Acta Technica 62 (2017), No. 4A, 13–22

The decision model and supply chain coordination for promotional products based on quantity discount strategies

YONG YE[2]

Abstract. Promotional products' management work has always been the difficulty of price coordination with the supply chain. So, how to share the additional cost is one of the most important factors deciding whether the supply chain can coordinate profit. The aim of research is to study the effect of retailer's promotional activities in the supply chain. A solution for property verification of quantity discount strategies design is introduced. Through the commodity characteristics of promotional product develop promotional plans with quantity discount, it gave supplier quantity discount adjust promotion plan. By analyzing a two-stage supply chain, it achieved the optimization goal of promotional products in the whole supply chain.

Key words. Promotional products, quantity discounts, supply chain coordination.

1. Introduction

Promotional product is a commodity chosen by an enterprise for the purpose of expanding the sales and publicity of the enterprise. Promotion strategy is in essence a kind of communication activities. Marketers (information providers or senders) pass information to one or more target such as listeners, viewers, readers or consumers etc. S.A. Chaharsoughi (2011) said that sales promotion has become a vital tool for marketing and its importance has been increasing significantly over the years. The product features and promotional purposes can be divided into four groups:

(1) Promotion of a product with a short life cycle: For these products, the short shelf life of goods or the expiration date is more important. For example, milk products are likely to cause a great loss for retailers if the promotional time period

[1]Acknowledgment - This work is partly supported by the Key Program in the Youth Elite Support Plan in Universities of Anhui Province (gxyqZD2016028) and the National Natural Science Foundation of China (Project No. 71771003, No.31371533, No.31771679).

[2]Workshop 1 - Logistics Engineering, College of Computer and Information, Anhui Agricultural University; e-mail: yeyong@ahau.edu.cn

is longer than the shelf life. For these kinds of goods, it is better to develop a short promotional time strategy, and make a bigger price discount to promote sales.

(2) The seasonal characteristics of sales promotions: Retailers will replace stocks of goods with seasonal characteristics, such as winter or summer clothing, at the end of a season. Most promotional products are one-time bargain purchases. Once the current stock is gone, it is replaced with something else entirely. For these kinds of goods, the purpose is a clearance sale, so retailers will devote more effort to propagating and promoting, whilst minimizing losses as much as possible.

(3) Promoting goods with low price elasticity: Some products, such as certain types of tissue paper, sold at a low price will have certain limits for price discounts, and may need a long time for sales promotions in order to attract more customers. Price discounts for such goods are smaller, so retailers may inform stores' promotion time period for extensions.

(4)Promoting goods with high price elasticity: Some products are sold at a high price, so that the retailer may gain larger profits. So, retailers need to consider both the promotional price and period for the impact on the customer.

For the whole supply chain, it also needs to make corresponding adjustments with promotion strategies to gain the optimal system profit between supply and requisitioning parties. For retailers, if sales income remains the same, cost savings would mean increased profits. In contrast, for suppliers, cost savings would mean reduced income. Specifically, it argues that price promotions lowers a consumer's motivation to exert mental effort, in which case purchase decisions are guided less by extensive information processing and more by a quicker, easier and stronger preference.

There are several studies on the quantity discount strategy of promotional products that need a contract mechanism. James P. Monahan (1984) analyzed how a supplier can structure the terms of an optimal quantity discount schedule, and pointed out that the vendor's challenge is to adjust the present pricing schedule to entice major customers to increase order sizes by a factor of "K". Steffen J?rgensen et al. (2003) used game theory to study a retailer's promotional support program. Su, Y. (2013) considered a strategy in which a supplier offers periodic off-invoice price discounts to a retail chain. Jiang, Y. et al. (2015) demonstrated that online price promotions and product recommendations should be jointly considered and optimally determined. Wang, C. (2015) investigated a news vendor problem in a joint ordering and pricing setting in the presence of option contracts under promotion. Kumar, A. et al. (2016) proposed a model that imitates the price discounting and promotional strategy for a product category in a retail organization.

Other studies have proposed optimization strategies through quantitative modeling. Christen, M. (1997) used market-level data to understand promotional effects by using a non-linear model. Aylin Aydinli et al. (2014) pointed out that price promotions were mere incentives and lowered a consumer's motivation to exert mental effort. Brojeswar (2015) analyzed coordination mechanisms among the members of a chain with several contracts and found the optimal range for the contract parameters. Kai, J. I. (2016) analyzed both online-channel price discounts and advertising decisions in a dual-channel supply chain that involved one manufacturer and one retailer.

Considering the limitations of models as well as the nature of promotional products, pricing and promotion time period all affect the profit of the supply chain optimization. It is different from supply chain coordination strategy for ordinary goods or deteriorating goods. Therefore, as the focus of research, the new study is the first to use promotion goods for which the price elasticity is larger. The study examines whether a retailer's coordination mechanism has certain promotional plans or not. First, the study considers a supplier's function in quantity discount policies when retailers have promotion plans. Then, the study analyzes the best promotional plans between suppliers and retailers when the retailer has no promotional plans. Finally, the study offers an optimal strategy for adjusting the promotional plan in order to optimize overall profits.

2. Quantity discount product promotion plans under supply chain coordination strategies

Retailers had promotion plan with a clear set of sale target. In this case, it can put the customer demand and promotion products pricing as known quantity. It can give retailer's optimal quantity. If there is a discount, suppliers' sales revenue would jump dramatically. It need to know which point is the balance, so it can not only reduce the retailer cost and increase the income of suppliers, and also make the supply chain to achieve optimal overall benefit.

2.1. Model Description

Consistent with the literature, we consider a two-stage supply chain including a supplier and a retailer. The retailer's sales goal is determined, in other words, the customer requirements, promotion time and price are certain. Then, the retailer has no supply shortage or an extended delivery. The supplier's order processing and delivery time are stable and do not affect the retailer's sales. Finally, the exchange of information between the two parties is done in real time. It lists the notation used in this paper: D is promotion products daily needs; T is promotion time; P is promotion price; H_C is every cost for promotional activities; Cr is retailer's re-order cost; H_l is retailer's unit inventory storage cost; P_S is purchase price; q is order quantity; C_m is supplier's re-order cost; C_g is supplier's fixed production cost; H_g is supplier's unit inventory keeping rates; R is supplier's production capacity; P_g is supplier's production cost; qs is supplier's production lot(qs=nq, n is constant); T_l is retailer's total cost; T_g is supplier's total cost; E_l are retailer's total profits; E_g are supplier's total profits; E_z are supply chain total profits.

2.2. Supply Chain Coordination Strategy for Promotion Plans with Quantity Discounts

It may pay the price of increasing more order quantity when retailers take quantity discount strategy. Assuming that the supplier is given the conditions of the discount for retailers to increase the original times of the optimum order batch:

$$\mathrm{P}_s\left(q,\beta\right)=\left\{\begin{array}{cc} P_s & q<mq^* \\ \left(1-\beta\right)P_s & q\geq mq^* \end{array}\right.$$

When the wholesale price with the quantity of goods changes, the retailer's profit may decrease, because of the promotional products increasing the order quantity on the basis of the optimum order batch. Therefore, the supplier should compensate for the retailer's profit, namely, the retailers' profit should satisfy the following relations:

$$\mathrm{E}_l\left(1-\beta\right)P_s,mq^*)-\mathrm{E}_l(P_s,mq^*)\geq E_l(P_s,q^*)-E_l(P_s,mq^*)$$

Among above equation:

$$E_l\left(1-\beta\right)P_s,mq^*)=pDT-\left(1-\beta\right)P_SDT-\frac{DTC_r}{mq^*}$$
$$-mq^*H_lP_s/2$$

$$E_l(P_s,mq^*)=pDT-P_SDT-\frac{DTC_r}{mq^*}-mq^*H_lP_s/2 \tag{1}$$

Plugging q^* into Eq.(1):

$$E_l\left(P_s,q^*\right)-E_l\left(P_s,mq^*\right)=\frac{\sqrt{2}(m-1)^2}{2m}\sqrt{DTC_rH_lP_s}$$

$$\beta P_sDT+\beta mq^*H_lP_s/2\geq\frac{\sqrt{2}(m-1)^2}{2m}\sqrt{DTC_rH_lP_s}$$

It can also get:

$$\beta\frac{\sqrt{2}(m-1)^2\sqrt{DTC_rH_lP_s}}{mP_sDT+m^2q^*H_lP_s} \tag{2}$$

When the formula, Eq. (2) is equal, it can know that the retailer's profit does not change even if the supplier gives a discount. If the supplier does not use a quantity discount strategy, then the retailer's order is q^*, and the supplier's production batch is:

$$q_s=nq^*=\sqrt{2DTC_gR/H_g(R-DT)}$$

When the supplier makes demands on the retailer to increase the order quantity, the retailer should expand the order batch to mq^* . So, the supplier's profit is:

$$M_{pq}=\int\int x^py^qf(x,y)dxdy\ p,q=0,1,2... \tag{3}$$

Setting the first derivative of n is zero, the optimum profit conditions of n values are:

$$n_s = \frac{1}{mq^*}\sqrt{\frac{2RDTC_g}{H_g(R-DT)}} = \frac{n}{m}$$

Moreover, the main goal of the supplier using quantity discount strategies with the downstream enterprises is to increase profits, which are determined by the following equation:

$$\mathrm{E}_g((1-\beta)\,P_s, nmq^*) - \mathrm{E}_g(P_s, nq^*) \geq 0$$

$$\beta\frac{(m-1)\,C_m}{mP_sq^*} + \frac{(m-1)\,q^*H_g(R-2DT)}{2P_sDTR} \tag{4}$$

When the Eq. (4) is equal, it can know that the supplier's profit does not increase. In conclusion, the supply chain's objective function is:

$$E_z\,(m,\beta) = E_l\,(m,\beta) + E_g(m,\beta)$$

In the optimal conditions of this objective function, the value of m, reusing the constraints the Eq. (3) and (4) constraints, it is concluded that the value of θ is normalized.

3. Quantity Discount Promotion Products under the best Promotion Plans

As previously discussed, it is mainly considered the situation for clear promotion target and the problems of optimum order batch with the best discount rate. While customer demand will change with promotion price. The longer the period of time during which the promotion is sustained, considering the promotion costs and shelf life, the more price discount is given. Below it will consider the promotion price increasing with the promotion time decay and the condition of price changing for promotion products to make the best promotion strategy. Then, we thought about how the supplier adjusts the promotion period under quantity discount strategy to optimize the overall supply chain efficiency.

3.1. Assumptions of the model

Suppose there is only one supplier and one retailer in a two-stage supply chain system. The supplier carries out timely replenishment, and the retailer will not produce out of stock and without lead time. It is assumed that the promotion time period is the ordering cycle and the demand during this period is the order batch. The customer's needs are influenced only by the retailer's pricing and the demand could be simulated by function. Suppose a demand change with the price function is a linear function:

$$q_s = nq^* = \sqrt{2DTC_gR/H_g(R-DT)}$$

The supplier's production period is n times longer than the retailer's promotional period. Thus, when the first derivative is zero, E_l is at a maximum. Let the first derivative be zero, and T* will be the best promotion plan for the retailer. Assumed that promotion price decline with promotion time. P(t) is the retailer's sales price ; D(t) are customers' daily needs ; I(t) is retailer's unit inventory lever at t moment ; is variation coefficient along with promotion time; T_z are supply chain total costs.

Since the retailer's promotional time period is determined, the supplier's optimal production period is D= a + b .

The supplier's cost is:

$$F_{pq} = \int\int f(r,\theta)g_p(r)e^{jq\theta}rdrd\theta$$

The supplier's profit is:

$$S(x) = \mathrm{f}(x) + n_1(x) * n_2(x)$$

It is unfair for the supplier that the supplier's profits may be count by knowing the retailer's optimal profits. The optimal production cycle is not necessarily the optimal one for the supplier, and the value of n is not likely to be an integer. It may also affect profits by the approximate values.

3.2. Promotion product' supply chain coordination under quantity discount

The supplier take the quantity discount strategy in order to expand its profits, so it needs to coordinate with retailers. In this section, it will discuss a decided promotion price and promotion period:

$$\mathrm{P}_s\left(T^l,\beta\right) = \begin{cases} P_s & T^l < mT^* \\ (1-\beta)\,P_s & T^l \geq mT^* \end{cases}$$

The multiple is m, the retailer may get more profits under the supplier's quantity discount than ever before:

$$\mathrm{E}_l\,(1-\beta)\,P_s, mT^*) - \mathrm{E}_l(P_s, mT^*) \geq E_l(P_s, T^*) - E_l(P_s, mT^*)$$

It calculated the minimum value of

$$\beta\frac{D\,(T)\,T\left[p\,(T) - P_s - \frac{H_l}{2}\right] - H_c T}{D\,(mT)\,mTP_s} - \frac{p\,(mT) - p - \frac{H_l}{2}}{P_s} + \frac{H_c}{D(mT)P_s} \tag{5}$$

The profits will increase:

$$E_g = P_s D\,(T^*)$$

It can calculate the maximum value of *m:*

$$\overline{\xi_{\mathrm{D}}}\left(\hat{x}_{\mathrm{D}k,\upsilon},\hat{y}_{\mathrm{D}k,\upsilon}\right)=\overline{\xi_{\mathrm{wD}}} \tag{6}$$

The overall objective function is:

$$\sum_{i=1}^{\mathrm{M}}\sum_{j=1}^{\mathrm{2N}}\left[\bar{q}_{i,j}\Delta L_{\mathrm{f}i,j}\right]=\frac{q_{\mathrm{sc}}}{u}$$

In the objective function optimal situation, it is concluded that the value of r range according to Eq. (5) and Eq.(6).

4. Analysis of examples

4.1. A clear promotional sales plan with quantity discounts

Assumes that a retailer has a clear promotional plan for a certain type of cup. The promotional plan for selling 100 cups a day means that sales will last for ten days. If the supplier's production capacity is 300 cups a day and the promotional price is 40 dollars, then the supermarket's re-ordering cost is 50 dollars, and the unit cost of inventory storage is 5 dollars. The supermarket's purchasing price from the suppliers is 25 dollars. The supplier can provide an acceptable re-order price of 50 dollars for promotional products. The supplier's fixed cost of production is 100 dollars per unit and the warehousing cost is 5 dollars per unit. Consequently, the supplier's production cost is 10 dollars per unit and the retailer's fixed cost of promotion is 100 dollars per day. Given in the case conditions are as follows:

D=100; t=10; r=100; p=40;

(1) Conditions without quantity discount

The retailer's best order batch can be calculated under the condition without quantity discount: $q^*=40$; The supplier's best production batch is $q_s=nq^*=280(n=7)$. The retailer's profit is $E_l(q^*)=9000$ dollars. The supplier's profit is $E_g(nq^*)=11823$dollars. The supply chain's total profit is $E_z=E_l\left(q^*\right)+E_g(nq^*)=20823$ dollars.

(2) Conditions with supplier's quantity discount

$$E_l\left(\left(1-\beta\right)P_s,mq^*\right)=40000-25000\left(1-\beta\right)-\frac{2500}{m}-2500m$$

The supplier's profits is:

$$E_g\left(\left(1-\beta\right)P_s,nmq^*\right)=25000\left(1-\beta\right)-10000-\frac{2500}{m}-\frac{2500}{7m}-320m$$

The supply chain's total profit is:

$$E_z=30000-\frac{37500}{7m}-2820m$$

When the whole supply chain profit is optimal, m=1.4 according to the differential principle. Then, E_z=23225 dollars. Thus it can be seen that the whole supply chain profit increases when the supplier gives quantity discounts. The price discount β is given according to Eq.(2) and Eq. (4):0.018β0.028 . That is to say, when the retailer's order quantity is equal to 56 unit, suppliers give quantity discounts of 30% or 40%, which optimize the whole supply chain. If so, it will not damage the interests of any one party of supplier or retailers. As to who can benefit more from the quantity discount strategy, it is up to the game of suppliers and retailers. The nearer β is to 0.018, the retailer benefits more, whereas the nearer β is to 0.028, the supplier benefits more.

4.2. Application of the model to an unclear promotional sales plan with quantity discounts

When the retailer has no clear promotion plans, it is known that the cup's price declines with time and the price is applied to forecasting based on past sales data. Then, it carries out the plan for promotional activities according to the history of sales data. The cup's sale price is 40 dollars in general. The product's purchase price is 25 dollars per unit. The supplier's production cost is 10 dollars. The retailer's unit inventory cost and the supplier's inventory cost is 5 dollars. The supplier's production cost is 200 dollars per day. The fixed cost of the retailer's promotional activities is 100 dollars per day and the promotion of attenuation rate is 1/20. Assumes that the demand rate function along with the price changing is D = 100 + 20(40 − p). According to Eq. (5) and (6), it can get the promotion price function along with the promotion's period of time:.

Putting p(t) into the demand function, it can eventually get the demand rate function to change with promotional time period: D = 100 + 20(40 − p (t)). Given in the conditions as follows:

p=40; $p_s = 25$; $p_g = 10$; $H_l = H_G = 5$;

Putting data into Eq. (4), the retailer's promotion period under optimal profits can be calculated using Matlab software: T=14 days. The retailer's profit is E_l= 18267.2 dollars. The supplier's production time is:

$$\mathrm{nT} = 9;;\ \mathrm{n} = \frac{9}{14}$$

The supplier's profit is E_g= 15680 dollars. The whole supply chain's profit is E_z= 33974 dollars.

As a whole, the supplier hopes that the retailer increases the promotion period in order to purchase more products. The supplier stipulates an m-fold increase in the original promotion period and takes the quantity discount strategy. Setting m=16, the whole supply chain's profit is E_z = 36560 dollars, which is 2613 dollars more than the profits without the supplier's quantity discount strategy. The price discount β is given according to Eq. (5) and (6).

That is to say, when the supplier gives quantity discounts, a minimum of 50% can ciase no damage. As to who benefits more from the quantity discounts strategy is up to how much extra profit is made by the suppliers or retailers.

5. Conclusion

In this paper, it discusses the situation of a retailer having clear promotion plans, namely the promotion price and promotion period, which are determined. Then, the paper considered that the supplier gives quantity discount and how to adjust the model to make the whole supply chain achieve optimal profits. Besides, the paper discussed the promotion price having a decay rate as time and the customer demand changed with the promotion price. On this occasion, the retailer must make a reasonable promotion plan to obtain the optimal promotion time. The purpose of the promotion is to increase sales. Our research finds that if only the best retailer's profit is considered, the supplier may not get the best profits.

Further research is needed to see different conditions, such as the season factor in promotion strategy. Although price promotion can enhance the transactional value of the purchase, it triggers value devaluation effects. So the price elasticity should be taken into consideration. As products move through the product life cycle, different promotional strategies should be employed at these stages to ensure the healthy success and life of the product in further studies.

References

[1] A. Aydinli, M. Bertini, A. Lambrecht: *Price promotion for emotional impact.* Social Science Electronic Publishing *78* (2014), No. 4, 80–96.

[2] S. A. Chaharsoughi, J. Hamdard: *The affect of sales promotion on consumer interest to purchase in ikco automotive company.* Journal of Knowledge Management Economics & Information Technology *1* (20111985), No. 4, 3–3.

[3] M. Christen, S. Gupta, J. C. Porter, R. Staelin, D. R. Wittink: *Using market-level data to understand promotion effects in a nonlinear model.* Journal of Marketing Research *34* (1997), No. 3, 322–334.

[4] Y. Jiang, J. Shang, Y. Liu, J. May: *Redesigning promotion strategy for e-commerce competitiveness through pricing and recommendation.* International Journal of Production Economics *167* (2015) 257–270.

[5] S Jorgensena, G. Zaccour: *Retail promotions with negative brand image effects: is cooperation possible.* European Journal of Operational Research *150* (2003), No. 2, 395–405.

[6] A. Kumar, A. Adlakha, K. Mukherjee: *Modeling of product sales promotion and price discounting strategy using fuzzy logic in a retail organization.* Industrial Management & Data Systems*166* (2016), No. 8, 1418–1444.

[7] J. I. Kai: *Research on Cooperative Advertising Decisions in Dual-Channel Supply Chain Under Asymmetric Demand Information When Online Channel Implements Discount Promotion.* Management Science and Engineering *10* (2016), No. 4, 13–19.

[8] H. Kawakatsu, T. Homma, K. Sawada: *An optimal quantity discount policy for deteriorating items with a single wholesaler and two retailers.* Iaeng International Journal of Applied Mathematics *43* (2013), No. 2, 81–86.

[9] J. P. Monahan: *A quantity discount pricing model to increase vendor profits.* Management Science *32* (1986), No. 11, 1513–1517.

[10] B. Pal, S. S. Sana, K. Chaudhuri: *Two-echelon manufacturer–retailer supply chain strategies with price, quality, and promotional effort sensitive demand.* International Transactions in Operational Research *22*, (2014), No. 6, 1071–1095.

[11] Y. Su, J. Geunes: *Multi-period price promotions in a single-supplier, multi-retailer supply chain under asymmetric demand information.* Annals of Operations Research *211* (2013), No. 1, 447–472.

[12] T. M. Choi, C. L. Hui, N. Liu, S. F. Ng, Y. Yu: *Fast fashion sales forecasting with limited data and time.* Decision Support Systems *59* (2014), No. 1, 84–92.

Received November 16, 2016