Research on Dynamic Pricing and Ordering Policy of Fresh Agriculture Product Considering Consumers’ Perceived Quality

K. Nie, D.F. Xie, W. Li
School of Economy and Trade
Hunan University
Changsha 410079, Hunan, China
Key Laboratory of Logistics Information and Simulation Technology
Hunan University
Changsha 410079, China

Abstract—In this article, we first formulated the demand function of price and quality. Then we analyzed the order quantity and the pricing decision under the single price markdown condition and the multiple price markdown condition respectively. We find that under the single price markdown condition and the multiple price markdown condition, the fresh agricultural products with different consumers’ perceived quality elasticity should make the different optimal ordering quantity and optimal pricing decision.

Keywords—fresh agriculture product; consumers’ perceived quality; price discount; ordering quantity

I. INTRODUCTION

Many scholars researched on fresh product pricing and ordering policy. Karen etc. [1] pointed out that the price is an important strategy for the supermarket. Van Ryzin[2] established a fresh product pricing model based on the demand of the production as random variables. When approaching the shelf life of products, businesses often take discounts to promote the products [3-5]. Cai[6] introduced the ideas and techniques of the supply chain management to the field of the fresh agricultural produces management. Wang and Li [7] established a consumer utility model which taking into account the price and the freshness of fresh produces with time-varying. This paper focused on the impact of the consumers perceives quality to the fresh agriculture product’s optimal utility. Then we analyzed the order quantity and the pricing decision under the single price markdown condition and the multiple price markdown condition respectively. We find that different optimal ordering quantity and optimal pricing decision.

II. MODEL DESCRIPTION

Model assumes: (1) the products’ demand was affected by the price named as \( p \) and the consumer perceived quality; (2) the fresh degree is related to its shelf time named \( t \), that \( p = p(t) \); (3) assuming the \( q \) is function of \( p \) and \( t \), that \( q = q(p,t) \).

Demand function: \( D_t = e^{-\alpha p_t + \beta q(p(t)) e^{-\beta t}} \)

\( y_t \) represents potential market demand; \( E \) represents the degree of demand to realize; \( f(x) \) and \( F(x) \) is the probability density function and distribution function, and \( E(x) = 1 \); \( q_t \) represents the initial quality of the product, \( \phi(p(t)) \in (0,1) \), and assume that \( \phi(p(t)) = \phi(p(t)) \); \( \lambda \) : the attenuation degree; \( \beta \) : the perceived quality of products; \( \alpha \) : the price elasticity of the products; \( T \) :the sales period of fresh products; \( c_t \) : the unit changing cost; \( W \) : unit wholesale price; \( r \) : save rate; \( c_t \) : transportation cost per unit; \( \theta \) : the quality of the products’ ; \( t \) :the products’ inventory levels at time; \( \theta \) : Price discount.

III. MODEL ANALYSIS

A. One-Time Price Adjustment Analysis

In order to promote the sales of the goods, sellers often adopt the discounts to attract more customers.

Then \( p(t) = p, 0 < t < t_1; p(t) = \theta p, t_1 < t < T \)

The Inventory model: \( dL_1(t)/dt = -D_t - D_1 = e^{-\alpha p_t + \beta q(p(t)) e^{-\beta t}} \)

From the initial inventory \( I(t) = \gamma Q \), we know that

\[
I(t) = \gamma Q - e^{-\alpha p_t + \beta q(p(t)) e^{-\beta t}}/\lambda
\]

From \( I(t) = 0 \), we know that

\[
I(t) = \gamma Q - e^{-\alpha p_t + \beta q(p(t)) e^{-\beta t}}/\lambda, t_1 < t < T
\]

The optimal order quantity

\[
Q^* = \frac{\beta q(p(t)) e^{-\beta t} + \theta q(p(t)) e^{-\beta t}}{\lambda} / \gamma \text{ for } \frac{\gamma Q}{\lambda} - \gamma < t_1 < t < T
\]

The retailer’s profit:

\[
\pi_t = \pi_t(D_t dt) - (\kappa + \gamma) Q - C_t(t) \int_0^t D_t dt - h_t \int_0^t I(t) dt - I(t) dt
\]
\[ \frac{\Delta I(t)}{\Delta t} = -D(t) = -\varepsilon (y - \alpha p_t + \beta q_{t-1} e^{-\theta (T - t)}) \]

From \( I(0) = \gamma Q_1 \), we get that

\[ I(t) = \gamma Q_1 - \varepsilon (y - \alpha p_t) T + \beta q_{t-1} (1 - e^{-\theta (T - t)}) \]

\[ Q_t^* = \frac{\varepsilon}{\gamma} I(t) + \alpha p_t T + \beta q_{t-1} (1 - e^{-\theta (T - t)}) \]

The demand of the fresh products during \( T \) is:

\[ ED = \int_0^T \varepsilon (y - \alpha p_t + \beta q_{t-1} e^{-\theta (T - t)}) dt = (\varepsilon (y - \alpha p) T + \beta q_{t-1} (1 - e^{-\theta (T - t)}) \]

The retailer’s profit is:

\[ \pi_t = \gamma Q_t - \varepsilon (y - \alpha p_t) T - \beta q_{t-1} (1 - e^{-\theta (T - t)}) \]

\[ \frac{\partial \pi_t}{\partial q_{t-1}} = \gamma T \varepsilon + 2\alpha y + 2\beta h T - 2p t \beta q_{t-1} (1 - e^{-\theta (T - t)}) \]

If it has several price adjustment, the demand function is:

\[ D_t = \varepsilon (y - \alpha p_t + \beta q_{t-1} e^{-\theta (T - t)}) \quad (t < t < t_{n+1}) \]

In order to simplify the calculations, we assume that the time factor of the quality \( \lambda_t \) is the same with \( \lambda \), and assume \( t_0 = 0 \), before the \( n \)-th price adjustment we know \( \lambda_{t_{n+1}}(t) = \lambda \), at the same time

\[ I_t(0) = \gamma Q_1, I_t(t_0) = I_t(t), I_{t-1}(t_1) = I_t(t), \quad \text{so we can obtain that}: \]

\[ I_t(t) = \gamma Q_1 - \beta q_{t-1} e^{-\theta (T - t)} \]

\[ I_t(t) = \gamma Q_1 - \beta q_{t-1} e^{-\theta (T - t)} \]

And because \( t_1(T) = 0 \), we can get the optimal order quantity:

\[ \theta^* = \frac{\lambda_{t_{n+1}}(t) - \lambda_{t_{n+1}}(t)}{2p t \beta q_{t-1} (1 - e^{-\theta (T - t)})} \]

\[ \theta^* = \frac{\lambda_{t_{n+1}}(t) - \lambda_{t_{n+1}}(t)}{2p t \beta q_{t-1} (1 - e^{-\theta (T - t)})} \]

\[ \theta^* = \frac{\lambda_{t_{n+1}}(t) - \lambda_{t_{n+1}}(t)}{2p t \beta q_{t-1} (1 - e^{-\theta (T - t)})} \]

IV NUMERICAL EXAMPLE

Assuming that the supermarket have 5 branches. Firstly, we analyze one price adjustment. And parameters involved are as follows:

\( \varepsilon = 0.8, \alpha = 3, \beta = 3, \gamma = 1, T = 10, t_1 = 7, w = 5 \)

\( c = 0.7, c = 0.7, c_p = 0.2, h = 0.2, \theta = 0.6, \psi = 0.8, \lambda = 0.005, p = 15 \)

We can get the relationship between parameters

\[ \theta^* = \frac{76.4 p - 8}{9 p - 6.8 p - 301.5 - 45 p} \]

\[ \theta^* = \frac{112.5 + 0.000675 \alpha - 0.000053 \beta + 0.10051 \beta - 1.5705}{0.0675 \alpha - 0.00432 + 5.4 \alpha - 0.3456 \beta} \]
As can be seen from the graphics, the relationship between the initial price of the product and $\theta^*$ are inversely proportional, the relationship among $\theta^*$, $T$, $t_i$ is not particularly evident. In the same way, we can get the relationship between $\theta^*$ and the other parameters. Further, we also can analysis the effect of the optimal price discount to distributors’ profits. The process of analysis is shown in the following table:

**TABLE I. ONE-TIME PRICE ADJUSTMENT.**

<table>
<thead>
<tr>
<th>store</th>
<th>$y_o$</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$Q^*$</th>
<th>$\theta^*$</th>
<th>$\Delta \pi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>store1</td>
<td>50</td>
<td>3.2</td>
<td>3.2</td>
<td>192</td>
<td>0.64</td>
<td>30.8</td>
</tr>
<tr>
<td>store2</td>
<td>50</td>
<td>3</td>
<td>3</td>
<td>212</td>
<td>0.69</td>
<td>66.2</td>
</tr>
<tr>
<td>store3</td>
<td>50</td>
<td>2.8</td>
<td>2.8</td>
<td>231</td>
<td>0.74</td>
<td>105.9</td>
</tr>
<tr>
<td>store4</td>
<td>50</td>
<td>2.5</td>
<td>2.5</td>
<td>261</td>
<td>0.83</td>
<td>173.6</td>
</tr>
<tr>
<td>store5</td>
<td>50</td>
<td>2.3</td>
<td>2.3</td>
<td>280</td>
<td>0.90</td>
<td>227.1</td>
</tr>
</tbody>
</table>

1) With the decrease of the fresh agriculture products’ price elasticity and perceived quality elasticity, which indicates that the higher the price elasticity of fresh agricultural products, the lower the retailer's optimal order quantity.  
2) With the decrease of the fresh agriculture products’ price elasticity and perceived quality elasticity, the optimal price discount of fresh agricultural products $\theta^*$ gradually increased;  
3) And along with the increase of the $\theta^*$ and $Q^*$.  

The analysis of depreciation in several times also can be obtained. Just taking an example for depreciation twice there, and $h=0.2$.

**TABLE II. TWO TIMES PRICE ADJUSTMENT.**

<table>
<thead>
<tr>
<th>store</th>
<th>$y_o$</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$Q^*$</th>
<th>$p_1$</th>
<th>$p_2$</th>
<th>$p_2^*$</th>
<th>$\Delta \pi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>store1</td>
<td>50</td>
<td>3.2</td>
<td>3.2</td>
<td>2473</td>
<td>11</td>
<td>5</td>
<td>5.82</td>
<td>30.8</td>
</tr>
<tr>
<td>store2</td>
<td>50</td>
<td>3</td>
<td>3</td>
<td>2364</td>
<td>11</td>
<td>5</td>
<td>5.86</td>
<td>66.2</td>
</tr>
<tr>
<td>store3</td>
<td>50</td>
<td>2.8</td>
<td>2.8</td>
<td>2255</td>
<td>11</td>
<td>5</td>
<td>5.90</td>
<td>105.9</td>
</tr>
<tr>
<td>store4</td>
<td>50</td>
<td>2.5</td>
<td>2.5</td>
<td>2089</td>
<td>11</td>
<td>5</td>
<td>5.97</td>
<td>173.6</td>
</tr>
<tr>
<td>store5</td>
<td>50</td>
<td>2.2</td>
<td>2.2</td>
<td>1926</td>
<td>11</td>
<td>5</td>
<td>6.07</td>
<td>227.1</td>
</tr>
</tbody>
</table>

1) As the fresh agriculture products’ price elasticity and perceived quality elasticity decreased, the optional pricing of fresh agriculture product gradually increased;  
2) with the decrease of the fresh agriculture products’ price elasticity and perceived quality elasticity, the optimal order quantity also gradually decrease.  
3) under the two times price adjustment, the retailers can obtain different maximum profits under different optimal order quantity $Q^*$ and different optimal price discount $p_2^*$.  

V CONCLUSIONS

We can concluded that:  
1) In the price adjustment of one time and two times, the retailers both have the optimal order quality and optimal price discount;  
2) The higher of the initial price, the lower of the price discount;  
3) The fresh agriculture product ‘s having higher price elasticity and perceived quality elasticity, should develop the lower price discount.

ACKNOWLEDGEMENT

This article is supported by Hunan province natural science fund project (13JJB001) and Hunan University Young Teacher Growth Plan. Thanks for their help and support.

REFERENCES