions of new and old customers are $D_n = (1-\alpha) \max(1-p_r,0)$ and $D_o = \alpha \max(1-p_r,0)$. Figure 1. Supply chain model with trade-in implemented by the retailer.
and $D_o = \alpha \max[1 - (p_r - p_o)/\gamma, 0]$ respectively. As a precondition of the autonomous trade-in strategy of retailers, we conclude customer demands as Equation (1).

\[
\begin{align*}
D_o &= \alpha [1 - (p_r - p_o)/\gamma] \\
D_n &= (1 - \alpha)(1 - p_r)
\end{align*}
\]

**Trade-in Model**

With the trade-in policy, new customers have to purchase products at original price, but old customers can receive a discount by returning old goods. Equation (1) represents the demand function of new and old customers. Therefore, the objective profit function of the retailer and the manufacturer are computed respectively as follows.

\[
\begin{align*}
\Pi_r &= \alpha(p_r - w - p_o + s)[1 - (p_r - p_o)/\gamma] + (p_r - w)(1 - \alpha)(1 - p_r) \\
\Pi_w &= (w - c)\{\alpha [1 - (p_r - p_o)/\gamma] + (1 - \alpha)(1 - p_r)\}
\end{align*}
\]

We develop the following proposition and corollary on the basis of the profit function:

**Proposition:** The best decisions $(p_r, p_n)$ of the retailer are $p_r^* = \frac{1}{2} + \frac{\gamma + \alpha c + \alpha s + c\gamma - \alpha c\gamma}{4(\alpha + \gamma - \alpha\gamma)}$ and $p_n^* = \frac{1 + s - \gamma}{2}$, while the best decision of the manufacturer is $w^* = \frac{\gamma + \alpha c + \alpha s + c\gamma - \alpha c\gamma}{2(\alpha + \gamma - \alpha\gamma)}$. The optimal market demands of old and new customers are computed as

\[
\begin{align*}
D_o^* &= \alpha \left[1 - \frac{\gamma - s}{2\gamma} - \frac{\gamma + \alpha c + \alpha s + c\gamma - \alpha c\gamma}{4(\alpha + \gamma - \alpha\gamma)}\right] \\
D_n^* &= (1 - \alpha) \left[\frac{1}{2} - \frac{\gamma + \alpha c + \alpha s + c\gamma - \alpha c\gamma}{4(\alpha + \gamma - \alpha\gamma)}\right]
\end{align*}
\]

Moreover, the optimal profits of the retailer and the manufacturer are computed as

\[
\begin{align*}
\Pi_r^* &= \frac{4\alpha\gamma^2 + \alpha(c - s)^2}{16\gamma} + \frac{3\alpha(1 + \alpha s - s)^2}{16(1 - \alpha)(\alpha + \gamma - \alpha\gamma)} + \frac{1 - 8\alpha + 2(1 - \alpha)(4\alpha s - c) + c^2(1 - 2\alpha) + \alpha^2(4 + c^2)}{16(1 - \alpha)} \\
\Pi_w^* &= \frac{(\gamma + \alpha c + \alpha\gamma - \alpha c\gamma)^2}{8\gamma(\alpha + \gamma - \alpha\gamma)}
\end{align*}
\]

**Corollary:** Under the trade-in policy, the offset price for old product is only affected by unit revenue $s$ and $\gamma$. The offset price increases along with $s$, but reduces as $\gamma$ increases. The retail and wholesale prices in the supply chain both decrease as $\alpha$ increases, but increases along with $\gamma$, $c$, and $s$. The profits of the retailer and the manufacturer decrease as $c$ increases, but the profit of the manufacturer increases along with $s$. The profit of the retailer increases along with $s$ only if $(4\gamma - c + s)(\alpha + \gamma - \alpha\gamma) > 3\gamma(1 + \alpha s - s)$.

We also analyze the effect of $\alpha$ and $\gamma$ on the profit of the retailer and the profit contribution of old and new customers under the trade-in policy. We set $\alpha = 0.6$ and $\gamma = 0.3$. Figure 2 and Figure 3 show the effects of certain parameters on the profit of the retailer.
Figure 2. Changes in the profit of the retailer and the profit contribution of customers with $\gamma$ when $\alpha=0.6$.

The right region of the dotted line $\gamma'$ in Figure 2 denotes the feasible solution range of the Trade-in policy. Therefore, the dotted profit line indicates the absence of a feasible solution. Figure 2 shows that under the trade-in policy, the gross profit of the retailer decreases as $\gamma$ increases, and then increases along with $\gamma$. The reason behind such observation is simple. Figure 2 shows that the profit that is contributed by new customers reduces continuously and its speed tends to be stable. In contrast, the profit which is contributed by old customers increases continuously and its speed tends to be fast. Therefore, after reaching a certain value, the profit from old customers who are attracted by the trade-in strategy will make up for the losses from new customers that are caused by increasing prices.

Figure 3. Changes in the profit of the retailer with $\alpha$ under different $\gamma$

Figure 3 shows the changes in the profit of the retailer with $\alpha$ and $\gamma$. The dotted lines $\alpha_{\gamma=0.5}$ in Figure 8 denotes the limited feasible value of $\alpha$ for the trade-in strategy under $\gamma=0.5$, the same to $\alpha_{\gamma=0.3}$. We find that in the feasible solution range, the profit of the retailer decreases as $\alpha$ increases, because the increase of $\alpha$ will compress the market demand of new customers and expand the market demand of old customers. Moreover, the consumer utility of old customers is always smaller than that of new customers, which fundamentally decreases the gross profit of the retailer. Figure 8 shows that when $\alpha$ is small (0.31 to 0.6), the profit of the retailer decreases as $\gamma$ increases. When $\alpha$ is relatively larger (0.6 to 0.77), the profit of the retailer decreases and then increases with the increase of $\gamma$ (this phenomenon is similar to that in Figure 6). When $\alpha$ is large (0.77 to 1), the profit of the retailer always increases along with $\gamma$. That is because both OCP and OLD affect the profit of the retailer. When $\alpha$ is small, the new customers are the main purchasing power. Proposition 3 shows that the retail price will increase along with $\gamma$ in such a way that the interests of new customers are harmed. Therefore, the loss of new customers will reduce the profit of the retailer. When $\alpha$ is large, the old customers will become the main purchasing power. Although an increase in $\gamma$ will damage the interests of new customers, such increase can also strengthen the willingness of old customers to pay for a new product that can increase the profit of the retailer. A relatively large $\alpha$ represents a tradeoff circumstance between a small $\alpha$ and a large $\alpha$, which will decrease and then increase the profit of retailers.
Summary

This article studies the decision making of retailer when it carries out Trade-in. Moreover, it analyzes the impact of market segmentation and depreciation of old products on decision making and supply chain efficiency. Finally, the following management revelations are obtained.

1. The product price and supply chain efficiency are affected by the old customer proportion, the old product loss degree and offset price by returning old goods. Therefore, when companies set retail prices, they need to consider these points in particular to avoid the loss of profits.

2. The offset price in the Trade-in can attract more old customers for the retailer, but retailer’s profit is reduced as the old customer proportion increases. Therefore, with the use of Trade-in policy in the market, new customers can bring more profits to the enterprise compared to the old customers. However, when the old customer proportion is large, companies need to raise prices to attract old customers to increase their profits.

3. When the old customer proportion increased, in order to win the market, retailer should reduce the price to attract old customers. When the depreciation of old products increases, retailer should raise prices to take more profit.

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