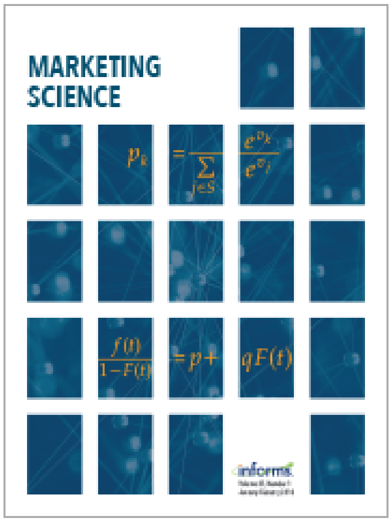

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Optimal Pricing and Return Policies for Perishable Commodities

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This paper considers the pricing decision faced by a producer of a commodity with a short shelf or demand life. A hierarchical model is developed, and the results of the single period inventory model are used to examine possible pricing and return policies. The paper shows that several such policies currently in effect are suboptimal. These include those where the manufacturer offers retailers full credit for all unsold goods or where no returns of unsold goods are permitted. The paper also demonstrates that a policy whereby a manufacturer offers retailers full credit for a partial return of goods may achieve channel coordination, but that the optimal return allowance will be a function of retailer demand. Therefore, such a policy cannot be optimal in a multi-retailer environment. It is proven, however, that a pricing and return policy in which a manufacturer offers retailers a partial credit for all unsold goods can achieve channel coordination in a multi-retailer environment.

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Introduction

One of the most important decisions a manufacturer must make is the price to charge for his products. This decision is typically made on either a cost basis or on a "what the market will bear" approach. Both of these techniques, however, tend to neglect the downstream effects of pricing. That is, the manufacturer sets the price charged retailers (or distributors), which affects the purchase decision made by the retailers. This, in turn, affects the price, demand, and availability of the product to the consumer and therefore the manufacturer's total profit.

This paper considers a bilateral monopoly in which a manufacturer produces a commodity for sale to retailers or distributors. The item produced has a relatively short shelf or demand life, and it is assumed that any retailer will only place one order with the manufacturer. The retailer will then sell the commodity until either his inventory is depleted or the shelf/demand life has been exhausted. In the case where inventory is depleted, the goodwill cost associated with customers whose demand is unsatisfied is assumed to be partially incurred by the retailer and partially incurred by the manufacturer. Such costs could be due to a variety of reasons such as the customer concluding that the given retailer is no longer a reliable vendor of the product or the customer deciding that a competing product is just as suitable for his needs. In the case where inventory remains beyond the shelf/demand life, we assume that a certain amount may be returned to the manufacturer for partial credit with the remainder disposed of by the retailer for its salvage value. Salvage value could be realized in a number of ways including a mark-down on the product (typical with baked goods, records, and books), transfer of the product into an alternative use, sale of the product for scrap or recycling, or donation of the product to charity.

The paper assumes that the manufacturing cost per item is independent of the production quantity and that all retailers charge the same fixed price for the product. Such a situation is quite common with franchise businesses and is oftentimes the case in other businesses (e.g., dairy products, periodicals) due to competitive pressures. It is further assumed that both the manufacturer and retailers are profit maximizers (risk neutral), the salvage value to retailers is the same as the salvage value to the manufacturer, and there are no transfer mark-ups between retailers and manufacturer (i.e. the amount paid by the retailer is the amount received by a manufacturer).

Policies are considered in which the amount of merchandise a retailer can return to the manufacturer for credit is a fixed percentage of the initial inventory purchase. A management science approach is developed to analyze how a manufacturer can set a pricing and return policy to ensure channel coordination.

The manufacturer's pricing policy specifies the amount per unit charged to the retailer, the per unit credit for returned goods, and the percentage of purchased goods allowed to be returned for this credit. Manufacturers of limited life commodities (e.g., newspapers, baked goods, periodicals, records, etc.) use various policies fitting this model. These range from a full credit on all unsold goods to no credit for unsold items. Middle road strategies, such as full credit for partial returns or partial credit for full returns, are also currently in use.

For example, as reported in the February 18, 1982 issue of the *Wall Street Journal*, record manufacturers had been allowing full credit for all unsold records by retailers. The article went on to report that recent policy changes by a number of manufacturers have limited the amount of returns for full credit to around 20%.

Much research has been done in both marketing and economics regarding channel distribution and pricing policy. Issues studied have focused on the bargaining powers and leadership of channel parties, the advantages of vertical integration, market development costs, and channel coordination.

Pashigan (1961) conducted an empirical study of the automobile industry. His work focused on some of the reasons why automobile manufacturers have adopted the franchise system for car distribution. He also looked at factors such as economies of scale in distribution to determine the number of sellers of automobiles for a given local market as well as the issue of whether manufacturers should exploit their dominant position over retailers by "forcing" cars upon them. Lindsay (1979) investigated pricing in a bilateral monopoly to determine business structure.

Wu (1964) compared the advantages of vertical integration versus a bilateral monopoly. Zusman and Etgar (1981) considered a three-level channel distribution system, looking at pricing policies and their relationship to monitoring schemes. Gould (1980) studied a two-trader system and examined the issue of resource expenditure to bring these traders together to make a market. Schul et al. (1983) considered the issue of channel leadership behavior. In an empirical study of a franchise business, they showed that interchannel conflict arising from administrative and product service issues diminishes when the franchisor exhibits a participatory leadership style.

McGuire and Staelin (1983) investigated a duopoly structure for determining when it is preferable for a manufacturer to sell through an independent retailer versus a company store. They considered two competing manufacturers, each of whom distributes the product through a single retailer, either independent or company-owned. Demand was taken to be a deterministic linear function of price and affected by the degree of product differentiation. They assumed that each manufacturer set his wholesale price to maximize his profit subject to the response of the competing wholesaler and the two retailers.

Using game theory, they showed that the optimal distribution system depended upon the degree of the commodity's demand interdependence at the retail level. If demand was highly interdependent, manufacturers were better off using independent retailers. Alternatively, if a retailer's marketing efforts did not strongly influence his competitor's demand, a company store distribution system was preferable.

This paper is concerned with developing policies to ensure channel coordination. Two recent articles which touched on this issue are by Jeuland and Shugan (1983) and Monahan (1984). Jeuland and Shugan studied the issue of channel coordination by investigating a bilateral monopoly in which a single manufacturer sold to a single retailer and in which neither the manufacturer nor retailer controlled pricing. Using a symmetric formulation, they considered a deterministic demand curve which was downward sloping in price and a function of both quality and the retailer's promotion costs. Given the deterministic nature of demand, it therefore followed that all of the items purchased from the manufacturer would be sold by the retailer. The paper showed that a discount pricing schedule, which is, in effect, a profit-sharing mechanism, could be developed to ensure that both the retailer and manufacturer would coordinate their decisions in a system optimal fashion.

Monahan considered the situation of a single supplier selling a product to a single customer. The intent of the analysis was to determine a price discount policy which ensured channel coordination between supplier and customer. In particular, the situation studied by Monahan involved a customer having a smaller order cost than a supplier and therefore ordering items more frequently. Monahan determined the increase in the customer order quantity which maximizes channel profits and the discount that the supplier must offer to the customer to induce him to place orders of that size.

Our work differs significantly from that of Jeuland and Shugan and Monahan in a number of respects. Whereas both of these papers assumed deterministic demand functions, we consider a short-lived commodity which has a fixed retail price but stochastic retail demands. Therefore, demand at the retail level will generally not equal the amount which the retailer has purchased from the manufacturer. Also, whereas Jeuland and Shugan assumed a negotiated settlement between manufacturer and retailer would occur in determining a pricing policy, we, like Monahan, assume that the manufacturer has control of the channel and is free to set the pricing policy. The only decision left for the retailer is whether to carry the commodity or not.

One of the major objectives of our research is to develop uniform policies which will achieve channel coordination in a multi-retailer environment. One difficulty of the Jeuland and Shugan work is in extending their results to a multi-retailer environment. Their model assumed equal price elasticities for demand at both the retail and manufacture levels. If, however, total demand for the item is relatively inelastic, while demand at the individual retail level is highly elastic, it is conceivable that all a pricing discount schedule would accomplish is to concentrate demand among a small number of retailers. The result of this would be an overall decrease in the manufacturer's total profit. Also, for such a discount schedule to work in achieving coordination, Jeuland and Shugan stated that "a different schedule will be needed for retailers whose costs are different." They suggested that this schedule should be set as a "result of bilateral negotiations between the parties" and left to further research the issue of when "a single schedule offered to a group of heterogeneous retailers may be more optimal than no schedule at all." Similar difficulties exist in extending Monahan's work to a multi-retailer environment due to the dependency of the optimal policy on an individual customer's parameters. As Monahan points out in the closing paragraph of his paper: "Despite such variety of application, management should know that there are sizable risks in using this model with a multiple-customer situation." ... "System-wide supplier net profits can theoretically go up, down or remain the same, when discount terms are set solely upon the economic input data of only one customer. Additional research is needed to further investigate the discount problem on behalf of multiple-customer suppliers."

A major result of our paper is that neither a policy of allowing for unlimited returns at full credit nor one which allows for no returns could be optimal. Limiting returns to a fixed percentage of sales may allow an optimal policy to be developed; however, such a policy will not be optimal in a multi-retailer environment. We demonstrate that an optimal policy in the multi-retailer environment is only achievable if unlimited returns are permitted for partial credit. In this case, formulae for the optimal price to be charged the retailer as well as the partial credit amount are presented along with formulae for the expected profit achievable by both the retailer and manufacturer. While such a policy can achieve channel coordination, it is shown that all retailers will, unfortunately, not be affected equally. That is, while the manufacturer may set a coordinated pricing and return policy which increases both his and the average retailer's expected profit, some retailers may actually experience a decrease in expected profit due to the policy change. As a consequence, some retailers may choose to no longer carry the product while, at the same time, others may now find it attractive to do so.

To obtain our results, we utilize the single period inventory model ("newsboy problem"). A number of papers have been written regarding this model and its relationship to distribution systems. Goodman and Moody (1970) used this technique to determine the optimal quantity a manufacturer should ship for items undergoing a special price promotion. Eppen (1979) considered the effects of centralized distribution using the single-period inventory model and concluded that the expected cost of a decentralized distribution system exceeded that of one which was centralized. In Atkinson (1979), a bilateral relationship between a manager and owner was considered. This paper showed that if the owner wishes to utilize the manager's expertise, a standard setting compensation plan is preferable to a paid worker incentive mechanism. The paper went on to argue against using internal cost and price adjustments as a means to modify the manager's behavior. Pasternack (1980), on the other hand, showed that cost and price modifications could be used to improve the overall profitability of a bilateral monopoly in which the manufacturer derived profits both from commodity sales to the retailer as well as from receiving a percentage of the retailer's overall sales.

While the single-period inventory model is used to derive the results herein, it should be stressed that the problem of interest is not finding the order quantity, but rather what pricing policy for the manufacturer will be optimal. While commodities such as records may, in fact, be reordered by retailers, it is felt that the single-period inventory model will serve as a good vehicle for investigating such policy implications.

The Model

Let

$c =$ manufacturing cost per item.
$c_1 =$ price per unit paid by the retailer to the manufacturer.
$c_2 =$ credit per unit paid by the manufacturer to the retailer for returned goods.
$c_3 =$ salvage value per unit.
$p =$ selling price per unit by the retailer.
$g =$ goodwill cost per unit due to stockout incurred by the retailer.
$g_1 =$ additional goodwill cost per unit due to stockout incurred by manufacturer.
$g_2 = g + g_1 =$ total goodwill cost.
$Q =$ amount ordered by the retailer from the manufacturer.
$R =$]percentage of order quantity, Q, which the retailer can return to the manufacturer for a credit of c_2 per item.
$f(x) =$ probability density function of demand; and
$F(k) = \int_0^k f(x)\,dx$.

(Note that the probability density function and cumulative frequency distribution of demand are, in general, functions of the selling price, p. Since the paper assumes, however, that this price is fixed, its argument does not appear in these functions.)

The following two relationships on the values are assumed to hold:

$$c_3 < c < c_1 < p, \tag{1}$$

$$c_3 < c_2 \le c_1 < p. \tag{2}$$

Consider first the case in which the manufacturer acts as his own retailer (i.e. company store). This will enable us to determine the optimal policy for the system as a whole.

If the manufacturer produces Q and sells to the public directly his expected profit, $\mathrm{EP}_T(Q)$, will be given by:

$$\mathrm{EP}_T(Q) = -cQ + \int_0^Q [xp + (Q-x)c_3] f(x)\,dx + \int_Q^\infty [pQ - g_2(x-Q)] f(x)\,dx. \tag{3}$$

In order to determine the optimal order/production quantity, Q_T^*, we differentiate $\mathrm{EP}_T(Q)$ with respect to Q and set this amount equal to 0. This gives

$$0 = -c + c_3 F(Q_T^*) + p[1 - F(Q_T^*)] + g_2[1 - F(Q_T^*)] \quad \text{or} \tag{4}$$

$$F(Q_T^*) = \frac{p + g_2 - c}{p + g_2 - c_3} \tag{5}$$

This is a global maximum, since from (1),

$$\frac{\partial^2 \mathrm{EP}_T(Q)}{\partial Q^2} = -f(Q)[p + g_2 - c_3] \le 0$$

(with strict inequality holding if $f(Q) \neq 0$).

Next, consider a hierarchical situation in which the retailer determines the order quantity to purchase from the manufacturer. The retailer's expected profit, $\mathrm{EP}_R(Q)$, will be given by the formula:

$$\begin{aligned}\mathrm{EP}_R(Q) &= -Qc_1 + \int_0^{(1-R)Q} [xp + RQc_2 + ((1-R)Q - x)c_3] f(x)\,dx \\ &\quad + \int_{(1-R)Q}^{Q} [xp + (Q-x)c_2] f(x)\,dx \\ &\quad + \int_Q^\infty [pQ - (x-Q)g] f(x)\,dx.\end{aligned} \tag{6}$$

To find the optimal order quantity for the retailer, Q^*, one solves for $\partial \mathrm{EP}_R(Q)/\partial Q = 0$ giving,

$$\begin{aligned}0 &= -c_1 + p + g - F(Q^*)[p + g - c_2] \\ &\quad - F((1-R)Q^*)[(1-R)(c_2 - c_3)].\end{aligned} \tag{7}$$

This again is a global maximum as

$$\begin{aligned}\frac{\partial^2 \mathrm{EP}_R(Q)}{\partial Q^2} &= -f(Q)(p + g - c_2) \\ &\quad - (1-R)^2 f(Q)(c_2 - c_3) \le 0\end{aligned}$$

from (1) and (2). In this case, the manufacturer's expected profit will be

$$\begin{aligned}\mathrm{EP}_M(Q^*) &= Q^*(c_1 - c) - \int_0^{(1-R)Q^*} RQ^*(c_2 - c_3) f(x)\,dx \\ &\quad - \int_{(1-R)Q^*}^{Q^*} [(Q^* - x)(c_2 - c_3)] f(x)\,dx \\ &\quad - \int_{Q^*}^\infty (x - Q^*) g_1 f(x)\,dx.\end{aligned} \tag{8}$$

The independent retailer will order an amount Q^*, which satisfies Equation (7), as this will maximize his profits. If, however, the manufacturer wishes the retailer to order an amount which maximizes total channel profits, then Q^* should be chosen to equal Q_T^* as defined by Equation (5) and

$$F(Q^*) = \frac{(p + g_2 - c)}{(p + g_2 - c_3)}. \tag{9}$$

Substituting (9) into (7) gives

$$\begin{aligned}0 &= (c_1 - p - g) + \frac{(p + g_2 - c)(p + g - c_2)}{(p + g_2 - c_3)} \\ &\quad + F((1-R)Q^*)[(1-R)(c_2 - c_3)]\end{aligned} \tag{10}$$

where Q^* is determined by (9) above.

Therefore, if the manufacturer chooses c_1, c_2, and R so that Equation (10) is satisfied, the independent retailer should order the same quantity from the manufacturer as would the manufacturer if operating a company store. This results in maximum total profits to the retailer and manufacturer, and the channel is said to be coordinated. As there is no unique solution to Equation (10), however, different values for c_1, c_2, and R will result in different divisions of expected profit between the manufacturer and retailer. These are given by Equations (6) and (8). In effect, therefore, the manufacturer's pricing and return policy will function as a risk sharing agreement between manufacturer and retailer.

Implications

Using these results the following two theorems can be proved (proofs of all theorems are contained in the appendix).

Theorem 1. *The policy of a manufacturer allowing unlimited returns for full credit is system suboptimal.*

Theorem 2. *The policy of a manufacturer allowing no returns is system suboptimal.*

Theorems 1 and 2 show that if the manufacturer allows the retailer to make unlimited returns for full credit or does not allow the retailer to make any returns at all, it is impossible to achieve channel coordination. If partial returns are permitted (i.e. 0 <

$R < 1$) then Equations (9) and (10) can be used to determine a system optimal pricing policy and Equations (6) and (8) will give the expected profits to the retailer and manufacturer from such a policy. When full returns are permitted for partial credit (i.e., $c_2 < c_1$ and $R = 1$) the following theorem can be proved.

Theorem 3. *A policy which allows for unlimited returns at partial credit will be system optimal for appropriately chosen values of c_1 and c_2.*

In this case the following relationship for c_1 and c_2 must hold in order to achieve channel coordination:

$$c_1 = (p+g) - \frac{(p+g_2-c)(p+g-c_2)}{(p+g_2-c_3)}. \tag{11}$$

If c_1 and c_2 are so chosen and the manufacturer allows for unlimited returns, then the total expected profit and the expected profit for the retailer and manufacturer are as follows:

$$EP_T(Q^*) = (p-c_3)\mu - (p+g_2-c_3)\int_{Q^*}^{\infty} xf(x)\,dx, \tag{12}$$

$$EP_R(Q^*) = (p-c_2)\mu - (p+g-c_2)\int_{Q^*}^{\infty} xf(x)\,dx, \text{ and} \tag{13}$$

$$EP_M(Q^*) = (c_2-c_3)\mu - (g_1+c_2-c_3)\int_{Q^*}^{\infty} xf(x)\,dx, \tag{14}$$

where Q^* is defined by (5) and $\mu = \int_0^{\infty} xf(x)\,dx$. If the demand for the commodity follows a normal distribution ($x \sim N(\mu, \sigma)$) then (12), (13), and (14) become

$$EP_T(Q^*) = (p-c)\mu - \sigma(p+g_2-c_3)\phi\left(\frac{Q^*-\mu}{\sigma}\right), \tag{15}$$

$$EP_R(Q^*) = (p-c_1)\mu - \sigma(p+g-c_2)\phi\left(\frac{Q^*-\mu}{\sigma}\right), \tag{16}$$

$$EP_M(Q^*) = (c_1-c)\mu - \sigma(g_1+c_2-c_3)\phi\left(\frac{Q^*-\mu}{\sigma}\right), \tag{17}$$

where $\phi(z) = \exp(-z^2/2)/\sqrt{2\pi}$ and Q^* is defined by (9).

Note that if c_1 is chosen at the low end of its feasible range (i.e., $c_1 = c + \epsilon$), then the manufacturer will not make any of the system profit (and will even incur some loss). Total gain will accrue to the retailer. Similarly, if c_1 is chosen at the high end of its feasible region (i.e., $c_1 = p - \epsilon$), then the manufacturer will accrue all of the system profit and the retailer will incur a loss.

Looking at the rate of change in expected profit to the retailer and manufacturer, while maintaining a system optimal solution and varying c_2, we find:

$$\frac{\partial c_1}{\partial c_2} = \frac{(p+g_2-c)}{(p+g_2-c_3)}, \tag{18}$$

$$\begin{aligned}\frac{\partial EP_R(Q^*)}{\partial c_2} &= \frac{-Q^*(p+g_2-c)}{(p+g_2-c_3)} + \int_0^{Q^*}(Q^*-x)f(x)\,dx \\ &= -\int_0^{Q^*} xf(x)\,dx, \quad \text{and}\end{aligned} \tag{19}$$

$$\begin{aligned}\frac{\partial EP_M(Q^*)}{\partial c_2} &= \frac{Q^*(p+g_2-c)}{(p+g_2-c_3)} - \int_0^{Q^*}(Q^*-x)f(x)\,dx \\ &= \int_0^{Q^*} xf(x)\,dx.\end{aligned} \tag{20}$$

While these results may seem counterintuitive, they are due to the fact that as c_2 increases, c_1 must also increase, thus reducing the expected profit for the retailer while increasing that of the manufacturer.

One important aspect of achieving channel coordination is determining which of the parties, retailer or manufacturer, should benefit from the coordination. As Jeuland and Shugan state for the model they considered "neither the retailer nor the manufacturer would be willing to accept less after coordination were achieved than before it were achieved."

In our model, while it is assumed the manufacturer controls the channel, such an implementation contraint also seems reasonable. In fact, we recommend that the pricing be set so that the average retail establishment captures at least some portion of the gain from channel coordination for the following two reasons:

(1) If it can be demonstrated to the retailers that their profits will improve as a result of price changes, then they should be more willing to accept the new pricing plan.

(2) Increasing the retailers' profits should result in additional distribution outlets being opened, thus resulting in an increase in overall demand.

Unfortunately, if the manufacturer desires to have a uniform pricing policy for all retailers, the resulting impact on retailer profitability will not be consistent. That is, while on average a policy can be set so that retailers' expected profits increase, there may in fact be some retailers whose expected profits decrease as a result of implementing a channel coordinated pricing policy. As shown by Equation (13), demand variability is the key factor in determining the impact of a coordinated pricing system on the retailers' expected profits. Hence, one possible consequence of coordination may be that some retailers will decide to no longer carry the product, while still others may find the pricing attractive and begin to offer it. Of course, if the pricing policy is set uniquely for each retailer, the manufacturer can always ensure that channel coordination will not negatively impact a retailer's expected profit. Unfortunately such actions may not be defendable under the Robinson-Patman Act.

Another important issue with implementing a uniform pricing policy concerns the retailers' goodwill costs, which as shown by Equation (11), affect the manufacturer's pricing policy. These costs are not only usually difficult to quantify, but also may vary among different retailers. Hence, a uniform pricing policy would not be coordinated for those retailers' whose goodwill costs vary significantly from that assumed by the manufacturer. Fortunately, an investigation of Equation (7) shows that when $R = 0$ the retailer's order quantity is relatively insensitive to small changes in goodwill cost. Therefore, retailers will generally act in close to a coordinated fashion.

For a new product, where a manufacturer wishes to develop a pricing policy which achieves channel coordination, a reasonable strategy would be to set the product's wholesale price and return credit at that level which enables retailers to earn a desirable enough return to induce them to carry the product. As Warshaw (1962) notes

> The area of pricing is of special importance in the appraisal by a manufacturer of his marketing program. ...Manufacturer pricing policy, therefore, not only has an effect on the wholesaler's ability to perform the selling function but also influences the wholesaler's willingness to allocate selling effort on a selective basis.

The manufacturer's only concern in this case would be to ensure that he himself earns a reasonable rate of return from such a policy.

Examples

The following examples may serve to illustrate these concepts.

Consider a product with a net retail price of \$8.00, a manufacturing cost of \$3.00, and a salvage value of \$1.00. Assume a goodwill cost due to stockouts of \$3.00 for the retailer and \$2.00 for the manufacturer.

Suppose the manufacturer's current policy is to charge the retailer \$4.00 for the item and not permit returns of unsold goods. In the context of our model we have

$$c = 3, \quad c_1 = 4, \quad c_3 = 1, \quad p = 8, \quad g = 3,$$
$$g_1 = 2, \quad g_2 = 5, \quad \text{and} \quad R = 0.$$

If demand at the retail level $\sim N(200, 50)$ and the retailer is a profit maximizer, then $Q^* = 226$ and

$$\mathrm{EP}_R(Q^*) = \$626.25, \qquad \mathrm{EP}_M(Q^*) = \$206.85.$$

From Theorem 2 above we know that such a pricing policy is not channel coordinated. If the manufacturer wishes to achieve channel coordination by allowing for unlimited returns, then from Equation (9) $Q^* = 249$. If he wishes to give all of the expected gain from such coordination to the retailer, then he would set

$$c_1 = \$4.28 \quad \text{and} \quad c_2 = \$2.936 \quad \text{and}$$
$$\mathrm{EP}_R(Q^*) = \$643.51, \qquad \mathrm{EP}_M(Q^*) = \$206.95.$$

Alternatively, if the manufacturer wishes to keep all of the expected gain from channel coordination, he would set

$$c_1 = \$4.37 \quad \text{and} \quad c_2 = \$3.044 \quad \text{and}$$
$$\mathrm{EP}_R(Q^*) = \$626.86, \qquad \mathrm{EP}_M(Q^*) = \$223.61.$$

One middle road strategy, in which both manufacturer and retailer benefit from coordination, would be to let

$$c_1 = \$4.32 \quad \text{and} \quad c_2 = \$2.984 \quad \text{and}$$
$$\mathrm{EP}_R(Q^*) = \$636.11, \qquad \mathrm{EP}_M(Q^*) = \$214.35.$$

Suppose this is the policy selected by the manufacturer. Now consider a second retailer for which the demand $\sim N(200, 10)$. Before channel coordination ($c_1 = 4, R = 0$) this profit-maximizing retailer would order $Q^* = 205$ and

$$\mathrm{EP}_R(Q^*) = \$765.25, \qquad \mathrm{EP}_M(Q^*) = \$201.05.$$

If the manufacturer changes the pricing policy to achieve channel coordination by selecting $c_1 = \$4.32$ and $c_2 = \$2.984$ then $Q^* = 210$ and

$$\mathrm{EP}_R(Q^*) = \$716.02, \qquad \mathrm{EP}_M(Q^*) = \$254.07.$$

Hence, while channel coordination still results in total expected channel profits increasing, this retailer's expected profit has actually decreased as a result of the coordination.

Now consider a retailer for which demand $\sim N(200, 50)$, but whose goodwill cost due to stockout is not \$3.00. If the manufacturer had assumed a \$3.00 goodwill cost we see, from above, that letting $c_1 = \$4.32$ and $c_2 = \$2.984$ achieves channel coordination with the retailer ordering $Q^* = 248$. If the retailer's goodwill cost was actually \$4.00, then the retailer should order 252 of the item. Alternatively, if the retailer's goodwill cost was \$1.00, then the order quantity should be 246. Hence, one can see that small changes in retailer goodwill costs will not severely impact channel coordination, and the amount the retailer will order will be close to the coordinated amount.

Conclusion

This paper has shown it is possible for a manufacturer to set a pricing and return policy which will ensure channel coordination. This can be accomplished by the manufacturer choosing the selling price charged to the retailer and the return credit offered to the retailer in accordance with formulae listed in the paper.

In the case where the manufacturer only allows for partial returns, the optimal values for the selling price to the retailer and the return credit offered on the item will both be functions of the individual retailer's demand. Hence, fixed price/return policies which allow for partial returns cannot be optimal in a multi-retailer environment in which retailers have different demand distributions.

If the manufacturer adopts a policy in which unlimited returns are permitted for partial credit, optimal values for the selling price charged to the retailer and return credit offered to the retailer can be determined independent of the retailer's demand distribution. In this case a range of optimal value pairs for the selling price charged to the retailer and return credit can be determined solely as a function of the manufacturing cost, retail sales price, salvage value, and goodwill costs. Choosing different optimal selling price and return credit pairs, however, results in different profit divisions between manufacturer and retailer. Hence, if the goodwill cost of a stockout is approximately the same for all retailers, the manufacturer can be assured that each retailer will order in a nearly system-optimal fashion. The only concern would be that as a result of channel coordination some retailers may incur a decrease in expected profit and choose not to carry the item.

As a manufacturer will normally sell his product not just to one, but to several retailers (or distributors), one can conclude that the only pricing/return strategy worthy of adoption for short-lived commodities is one in which full returns are permitted for partial credit.

Appendix. Proof of Theorems

Proof of Theorem 1. If $R=1$, then from (10),

$$(p+g-c_1)=\frac{(p+g_2-c)(p+g-c_2)}{(p+g_2-c_3)}.$$

If $c_1=c_2$, then (10) is equivalent to

$$1=\frac{(p+g_2-c)}{(p+g_2-c_3)}.$$

However, this gives a contradiction since $c_3<c$. Q.E.D.

Proof of Theorem 2. If $R=0$, then from (9) and (10),

$$0=c_1-p-g+\frac{(p+g_2-c)(p+g-c_3)}{(p+g_2-c_3)},$$

which is equivalent to

$$c_1=c-\frac{g_1(c-c_3)}{(p+g_2-c_3)}.$$

However, this gives a contradiction since $c>c_3$ and $c_1>c$. Q.E.D.

Proof of Theorem 3. In this case we have Equation (11),

$$c_1=(p+g)-\frac{(p+g_2-c)(p+g-c_2)}{(p+g_2-c_3)}.$$

To prove the theorem it must be shown that if c_1 is chosen such that $c<c_1<p$, then a c_2 can be found satisfying (11) such that $c_3<c_2<c_1$.

To show $c_2<c_1$, note that since $c_3<c$,

$$\frac{p+g_2-c}{p+g_2-c_3}<1 \quad\text{and}\quad c_1=(p+g)-\frac{(p+g_2-c)}{(p+g_2-c_3)}(p+g-c_2)>c_2.$$

To show $c_3<c_2$, note that since $c<c_1$, from (11)

$$c<p+g-\frac{(p+g_2-c)(p+g-c_2)}{(p+g_2-c_3)}.$$

This is equivalent to

$$(p+g_2-c_3)>\frac{(p+g_2-c)}{(p+g-c)}(p+g-c_2)\geq(p+g-c_2),$$

implying $c_3<c_2$. Q.E.D.

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