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Optimal contract strategies for two stage supply chain

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ABSTRACT

The present article investigates the issue of channel coordination of a manufacturer and a retailer facing stochastic demand that is sensitive to promotional effort. In newsvendor setting, the return policy, sharing contract on promotional effort, and discount on whole sales price provided by the manufacturer have been shown to be able to align incentives of the members of the chain. An analytical method has been provided to determine the optimal contract parameters of the channel. Numerical examples are also illustrated to justify the model.

1. Introduction

Coordination among the members of a supply chain is an essential strategic issue. In supply chain coordination, i.e., in contract system, the upstream member offers a set of appropriate contract (with negotiation) parameters to the downstream member such that they enrich nearer to their expected target profits. In decentralized supply chain, there exist many profit margins in which each member does not bother the margin of the entire supply chain when making a decision. A proper coordination contract overcomes the problem of decentralized supply chain. Among other strategies, return/buyback policy, sharing of promotional effort and cash discount on sales prices are well-explored factors of a contract to achieve the target of the members of the chain.

Return/buyback policy is widely used in industries such as fashion, apparel, books, computers, toys, etc. Quite often, the demand of the end customers is uncertain in nature. Consequently, the retailer has to face the overstocking or under stocking of the inventory. Return policy mitigates the risk of overstocking faced by the retailer.

Promotional effort is another important strategy to enhance the demand of the goods in a market. A retailer can increase the demand of the goods by applying promotional effort such as advertising, sales team, gift, discount on sales price, attractive shelf space, etc. All of these efforts are costly. In centralized supply chain, the costs related to the promotional effort are shared by the members of the chain.

Incorporating the above factors, a single period with one manufacturer and one retailer production–inventory model is investigated. The manufacturer is responsible for contract parameters before the production season. The manufacturer produces goods and delivers to the retailer before the selling season. The expected profits of both the members are formulated by trading off sales revenues, cost for promotional effort and discount on sales price. Then, it is analyzed in the light of centralized and decentralized systems.

The rest of the paper is organised as follows: Section 2 provides literature review of the works in this direction, Section 3 contains the notations of the parameters and variables, Section 4 formulated the model, Section 5 illustrates numerical examples, and Section 6 concludes the proposed work.

2. Brief review of the literature

Many researchers and practitioners have given more attention on coordination of the supply chain in the past decade. According to the researchers (Cachon, 2003; Li et al., 2009; Ru and Wang, 2010), in a single chain with perfect competing retailers, a vertically collaborating supply chain maximize the profit of the chain. Wang (2004) developed a generalized newsvendor model to analyze the coordination between the manufacturer and the buyer. Xiao et al. (2010) determined an optimal order quantity, whole sale price and lead time-decisions, by game theoretic approach for a three stage supply consisting of one retailer, one manufacturer and one subcontractor. Sana (2011a, 2012) presented and integrated production–inventory model for deterministic demand in a three layer supply chain. Taleizadeh et al. (2012) developed an inventory model for multiple buyer and single vendor when demand followed uniform distribution and lead time was dependent on lot size. Several researchers have investigated inventory model related with supply chain system; some of them are Cárdenas-Barrón et al., 2011, 2012a, 2012b, 2012c; Chen et al., 2005; He et al., 2009; Krishnan et al., 2004; Kurata and Liu, 2007; Li and Wang, 2007; Sarkar, in press.

In supply chain contract, many promotional strategies are applied to attract the customer to buy more. Generally, the promotional strategies include price cuts, free gifts, advertising, special services, discount on purchasing cost, etc. Krishnan et al. (2004) obtained the

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Table 1
Optimal values of sharing factor (B^*) and the profits of both the parties, when cash discount offered by the manufacturer is nil ($\delta=0$).

$\delta=0$	Example 1	Example 2	Example 3	Example 4
(Q_c,ρ)	(115.46,2.44)	(56.52,0.44)	(360.00,8.00)	(42.73,0.24)
B_{min}	0.0284	0.0040	0.9375	0.2796
B_{max}	0.1472	0.2769	0.9531	0.8202
B^*	0.0878	0.1405	0.9453	0.5499
π_R^B	443.54	261.32	475.00	201.25
π_M^B	163.54	141.32	325.00	116.25
π_R^{Target}	440.00	260.00	470.00	200.00
π_M^{Target}	160.00	140.00	320.00	115.00
$\Delta\pi_R^B$	3.54	1.32	5.00	1.25
$\Delta\pi_M^B$	3.54	1.32	5.00	1.25
π_c	607.08	402.64	800.00	317.50

optimal promotional effort to maximize the profit function. Szmerekovsky and Zhang (2009) found out optimal retail price and advertising level in two-layer supply chain where demand of the end customers depends on retail price and advertisement by a manufacturer and a retailer. In two-layer distribution channel, Xie and Wei (2009) and Xie and Neyret (2009) provided an optimal cooperative advertising strategies and equilibrium pricing in the channel.

Operations management and operations research literature is rich with articles focussed on uncertain demand. The sources of uncertainty are sometimes captured using risk models. Risk models capture the nature of uncertain demand with the use of probability distribution. The optimal economic order quantity (EOQ) of this problem is determined by balancing between the expected cost of overstocking and the expected cost of under stocking. Petruzzi and Dada (1999) provided an extension and comprehensive review of newsvendor problem in which stocking units and selling prices were obtained simultaneously. Zhang (2010) investigated the classical newsvendor model by considering the budget constraint and supplier quantity discount. Recently, Sana (2011b) provided a comprehensive review of newsvendor problem and extended the model considering the demand as a function of random sales price. In this direction, the works by Johansen and Thorstenson (1993), Chen and Chuang (2000), Chou and Chung (2009), Wang (2010) and Hsieh and Lu (2010) should be mentioned, among others.

3. The nomenclature

The following notations are used to develop the model.

Notation

ρ	promotional/advertisement effort
ρ_c	promotional/advertisement effort for the collaborating system
Q	the retailer's order quantity
Q_c	the retailer's order quantity for the collaborating system
v_1	per unit salvage value/return price of unsold goods of the manufacturer to the retailer
w	whole sale price per unit by the manufacturer to the retailer
w_1	whole sale price per unit by the manufacturer to the retailer when return/buyback policy is waived
r	selling price per unit of the retailer
c	purchasing/production cost of the manufacturer
$D(x,\rho)$	uncertain demand function determined by promotional effort ρ and random variable x
$f(x)$	probability density function (pdf) of x
$F(x)$	cumulative distribution function (cdf) of x
B	sharing cost $(0\leq B\leq 1)$ of expenditure for promotional effort by the retailer
δ	cash discount $(0\leq\delta\leq 1)$ on whole sale price (w) offered by the manufacturer
π_c	expected profit of the chain
π_R^C	expected profit of the retailer when the optimal strategy of the chain is followed by the retailer
π_M^C	expected profit of the manufacturer when the optimal strategy of the chain is followed by the manufacturer
π_R^B	individual expected profit of the retailer while B is the sharing of the promotional cost
π_M^B	individual expected profit of the manufacturer while $(1-B)$ is the sharing of the promotional cost
π_R^δ	individual expected profit of the retailer while discount on whole sale price is δ
π_M^δ	individual expected profit of the manufacturer while discount on whole sale price is δ
$\pi_R^{B,\delta}$	individual expected profit of the retailer while B is the sharing of the promotional cost and discount on whole sale price is δ
$\pi_R^{B,\delta}$	individual expected profit of the manufacturer while B is the sharing of the promotional cost and discount on whole sale price is δ
π_R^{Target}	target profit of the retailer
π_M^{Target}	target profit of the manufacturer

4. Formulation of the Model

In this model, one manufacturer and one retailer are considered as the members of the supply chain (SC). The retailer and the manufacturer are two risk-neutral firms those are controlled by a centralized decision maker. Consequently, the manufacturer and the retailer face same market. The retailer purchases Q lot size with whole sale price w from the manufacturer and the unsold items at retailer are buyback to the manufacturer at a salvage value v_1. The demand function is

$$D(x,\rho)=x*\gamma(\rho) \tag{1}$$

where '*' is addition or multiplication composition, x is a random variable that follows p.d.f. $f(x)$ and

$$\gamma(\rho)=\frac{\tau\rho}{1+\rho}=\tau\left(1-\frac{1}{1+\rho}\right). \tag{2}$$

Here, ρ is a decision variable (effort for promotional activities) and τ is a positive constant which is estimated from a previous data by any curve fitting method. $\gamma(\rho)$ is an increasing function of ρ because, $\dot{\gamma}(\rho)=\frac{\tau}{(1+\rho)^2}>0,\ \forall\rho\geq 0.$ $\gamma(0)=0$ when $\rho=0$ and $\lim_{\rho\to\infty}\gamma(\rho)\to\tau$ which is maximum. So, $\gamma(\rho)\in[0,\tau]\,\forall\tau\in[0,\infty)$.

Table 2
Optimal values of discount factor (δ^*) and the profits of both the parties, when sharing of the promotional cost by the manufacturer is nil ($B=1$).

$B=1$	Example 1	Example 2	Example 3	Example 4
(Q_c,ρ)	(115.46,2.44)	(56.52,0.44)	(360.00,8.00)	(42.73,0.24)
δ_{min}	0.0879	0.0602	0.0111	0.0552
δ_{max}	0.1002	0.0695	0.0222	0.0853
δ^*	0.0941	0.0648	0.0166	0.0702
π_R^B	443.54	271.32	470.00	213.12
π_M^B	163.54	131.32	330.00	103.12
π_R^{Target}	440.00	270.00	460.00	210.00
π_M^{Target}	160.00	130.00	320.00	100.00
$\Delta\pi_R^B$	3.54	1.32	10.00	3.12
$\Delta\pi_M^B$	3.54	1.32	10.00	3.12
π_c	607.08	402.64	800.00	316.23