

The Impact the Price Promotion Has on the Manufacturer's Performance

Wenting Pan¹, Yung-Jae² and Tina Zhang³

¹*School of Economics and Business Administration, Saint Mary's College of California,
380 Moraga Road, 94556 Moraga, U.S.A.*

²*Operations Management, Saint Mary's College of California, 380 Moraga Road, 94556 Moraga, U.S.A.*

³*Saint Mary's College of California, 380 Moraga Road, 94556 Moraga, U.S.A.*

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Abstract: We consider a supply chain network where there is one manufacturer and multiple identical retailers in a consumer non-durable market. The retail purchase price is exogenous, and demand is deterministic. The retailers apply the Economic Order Quantity (EOQ) model to minimize the total cost. In observation of the manufacturer's periodic instantaneous promotion, the retailers would place a one-time order from the manufacturer to take advantage of the deal during the promotion period. The objective of this paper is to examine the impact this price promotion has on the manufacturer's performance. We find that this promotion policy has a negative impact on the manufacturer's performance. Interestingly, we also find that this negative impact is less damaging when the utilization of the facility is lower.

1 INTRODUCTION

Trade promotions are deep-rooted marketing practices to temporarily increase sales volume, especially in the consumer non-durable market. Even though trade promotions are designed to serve certain marketing objectives, they also create inefficiency in distribution channels. Research papers include Jones (1990), Buzzell et al., (1990) and Ailawadi et al., (1999).

The purpose of this paper is to provide an analytical framework to quantify the economic impact the price promotions have on the manufacturer's performance.

2 THE BASIC FRAMEWORK

We consider a supply chain network, comprised of one manufacturer and multiple identical retailers. The retailer model studies the retailers' purchasing pattern and the manufacturer model focuses on the optimal production schedule. Based on the results derived from these two models, we can then analyze the impact of price promotions on the manufacturer's performance.

The Retailer Model. Here are the assumptions for the retailer model. Lead time is zero. Shortages are not allowed. All the retailers are identical. The manufacturer's promotion period is instantaneous. We further assume that the discount is offered by the manufacturer at the beginning of each period. We use the following notations throughout the paper for the retailers:

D = the retailer's demand per period (say, year) assumed constant and uniform;

s_r = retailer's setup cost per order;

c_r = retailer's unit purchasing cost;

h_r = retailer's unit inventory holding cost per period, expressed as a percentage of the value of the item;

Q_r = retailer's order quantity

d = discount expressed as a percentage of price during the promotion period.

Let Q_r^* denote the retailer's optimal order quantity. It is straightforward to see that when $d = 0$, Q_r^* is solved by,

$$Q_r^* = \sqrt{\frac{2Ds_r}{c_r h_r}}. \quad (1)$$

We next consider the general case when $d > 0$. Since the manufacturer offers a discount d for a very

short period of time, the retailer only makes a one-time purchase during the promotion period to take advantage of the discount. After the short promotion time, the retailer resumes its economic order quantity Q_r^* for the rest of this period until the next discount occurs at the beginning of the next period. In particular, let Q_{r1} be this one time order quantity. Since we assume that the discounts are offered by the manufacturer regularly, the retailer has no reason to order more than D units when the deal is on. Thus, we can restrict $Q_{r1} < D$ without loss of generality. It follows that the retailer's total cost in one period is given by

$$C_r(Q_{r1}) = Q_{r1}(1-d)c_r + (D - Q_{r1})c_r + \left[1 + \frac{(D-Q_{r1})}{Q_r^*}\right]s_r + \frac{Q_{r1} Q_{r1}}{2D}(1-d)c_r h_r + \frac{Q_{r1}^2}{2}\left(1 - \frac{Q_{r1}}{D}\right)c_r h_r. \quad (2)$$

Differentiating $C_r(Q_{r1})$ with respect to Q_{r1} , we obtain

$$C_r'(Q_{r1}) = -dc_r - \sqrt{\frac{2s_r c_r h_r}{D}} + \frac{Q_{r1}(1-d)c_r h_r}{D} \quad (3)$$

and

$$C_r''(Q_{r1}) = \frac{(1-d)c_r h_r}{D} > 0. \quad (4)$$

Hence, $C_r(Q_{r1})$ is convex in Q_{r1} and the optimal order quantity, denoted by Q_{r1}^* , is uniquely solved by equation $C_r'(Q_{r1}) = 0$. It directly follows that

$$Q_{r1}^* = D \left[\frac{d}{h_r(1-d)} + \frac{\sqrt{2s_r}}{(1-d)\sqrt{c_r h_r D}} \right]. \quad (5)$$

Clearly that Q_{r1}^* is strictly increasing in the discount level d . Furthermore, notice that $Q_r^* = Q_{r1}^*$ when $d = 0$. Thus, $Q_{r1}^* > Q_r^*$. Since the retailer would never order more than D units when the deal is on, the maximum level of discount \bar{d} is given by

$$\frac{\bar{d}}{h_r(1-\bar{d})} + \frac{\sqrt{2s_r}}{(1-\bar{d})\sqrt{c_r h_r D}} = 1, \quad (6)$$

or equivalently

$$\bar{d} = \frac{h_r}{(1+h_r)} \left[1 - \sqrt{\frac{2s_r}{c_r h_r D}} \right]. \quad (7)$$

Clearly, for any $d \geq \bar{d}$, the retailer would order D units at the discount price. Therefore, we shall assume that $d \leq \bar{d}$ in the following analysis, and so $Q_{r1}^* \leq D$.

Let α denote the proportion of the one-time purchase out of its total demand D when the price discount is offered, i.e.,

$$\alpha = \frac{Q_{r1}^*}{D} = \frac{d}{h_r(1-d)} + \frac{\sqrt{2s_r}}{(1-d)\sqrt{c_r h_r D}} \leq 1. \quad (8)$$

2.1 The Manufacturer Model

The manufacturer model studies the optimal production schedule that minimizes the manufacturer's production and inventory holding costs given the retailers' purchasing pattern and the capacity of the manufacturer's facility. In this model, we assume that there are many identical individual retailers who independently make purchasing decisions from this manufacturer. Here are the notations we will use throughout the paper for the manufacturer.

- s_m = the manufacturer's setup cost per order;
- c_m = the manufacturer's unit production cost;
- h_m = the manufacturer's unit holding cost per period, expressed as a percentage of the value of the item;
- μ = the manufacturer's production rate per period;
- λ = the manufacturer's aggregate demand rate per period.
- $\rho = \frac{\lambda}{\mu}$, utilization of the manufacturer's facility.

The retailer model discussed in Section 2.1 suggests that individual retailer purchases a certain portion (α) of its total one-period demand when the discount is offered at the beginning of each period. Since we assume identical retailers, it is clear that α portion of the aggregate demand λ occurs when the discount is offered at the beginning of the period, with no demand for the following α period of time, and the remaining demand ($\lambda - \alpha\lambda$) occurs for the next $(1 - \alpha)$ period of time. We assume that demand ($\lambda - \alpha\lambda$) occurs uniformly between time $(1 - \alpha)$ and time 1.

We now study the manufacturer's optimal production schedule that minimizes the total cost. There exist four cases depending on the value of α and the utilization of the facility ρ .

Case (i) $0 < \alpha < 1$ and $\rho < 1 - \alpha$

Case (i) represents the situation where some discount is offered at the beginning of each period and the utilization of the facility is lower than a threshold $(1 - \alpha)$. In this case, the manufacturer would start to build up the inventory at time $[1 - \frac{\alpha\lambda}{(\mu - \lambda)}]$ so that he can get ready for the price promotion that occurs at the beginning of the next time period. Therefore, the last production run in this period begins at time $[1 - \frac{\alpha\lambda}{(\mu - \lambda)}]$.

We next adopt the idea of the Economic

Production Lot Size model to approximate the manufacturer's optimal production quantity. We shall determine the optimal number of production runs between the time period α and time period $(1 - \frac{\alpha\mu}{\mu - \lambda})$. Let n denote the number of production runs between the time period α and time period $(1 - \frac{\alpha\mu}{\mu - \lambda})$.

The production and inventory costs are given by

$$C_1(n) = c_m\lambda + \frac{c_m h_m \rho (\mu - \lambda - \alpha\mu)^2}{2n(\mu - \lambda)} + s_m(n + 1) + \frac{c_m h_m (\alpha\lambda)^2}{2(\mu - \lambda)} \quad (9)$$

To simplify the analysis, we here assume that n is a real number. Clearly, the optimal number of the production runs, denoted by n^* , is given by

$$n^* = (\mu - \lambda - \alpha\mu) \sqrt{\frac{c_m h_m \rho}{2s_m(\mu - \lambda)}} \quad (10)$$

It directly follows that the optimal manufacturer's cost

$$C_1 = C_1(n^*) = c_m\lambda + 2(\mu - \lambda - \alpha\mu) \sqrt{\frac{c_m h_m s_m \rho}{2(\mu - \lambda)}} + s_m + \frac{c_m h_m \lambda \alpha^2 \rho}{2(1 - \rho)} \quad (11)$$

Case (ii) $0 < \alpha < 1$ and $\rho \geq 1 - \alpha$

Case (ii) represents the situation where some discount is offered at the beginning of the period and the utilization of the facility is higher than the threshold $(1 - \alpha)$.

During the first α period of time when there is no demand, the manufacturer's inventory level can be increased with the rate of μ if there is a production run. The manufacturer's inventory level can be accumulated with the rate of $(\mu - \lambda)$ during the remaining $(1 - \alpha)$ period of time when the demand occurs at the rate of λ . Therefore, to accumulate $\alpha\lambda$ units at the end of the period, the manufacturer must start the production run at time $(1 - \rho)$.

Thus, the production and inventory costs are given by

$$C_2 = c_m\lambda + s_m + \frac{c_m h_m \lambda [\alpha(2 - \alpha) - (1 - \rho)]}{2} \quad (12)$$

Case (iii) $0 < \alpha < 1$ and $\rho = 1$

In this case, the facility is dedicated to making just one specific product without any excess capacity. During the first α period of time when there is no demand, the manufacturer would build up $\alpha\lambda$ units of the product to meet the demand at the beginning of

the next period. The manufacturer would then hold this amount of inventory for the remaining $(1 - \alpha)$ period of time since the demand rate λ is equal to the production rate μ .

Thus, the production and inventory costs are given by

$$C_3 = c_m\lambda + \frac{\alpha^2 \lambda c_m h_m}{2} + \alpha\lambda(1 - \alpha)c_m h_m \quad (13)$$

Case (iv) $\alpha = 1$ and $\rho < 1$

This case corresponds to the situation where $d \geq \bar{d}$. Since the discount is so large, the retailers purchase the entire one-period demand when the discount is offered. In this case, the manufacturer must start building up the entire amount of one period demand λ at time $(1 - \rho)$. The entire amount would be sold to the retailers at the beginning of the next period.

Thus, the production and inventory costs are given by

$$C_4 = c_m\lambda + s_m + \frac{c_m h_m \lambda \rho}{2} \quad (14)$$

2.2 Model Combination

Clearly, the manufacturer's revenue is equal to $\alpha\lambda(1 - d)c_r + (1 - \alpha)\lambda c_r$. Let π_i denote the profit for case i .

$$\pi_1 = \alpha\lambda(1 - d)c_r + (1 - \alpha)\lambda c_r - [c_m\lambda + 2(\mu - \lambda - \alpha\mu) \sqrt{\frac{c_m h_m s_m \rho}{2(\mu - \lambda)}} + s_m + \frac{c_m h_m \lambda \alpha^2 \rho}{2(1 - \rho)}] \quad (15)$$

$$\pi_2 = \alpha\lambda(1 - d)c_r + (1 - \alpha)\lambda c_r - [c_m\lambda + s_m + \frac{c_m h_m \lambda [\alpha(2 - \alpha) - (1 - \rho)]}{2}] \quad (16)$$

$$\pi_3 = \alpha\lambda(1 - d)c_r + (1 - \alpha)\lambda c_r - [c_m\lambda + \frac{\alpha^2 \lambda c_m h_m}{2} + \alpha\lambda(1 - \alpha)c_m h_m] \quad (17)$$

$$\pi_4 = \alpha\lambda(1 - d)c_r + (1 - \alpha)\lambda c_r - [c_m\lambda + s_m + \frac{c_m h_m \lambda \rho}{2}] \quad (18)$$

3 NUMERICAL EXAMPLES

We have conducted extensive numerical experiments to understand the impact this price promotion has on the manufacturer's performance.

Consider the following parameters for the retailers: $D = 10,000$, $c_r = 70$, $h_r = 0.4$, and $s_r = 200$; and the following parameters for the manufacturer: $\mu = 100,000$, $c_m = 50$, $h_m = 0.3$, and $s_m = 1,000$. Three levels of aggregate demand are: $\lambda = 50,000$, $\lambda = 70,000$, $\lambda = 90,000$. Therefore, the corresponding

utilization is 0.5, 0.7, and 0.9 respectively.

Observation: The Manufacturer’s Profit Decreases as the Level of Discount Increases. Furthermore, the Marginal Decrease is Higher when the Utilization of the Facility is Higher.

Figure 1 illustrates the relationship between the manufacturer’s profit and the level of discount offered by the manufacturer. As shown in Figure 1, the profit decreases as the discount level d increases for all three different levels of utilization. Figure 1 also shows that the marginal decrease is higher when the utilization of the facility is higher, as the discount level increases.

Interestingly, at 0.225 discount level, the manufacturer’s profit when the utilization of the facility is 0.5 is higher than the manufacturer’s profit when the utilization of the facility is 0.7 and 0.9. This implies that the detrimental effect of trade deals on manufacturer’s profit is not so severe when the manufacturer has a relatively large capacity cushion or equivalently, the manufacturer operates at a low rate. Even though the promotion deal helps decrease the inventory level faster due to the larger order quantities from the retailers, this benefit is usually offset by the fact that the manufacturer has to prepare for the deal. Since the manufacturer has to start the production much earlier than he would when there was no deal offered to the retailers, the manufacturer has to carry extra inventory, which increases the inventory holding cost. However, if the manufacturer has large enough capacity, he does not need to start the production too early, thus decreasing the time to carry inventory before and after the completion of a production run.

4 CONCLUSIONS

In this paper, we develop a framework to study the impact the price promotion has on the manufacturer’s performance, taking into account the retailers’ purchasing pattern, under deterministic demand. We find that the price promotion has a negative impact on the manufacturer’s performance. We also find that the detrimental effect of the price promotion is less damaging when the facility utilization is lower. Price sensitive demand is of great interest for the further research, especially the stochastic case. Different but interesting insights might be derived if price promotions affect the total aggregate demand.

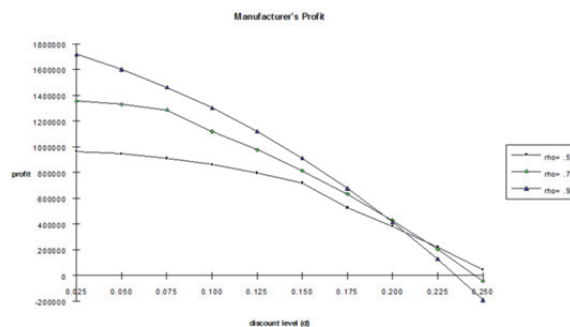


Figure 1: Manufacturer’s profit versus discount level.

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