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The pricing policy of perishable supply chain with recycling mode

Sheng Qiong-Fen, Li Jing*
School of Engineering, Nanjing Agricultural University,
Nanjing 210031, (CHINA)
E-mail : phdlijing@njau.edu.cn

ABSTRACT

Many companies offer perishable products to meet diversified demands of customers. Because of the uncertain demand, the ordering quantity is always more than the demand. So suppliers recycle products from the retailers and reproduce for reusing. The early work done on pricing policy of perishable supply chain was about the single product without recycling. The extension of this problem (to consider substitution and recycling) complicates the problem. This paper aims to research the pricing policy of perishable products considering recycling to maximize the supplier and the retailer expected total profits. Considering recycling in two-layer supply chain, this paper establishes the pricing model of substitutable perishable products with game theory, discusses the pricing policy under the centralized and decentralized decision-making. Moreover, this paper also researches the influence of sales cycle time on the sales price and the total profit. At the end, the paper finds the following conclusions. Firstly, the pricing policy under the centralized decision-making is better than under the decentralized decision-making. Secondly, firms get the optimal sales prices and maximize the profit under the centralized decision-making. Finally, the conclusions are illustrated by a numerical analysis.

KEYWORDS

Two-layer supply chain; Pricing policy; The game theory; Substitutable perishable products; Recycle.

INTRODUCTION

Perishable commodities[1,2] are also called seasonal products or short life cycle products. In practical business, most firms support various goods including perishable goods to improve competitiveness and meet the needs of the customer diversification. However, those perishable products are always substitutable, such as the green pepper and red pepper in the supermarket. On the other hand, the demand of perishable products is uncertain. When the ordering quantity is more than the reality demand, the upstream supply chain members always recycle products from the downstream members and reproduce for other use except discounting. So recycling and reusing of products is an increasing concern by people in recent years. Obviously, it becomes more important to research on substitutable perishable products pricing policy considering the supply chain recycling to maximize the supplier and the retailer expected total profits respectively.

This paper researches the problem of pricing policy of a retailer and a supplier for substitutable perishable products in the supply chain considering recycling. Because the research object. is substitutable perishable products, this paper assumes that the demand of the perishable product is not only related with itself sales price, but also with another substitution sales price and sales cycle time.

The rest paper is organized as follows. In Section 2, related literatures are presented. In Section3-5, pricing policy models under the centralized and decentralized decision-making are established and discussed. In Section 6, a numerical analysis is given. Section 7 is a concluding section.

RELATED LITERATURE AND OUR CONTRIBUTIONS

The study on substitutable multi-products is concentrated in two aspects: ordering policy and dynamic pricing. There is rich literature about ordering policy. Pentico(1978)[3] considered probabilistic demands and multiple periods. The assortment problem assumed about the pattern of demands and the form of a reasonable solution can be solved by using dynamic programming. Goh et al (1993)[4] discussed perishable inventory systems with two types of demand. Chand et al (1994)[5] develops a parts selection model with one-way substitution. It assumed cost and demand parameters are stationary over the problem horizon, and the optimal combination of parts inventory was found using dynamic programming algorithm. Smith et al (2000)[6] discussed the optimal inventory policy for items in an assortment that were substitutable to maximize total profit, considering service level and resource constraints. Parlar(1988)[7] used the game theory to analyze the substitutable product inventory problem with random demands, and proved the existence and uniqueness of the Nash solution. Chen(2004)[8] discussed the retailer's ordering policy for substitutable and perishable commodities with stochastic demand through mathematical calculation. Then the influences of the order quantity on the substitutable factor, commodity's marginal profit and retailer's price were further studied. There is rich literature about dynamic pricing. The study on dynamic pricing was mostly about the single product revenue management[9,10]. The study on substitutable multi-product dynamic pricing is short. Constantinos et al (2003)[11] reduced these well-studied revenue management problems to the aggregate rate at which all products jointly consume resource capacity. Birge et al (1998)[12] believed the way that a company made arrangements for producing two substitutable products would determine the optimal level of capacity and the prices of these goods in a single period. Some study is about pricing and ordering together. Liu et al (2004)[13] discussed the product pricing and ordering problem with the alternative demand considering price demand driven and inventory coexist. Guan et al (2007)[14] considered the ordering and pricing policy for two perishable commodities with stochastic demand based on multi-logit consumer choice model and service level.

This paper takes the supermarket fresh agricultural products as the research object. The demand is uncertain and always generates additional demand. Hence, except discounting, the suppliers always recycle products from the retailers and reproduce for reusing. For example, the Chinese newspaper called Life Time reported that the supermarket fresh agricultural products could be reproduced for agricultural and sideline products or the organic fertilizer. Therefore, we have the practical significance of discussing pricing policy for substitutable perishable products considering recycling. This paper discusses the centralized and decentralized decision-making pricing policy for substitutable fresh agricultural products considering the supply chain recycling. And it also analyzes the influence of sales cycle on recycle cost, the sales price of substitutable products and the total profit.

MODEL DEVELOPMENT

This paper considers two-layer supply chain that consists of one supplier and one retailer. The retailer purchases products from the supplier with wholesale price, and sells them to consumers with sales price at the same time. But the demand is always uncertain. When the ordering quantity is more than the demand, the supplier always recycle products from the retailer with the recycle cost for other use. This paper discusses two substitutable-fresh agricultural products. The parameters are as follows:

$\omega_i (i=1,2)$ The unit wholesale price of i fresh agricultural product;

$p_i (i=1,2)$ The unit sales price of i fresh agricultural product;

$c_i (i=1,2)$ The unit cost of production for i fresh agricultural product;

In addition, this paper assumes that:

(1) The two kinds of fresh agricultural products are substitutable. The upstream supplier recycles the two products with the same recycle cost b and produces the same reuse value v, and $b < v$;

(2) $p_i > \omega_i > c_i (i = 1,2)$, p_i is the decision variables, ω_i, c_i are the known values;

(3) Regardless of the shortage: $Q_i > D_i (i = 1,2)$, Q_i means the ordering quantity of the i fresh agricultural product, D_i means the demand of the i fresh agricultural product.

Wang et al[15] presented the demand of the perishable product related with itself sales price and sales cycle. Pan et al[16] presented the demand of one product is affected by its own sales price, also related to the price of another substitutable product. So the demand function may be written as:

$$D_i = a - \alpha p_i + \beta p_j + \lambda I_i e^{-t} (i, j = 1,2) \tag{1}$$

a is a nonnegative demand parameter dependent on market size, α and β are nonnegative coefficients representing demand sensitivity to itself price and the substitutable product. Also, demand sensitivity to itself price is greater than to the substitutable product $(0 < \alpha < 1, 0 < \beta < 1, \beta < \alpha)$. I_i is the initial value of i fresh agricultural product. e^{-t} means the product value will reduce as the sales cycle T. λ represents fresh agricultural products value coefficient $(0 < \lambda < 1)$.

The demand of fresh agricultural products during the sales cycle time T is defined as:

$$E[D_i] = \int_0^T a - \alpha p_i + \beta p_j + \lambda I_i e^{-t} dt = aT - \alpha p_i T + \beta p_j T - \lambda I_i e^{-T} + \lambda I_i (i, j = 1,2) \tag{2}$$

The profit of the retailer and the supplier can be described as Π_r, Π_s:

$$\Pi_r = p_1 D_1 - \omega_1 Q_1 + b(Q_1 - D_1) + p_2 D_2 - \omega_2 Q_2 + b(Q_2 - D_2) \tag{3}$$

$$\Pi_s = (\omega_1 - c_1)Q_1 + (v - b)(Q_1 - D_1) + (\omega_2 - c_2)Q_2 + (v - b)(Q_2 - D_2) \tag{4}$$

Combine (3) and (4), the total profit function is obtained as Π_c:

$$\Pi_c = \Pi_r + \Pi_s = p_1 D_1 + p_2 D_2 - c_1 Q_1 - c_2 Q_2 + v(Q_1 - D_1) + v(Q_2 - D_2) \tag{5}$$

CENTRALIZED DECISION-MAKING PRICING POLICY MODEL

The target of centralized decision-making is to maximize the total profit. The optimal sales price and recycle cost are jointly made by the retailer and supplier. The optimal total profit can be expressed:

$$max\, \Pi_c = p_1 D_1 + p_2 D_2 - c_1 Q_1 - c_2 Q_2 + v(Q_1 - D_1) + v(Q_2 - D_2) \tag{6}$$

Substituting (2) into (6), the solution of (6) is:

$$\begin{aligned} max\, \Pi_c = {} & p_1(aT - \alpha p_1 T + \beta p_2 T - \lambda I_1 e^{-T} + \lambda I_1) + p_2(aT - \alpha p_2 T + \beta p_1 T \\ & - \lambda I_2 e^{-T} + \lambda I_2) - c_1 Q_1 - c_2 Q_2 + v(Q_1 - aT + \alpha p_1 T - \beta p_2 T + \lambda I_1 e^{-T} - \lambda I_1) \\ & + v(Q_2 - aT + \alpha p_2 T - \beta p_1 T + \lambda I_2 e^{-T} - \lambda I_2) \end{aligned} \tag{7}$$

Proposition 1: Π_c is concavity. There exists the optimal sales price p_1^* and p_2^*.

Proof of Proposition 1: Solve the Hessian matrix about p_1 and p_2 for (7), the solution is:

$$H = \begin{bmatrix} \frac{\partial^2 \Pi_c}{\partial p_1^2} & \frac{\partial^2 \Pi_c}{\partial p_1 \partial p_2} \\ \frac{\partial^2 \Pi_c}{\partial p_2 \partial p_1} & \frac{\partial^2 \Pi_c}{\partial p_2^2} \end{bmatrix} = \begin{bmatrix} -2\alpha T & 2\beta T \\ 2\beta T & -2\alpha T \end{bmatrix} \tag{8}$$

Since $\frac{\partial^2 \Pi_c}{\partial p_1^2} = -2\alpha T < 0$ and $\begin{vmatrix} -2\alpha T & 2\beta T \\ 2\beta T & -2\alpha T \end{vmatrix} = 4T(\alpha^2 - \beta^2) > 0$, proposition 1 is proved.

The optimal price solution is acquired through differentiating the profit functions with respect to p_1^* and p_2^*. We set $\frac{\partial \Pi_c}{\partial p_1}=0$, $\frac{\partial \Pi_c}{\partial p_2}=0$. p_1^* and p_2^* in centralized decision-making are obtained as:

$$p_1^*=\frac{\lambda(\alpha I_1+\beta I_2)(1-e^{-T})}{2(\alpha^2-\beta^2)T}+\frac{v}{2}+\frac{a}{2(\alpha-\beta)} \quad (9)$$

$$p_2^*=\frac{\lambda(\alpha I_2+\beta I_1)(1-e^{-T})}{2(\alpha^2-\beta^2)T}+\frac{v}{2}+\frac{a}{2(\alpha-\beta)} \quad (10)$$

Substituting (9)-(10) into (2), we get $E[D_1^*]$ and $E[D_2^*]$ in centralized decision-making:

$$E[D_1^*]=\frac{aT-\lambda I_1e^{-T}+\lambda I_1-(\alpha-\beta)vT}{2} \quad (11)$$

$$E[D_2^*]=\frac{aT-\lambda I_2e^{-T}+\lambda I_2-(\alpha-\beta)vT}{2} \quad (12)$$

Proposition 2: Recycle cost is not related with p_1^*, p_2^* under the centralized decision-making.

Proposition 3: The optimal sales prices (p_1^*, p_2^*) under the centralized decision-making are related with itself and substitutable fresh agricultural product initial value. p_1^* and p_2^* are both proportional to v (reuse value) and a (market size), inversely proportional to T (sales cycle time).

Proof of Proposition 3: p_1^* and p_2^* are obviously proportional to v (reuse value) and a (market size) according to (9)-(10). Differentiating the price functions with respect to T.

$$\frac{\partial p_1}{\partial T}=\frac{\lambda(\alpha I_1+\beta I_2)(e^{-T}(1+T)-1)}{2(\alpha^2-\beta^2)T^2} \quad (13)$$

As $T>0, e^{-T}(1+T)-1<0, \beta<\alpha$, therefore $\frac{\partial p_1}{\partial T}<0$, p_1^* is inversely proportional to T (sales cycle time), we can get the same conclusion for p_2^*.

DECENTRALIZED DECISION-MAKING PRICING POLICY MODEL

In the decentralized decision-making policy, the supplier and the retailer make their own profit maximization as the goal to determine the optimal sales price and recycle cost. In this situation, decision making is a process of dynamic game between the supplier and the retailer: suppliers occupy the dominant position, they firstly decide the optimal recycle cost according their own profit maximization before the sales cycle is over; then retailers obtain the optimal sales price according their own profit maximization and the optimal recycle cost from suppliers. Therefore, this paper establishes stackelberg game model to make optimization. So, the stackelberg game model can be expressed:

$$\begin{aligned}\max_{b} \Pi_s &= (\omega_1-c_1)Q_1+(v-b)(Q_1-aT+\alpha p_1T-\beta p_2T+\lambda I_1e^{-T}-\lambda I_1)\\ &+(\omega_2-c_2)Q_2+(v-b)(Q_2-aT+\alpha p_2T-\beta p_1T+\lambda I_2e^{-T}-\lambda I_2)\end{aligned} \quad (14)$$

$$\begin{aligned}s.t.\max_{p_1,p_2} \Pi_r &= p_1(aT-\alpha p_1T+\beta p_2T-\lambda I_1e^{-T}+\lambda I_1)-\omega_1Q_1\\ &+p_2(aT-\alpha p_2T+\beta p_1T-\lambda I_2e^{-T}+\lambda I_2)-\omega_2Q_2\\ &+b(Q_1-aT+\alpha p_1T-\beta p_2T+\lambda I_1e^{-T}-\lambda I_1)\\ &+b(Q_2-aT+\alpha p_2T-\beta p_1T+\lambda I_2e^{-T}-\lambda I_2)\end{aligned} \quad (15)$$

In this paper, we use backward induction to solve the optimal solution.

Step 1 We discuss if the constraint function Π_r exists the optimal solution. So solve the Hessian matrix about p_1 and p_2 for (15), the solution is:

$$H=\begin{bmatrix}\frac{\partial^2 \Pi_r}{\partial p_1^2} & \frac{\partial^2 \Pi_r}{\partial p_1 \partial p_2} \\ \frac{\partial^2 \Pi_r}{\partial p_2 \partial p_1} & \frac{\partial^2 \Pi_r}{\partial p_2^2}\end{bmatrix}=\begin{bmatrix}-2\alpha T & 2\beta T \\ 2\beta T & -2\alpha T\end{bmatrix} \quad \textbf{(16)}$$

Since $\frac{\partial^2 \Pi_r}{\partial p_1^2}=-2\alpha T<0$ and $\begin{vmatrix}-2\alpha T & 2\beta T \\ 2\beta T & -2\alpha T\end{vmatrix}=4T(\alpha^2-\beta^2)>0$, Proposition 4 is proved.

Proposition 4: The function of the retailer profit Π_r is concavity. There exists the optimal sales price p_1^{**} and p_2^{**} for the objective function optimal.

Step 2 To maximize the retailer's profit, the optimal price solution is acquired through differentiating Π_r with respect to the sales price p_1^{**} and p_2^{**}, so we set $\frac{\partial \Pi_r}{\partial p_1}=0$, $\frac{\partial \Pi_r}{\partial p_2}=0$. p_1^{**} and p_2^{**} in decentralized decision-making are obtained as:

$$p_1^{**}=\frac{\lambda(\alpha I_1+\beta I_2)(1-e^{-T})}{2(\alpha^2-\beta^2)T}+\frac{b}{2}+\frac{a}{2(\alpha-\beta)} \quad \textbf{(17)}$$

$$p_2^{**}=\frac{\lambda(\alpha I_2+\beta I_1)(1-e^{-T})}{2(\alpha^2-\beta^2)T}+\frac{b}{2}+\frac{a}{2(\alpha-\beta)} \quad \textbf{(18)}$$

Substituting (17)-(18) into (2), we finally get $E[D_1^{**}]$ and $E[D_2^{**}]$.

$$E[D_1^{**}]=\frac{aT-\lambda I_1 e^{-T}+\lambda I_1-(\alpha-\beta)bT}{2} \quad \textbf{(19)}$$

$$E[D_2^{**}]=\frac{aT-\lambda I_2 e^{-T}+\lambda I_2-(\alpha-\beta)bT}{2} \quad \textbf{(20)}$$

Proposition 5: Recycle cost b is proportional to p_1^{**}, p_2^{**} under decentralized decision-making.

Step 3 To make the supplier's profit maximization, we differentiate Π_s with respect to b.

Substitute (17)-(18) into (14) and differentiate the objective function Π_s with respect to the recycle cost b. Set $\frac{\partial \Pi_s}{\partial b}=0$, the optimal recycle cost b^* is obtained as:

$$b^*=\frac{2(\alpha-\beta)vT-2Q_1-2Q_2+2aT-\lambda(I_1+I_2)(e^{-T}-1)}{4(\alpha-\beta)T} \quad \textbf{(21)}$$

Subject to $\left\{T \middle| 0<b^*<v, E[D_1^{**}]<Q_1, E[D_2^{**}]<Q_2\right\}$.

The polynomial is complex. We will discuss the relationship between b^* and T in next section.

Step 4 The retailers obtain the optimal sales price (p_1^{**}, p_2^{**}) according b^* from the suppliers. Substituting (21) into (17-20); p_1^{**}, p_2^{**} and $E[D_1^{**}]$, $E[D_2^{**}]$ are obtained as:

$$p_1^{**}=\frac{\lambda(5\alpha I_1+5\beta I_2+\beta I_1+\alpha I_2)(1-e^{-T})}{8(\alpha^2-\beta^2)T}+\frac{v}{4}+\frac{3a}{4(\alpha-\beta)}-\frac{Q_1+Q_2}{4(\alpha-\beta)T} \quad \textbf{(22)}$$

$$p_2^{**}=\frac{\lambda(5\beta I_1+5\alpha I_2+\alpha I_1+\beta I_2)(1-e^{-T})}{8(\alpha^2-\beta^2)T}+\frac{v}{4}+\frac{3a}{4(\alpha-\beta)}-\frac{Q_1+Q_2}{4(\alpha-\beta)T} \quad \textbf{(23)}$$

$$E[D_1^{**}]=\frac{2aT-\lambda(3I_1-I_2)(e^{-T}-1)-2(\alpha-\beta)vT+2(Q_1+Q_2)}{8} \quad \textbf{(24)}$$

$$E[D_2^{**}]=\frac{2aT-\lambda(3I_2-I_1)(e^{-T}-1)-2(\alpha-\beta)vT+2(Q_1+Q_2)}{8} \quad \textbf{(25)}$$

Proposition 6: Compared with the centralized decision-making policy, p_1^{**}, p_2^{**} under the decentralized decision-making is inversely proportional to the total of all product quantity (Q_1+Q_2); in addition, the price sensitivity of reuse value v is less than the optimal sales prices (p_1^*, p_2^*) under the centralized decision-making policy. And market size a has opposite conclusions.

Proposition 7: ① $p_1^* > p_1^{**}$, $p_2^* > p_2^{**}$; ② $\Pi_c^* > \Pi_r^{**}+\Pi_s^{**} > 0$.

For①, since $b < v$, according (9-10),(17-18), obtain obviously $p_1^* > p_1^{**}$, $p_2^* > p_2^{**}$.

For②, we give the following proof:

$$\Pi_c^*-(\Pi_r^{**}+\Pi_s^{**})=(p_1^*-v)E[D_1^*]+(p_2^*-v)E[D_2^*]-(p_1^{**}-v)E[D_1^{**}]-(p_2^{**}-v)E[D_2^{**}] \quad \textbf{(26)}$$

Set

$$\frac{\lambda(\alpha I_1+\beta I_2)(1-e^{-T})}{2(\alpha^2-\beta^2)T}+\frac{a}{2(\alpha-\beta)}=A\,,\ \frac{\lambda(\alpha I_2+\beta I_1)(1-e^{-T})}{2(\alpha^2-\beta^2)T}+\frac{a}{2(\alpha-\beta)}=B\,;$$

$$\frac{aT-\lambda I_1e^{-T}+\lambda I_1}{2}=M\,,\ \frac{aT-\lambda I_2e^{-T}+\lambda I_2}{2}=N\,,\ \frac{(\alpha-\beta)T}{2}=k\,;$$

So

$$p_1^*=A+\frac{v}{2}\quad E[D_1^*]=M-kv\quad p_1^{**}=A+\frac{b}{2}\quad E[D_1^{**}]=M-kb$$

$$p_2^*=B+\frac{v}{2}\quad E[D_2^*]=N-kv\quad p_2^{**}=B+\frac{b}{2}\quad E[D_2^{**}]=N-kb$$

$$\Pi_c^*-(\Pi_r^{**}+\Pi_s^{**})=k(A+B)(b-v)+\frac{M+N}{2}(v-b)+k(v-b)^2=\frac{(\alpha-\beta)T}{2}(v-b)^2 \quad \textbf{(27)}$$

Since $\beta<\alpha$ and $b<v$, $\Pi_c^*-(\Pi_r^{**}+\Pi_s^{**})>0$, and ② $\Pi_c^*>\Pi_r^{**}+\Pi_s^{**}$ is proved.

Thus, the two substitutable-fresh agricultural products optimal retail prices are both higher under the centralized than decentralized decision-making. At the same time, the total profit under the centralized is greater than the optimal profit with the retailer and supplier combined under the decentralized decision-making. All these facts show that the supplier and the retailer are suggested global coordinating so that they can achieve win-win profits.

NUMERICAL ANALYSIS

We set $a=50$, $\alpha=0.9$, $\beta=0.3$, $\lambda=0.4$, $v=60$, $Q_1=100$, $Q_2=110$, $c_1=25$, $\omega_1=35$, $\omega_2=30$.

Refer to (21), we firstly discuss the value range of T . T can be solved according to (21):

(1) The optimal recycle cost b^* is less the reuse value v : $0<b^*<v$;

(2) Regardless of the shortage: $0<E[D_1^{**}]<Q_1$ $0<E[D_2^{**}]<Q_2$.

$$\begin{cases} 0<b^*=\dfrac{215T-525+40(1-e^{-T})}{3T}<60 \\ 0<E[D_1^{**}]=\dfrac{7T-12(1-e^{-T})+105}{2}<110 \\ 0<E[D_2^{**}]=\dfrac{7T-4(1-e^{-T})+105}{2}<100 \end{cases} \quad \textbf{(28)}$$

Solve $\{T | 2.27 < T < 13.85\}$.

We solve Π_c^* , Π_s^{**} , Π_r^{**} , p_1^* , p_2^* , p_1^{**} , p_2^{**} , b^* through (3-5), (9-12) and (21-25), and get results in the value range of T shown in Figure 1-6. The following points are noted from Figure 1-6:

(i) p_1^* , p_2^* under the centralized decision-making decreases as T increases. It is accorded with the characteristics of perishable product price decreasing over time.

(ii) Compared (9-10) with (17-18), b just have influent on the optimal sales price under decentralized decision making. Because b^* increases as the T increases. So the optimal sales price p_1^{**} , p_2^{**} under the decentralized decision-making increases as the T increases.

(iii) The optimal sales prices are closely because of substitution. However, p_1^* , p_2^* are both higher than p_1^{**} , p_2^{**} . So we can get the optimal sales prices under the centralized decision-making policy.

(v) Π_c^* , Π_s^{**} , Π_r^{**} increase as the T increases. But, the total profit Π_c^* under the centralized is greater than the optimal profit with Π_r^{**} and Π_s^{**} combined under the decentralized decision-making. And we can get the optimal total profit Π_c^* under the centralized decision-making policy.

Thus, the optimal sales prices are higher under the centralized than decentralized decision-making; the total profit under the centralized is greater than the optimal profit with the retailer and supplier combined under the decentralized decision-making. Therefore, the supplier and the retailer should cooperate with each other so that they can make the profit maximization and achieve win-win profits.

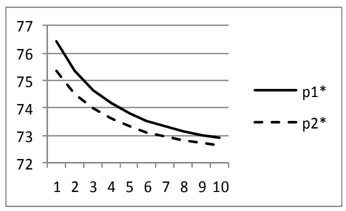

Figure 1 : The optimal sales prices under the centralized decision-making

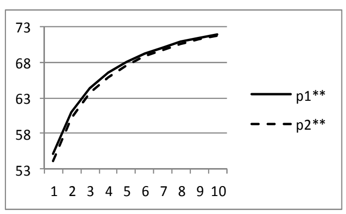

Figure 2 : The optimal sales prices under the decentralized decision-making

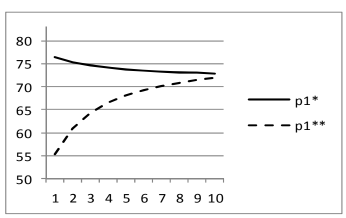

Figure 3 : The product 1 optimal sales price comparison in two decision

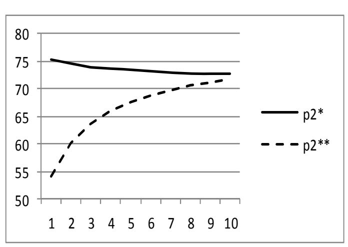

Figure 4 : The product 2 optimal sales price comparison in two decison

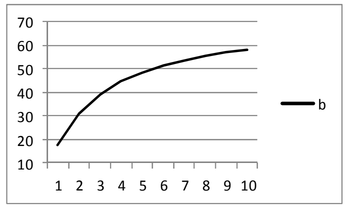

Figure 5 : The optimal recycle cost under the decentralized decision-making

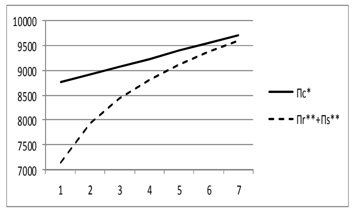

Figure 6 : The optimal profit comparion between the two decision-making

CONCLUSIONS

This paper discussed the centralized and decentralized decision-making pricing policy for substitutable fresh agricultural products considering the supply chain recycling. Because the research object is fresh agricultural products, we analyzed the influence of sales cycle time on recycle cost, the sales price and the total profit. Then, the optimal sales price and total profit under the centralized decision-making were compared with the decentralized pricing policy. Conclusions are as followed:

(i) Recycle cost just have influent on the optimal retail price under decentralized decision making, and it increases as the sales cycle time increases. So we should pay more attention to recycle cost when make the pricing policy under decentralized decision-making.

(ii) The two fresh agricultural products optimal sales prices are closely because of substitution. The optimal sales price under the centralized decision-making is related with the reuse value and it decreases as sales cycle time increases; the optimal sales price under the decentralized decision-making is related with the recycle cost and it increases as sales cycle time increases. However, the optimal sales prices under the centralized decision-making are both higher than under decentralized decision-making.

(iii) The total profit under the centralized is always greater than the optimal profit with the retailer and supplier combined under the decentralized decision-making. Therefore, the supplier and the retailer should cooperate so that they can make the profit maximization and achieve win-win profits.

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