International Journal of Supply and Operations Management

IJSOM

May 2020, Volume 7, Issue 2, pp. 129-138
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com

Determining Decision Variables for Manufacturer and Retailer in the Co-operative and Non-cooperative Environment: A Game Theory Approach

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Abstract
Several inventory models are proposed for manufacturer and retailer which include competition and cooperation between manufacturer and retailer to maximize their profits. Esmaeili M *et al.* (2009) developed the relationship between manufacturer and retailer for non-cooperative and cooperative games. But the model did not involve any shortage cost as no shortage was allowed. In this paper, the researcher considers market demand to be affected by marketing expenditure and price charged by retailer. This research allows shortages for the infinite planning horizon and investigates 1. The non-cooperative game for manufacturer-Stackelberg model allowing shortage when manufacturer is the leader and would like to maximize his profit, 2.retailer-stackelberg model when retailer is the leader and would like to maximize his profit, and 3.The co-operative game approach to obtain Pareto Efficient solution. The model is verified through some numerical examples.

Keywords: Manufacturer-Retailer; Cooperative and non-cooperative games; Game theory; Marketing expenditure; Shortage.

1. Introduction

In a competitive environment, it is expected of all manufacturers and retailers to manage inventory. In a global environment, boundaries are broken and companies are dealing almost all over the world. Manufacturing requires raw material from every corner of the world. The management has to manage inventory in a multi-echelon system. It is not only important for the manufacture but also for the retailer to manage inventory according to market demand. The sole purpose to maintain inventory is to provide service to the customer as prompt as possible and to maintain resources to maximize profit at each stage of the multi-echelon system. In this literature review, the term manufacturer represents the first stage, i.e. production of a product. The three-stage system, a manufacturer, retailer, and market is considered in this work. The retailer term represents a part of the system that works as a bridge between market and manufacture.

Several models were proposed earlier, using quantity discount by Viswanathan & Wang (2003), Corbett & de Groote (2000) and Chiang *et al.* (1994). A mathematical model was developed by Abad (1994) for manufacturer and retailer relationships to manage inventory. He considered demand as price sensitive and provided solutions for a model in a cooperative environment, where manufacturers and retailers work together to maximize their profit. Abad and Jaggi (2003) also developed the same model with change where manufacturers share profit with the retailer. Several works including Heuvel *et al.* (2007), Sucky (2005, 2006), Chan & Kingsman (2007), Dai and Qi (2007) developed models with fixed demand rate and determined decision variables lot size, economic order quantity for manufacturer and retailer and production cycle in cooperative environments.

While in some other work fixed market demand is avoided, combined decision variables like lot size and pricing decisions are considered to determine optimal order quantity and optimal price. In this work, demand is price sensitive. Lee *et al.* (1996), Kim & Lee (1998), Abad (1994), Lee (1993), Jung & Klein (2001, 2005) proposed models with the

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same approaches. In some other models, demand is also sensitive to price and marketing expenditure. Lee & Kim (1993, 1998), Freeland (1982), Sajadi *et al*. (2005) also considered the same approach where demand is influenced by marketing expenditure and prices. But all these models were developed in a non-cooperative environment.

In a global economy, marketing expenditure is also an important factor for maximizing profit. In a cooperative environment, it is better to share this expenditure between manufacturer and retailer. Huang & Li (2001) and Li *et al*. (2002) developed a model where both the manufacturer and retailer share marketing expenditure. They investigated the impact of brand image, marketing cost and sharing policy between manufacturer and retailer in a cooperative environment, where retailers and manufacture agree to share marketing expenditure. Yue *et al*. (2006) developed a model where the manufacturer offers some price discounts to customers. M.Esmaeili *et al.* (2008) investigated a seller-buyer relationship in reference to marketing expenditure in an environment where demand was sensitive to price and marketing expenditure. In most of the work, the shortage cost was ignored, which in fact has a real-life implication. In this paper, the researcher has developed a model in a three-stage system, and has supposed manufacturer represents production and makes the available product to the retailer, who then makes the available product to the customer. The market demand is sensitive to marketing expenditure and unit price.

The novel aspect of this work is that the shortages are allowed in the manufacturer's inventory model. The researcher has considered that before dealing directly with the market, retailer orders some quantities to the manufacturer but at the time of orders manufacturer has limited inventory whose level may be less than the economic order quantity (EOQ). Hence the shortage occurred on the side of the manufacturer. Having got the EOQ Retailer contacts to the market after the consumption of the entire quantity by the consumer, the retailer again contacts the manufacturer for the next order and this process continues. Section2 represents the assumptions and notations considered in the models. In Section 2, models for manufacturer and retailer are also developed. Section3 represents the non-cooperative Manufacturer-Stackelberg and Retailer-Stackelberg models. The cooperative model is discussed in Section4. Computational results and numerical verification of the model are discussed in Section 5. In Section 6 conclusions and suggestions for future work are discussed.

2. Assumptions and Notations for model formulation

Here the general models for manufacturers' and retailer's profit are developed to determine their decision variables.

2.1. Assumptions

Following assumptions are regarded for modeling

1. Deterministic parameters are considered.
2. The planning horizon is infinite.
3. Annual market demand is dependent on marketing expenditure and selling price charged by the retailer.
4. Shortages are permitted.
5. The production rate is infinite.
6. Retailers determine lot size.

2.2. Notations

In this section, all the notations are defined to develop an inventory model

2.2.1. Decision variables

q: Selling price charged by the manufacture to retailer
z: Inventory level of manufacturer
p: Selling price retailer charged to the customer
m: Marketing expenditure decided by the retailer
Q: Lot size (units) determined by the retailer

2.2.2. Input variables

k: Scaling constant for demand function ($k>0$)
α: Price elasticity of demand function ($\alpha>1$)
β: Marketing expenditure elasticity of demand ($\beta+1<\alpha$)
A_b: Ordering cost of the retailer
A_s: Set up the cost of manufacturer
H_s: Holding cost of manufacturer
S: Shortage cost of the manufacturer (unit/time)
C_s: Production cost for manufacturer including purchase cost ($/unit)
i: Percentage inventory carrying charge per unit per year for Retailer
d: demand rate (units/time)
D: Yearly market demand
Since demand is assumed sensitive to marketing expenditure and unit price, so according to Lee and Kim (1993) D can be written as

$D=kp^{-\alpha}m^{\beta}$ (1)

2.3. General model formulation:

2.3.1. The inventory model for the manufacturer:

Here the researcher finds the decision variables of price q and inventory level z for the manufacturer so that he can maximize his profit. The researcher considers the model proposed by Mir Bahadur *et al.* (2008) with the addition of shortage cost and considering that Q is not the decision variable of the manufacturer. Manufacturer's profit model will be given by

Manufacturers annual profit (Π_s) =Total sales revenue -Production cost - Setup cost - Holding cost – Shortage cost

Or mathematically it can be expressed as

$$\Pi s = qD - C_s D - A_s \frac{D}{Q} - 0.5z H_s \frac{z}{d}\frac{D}{Q} - 0.5(Q-z)\frac{(Q-z)}{d}\frac{D}{Q}S \quad (2)$$

Here annual holding and shortage costs are determined by multiplying the number of orders by the costs for one order period. With the help of the first-order condition of maximization, we obtain z that maximizes the profit of manufacturer for a fixed q

$$z = \frac{QS}{S + H_s} \quad (3)$$

For zero profit, Π_S=0 gives:

$$q0 = \left(C_s + \frac{A_s}{Q} + 0.5z^2 H_s \frac{1}{d}\frac{1}{Q} + 0.5(Q-z)^2 \frac{1}{d}\frac{1}{Q} S \right) \quad (4)$$

Since (2) is an increasing linear function of q, the optimal q occurs at the highest price that is possible for the manufacturer to charge the Retailer.

$$q = Rq_0 \quad q = R\left(C_s + \frac{A_s}{Q} + 0.5z^2 H_s \frac{1}{d}\frac{1}{Q} + 0.5(Q-z)^2 \frac{1}{d}\frac{1}{Q} S \right), \quad (5)$$

for some R >1.

2.3.2. Retailer's model formulation:

Here researcher finds the decision variables including lot size Q, marketing expenditure m, unit price p for a retailer. We consider the model to be similar to Mir Bahadur *et al.* (2008) where p and m together with Q are the decision variables of the retailer while in the paper of Mir Bahadur (2008) Q was decision variable of the manufacturer. Therefore, the retailer's annual profit is given by Retailer's profit(Π_b)= Total sales revenue - purchase cost - Market cost- Ordering cost- Holding cost Or mathematically it can be represented by

$$\Pi_b = pD - qD - mD - A_b . \frac{D}{Q} - 0.5iqQ$$

By putting the value of $D=kp^{-\alpha}m^{\beta}$ from equation (1) we get:

$$\Pi b = kp^{-\alpha+1}m^{\beta} - qkp^{-\alpha}m^{\beta} - kp^{-\alpha}m^{\beta+1} - A_b \frac{kp^{-\alpha}m^{\beta}}{Q} - 0.5iqQ \quad (6)$$

Using first-order conditions with respect to p, m, and Q to maximize the profit of the retailer

$$\frac{\partial \Pi_b}{\partial p} = 0, \quad \frac{\partial \Pi_b}{\partial m} = 0, \quad \frac{\partial \Pi_b}{\partial Q} = 0$$

which gives

$$p = \frac{\alpha\left(q + m + A_b Q^{-1}\right)}{\left(\alpha - 1\right)} \quad \text{(a)}$$

And

$$m = \frac{\beta\left(q - p + A_b Q^{-1}\right)}{\left(\beta + 1\right)} \quad \text{(b)}$$

$$Q = \sqrt{\frac{2 A_b D}{iq}} \quad (7)$$

Solving equations (a) and (b) simultaneously for p and m we get-

$$p = \frac{\alpha\left(q + A_b\, Q^{-1}\right)}{(\alpha-\beta-1)} \tag{8}$$

$$m = \frac{\beta(q + A_b\, Q^{-1})}{(\alpha-\beta-1)} \tag{9}$$

3. Non-cooperative model

In the non-cooperative model, one player is given preference so he is known as the leader and the second player is known as a follower. The leader can enforce his strategies on the follower. In Stackelberg's scenario, the leader always wants to maximize his profit and does not think about the follower.

3.1. The manufacturer-Stackelberg model

In the Manufacturer-Stackelberg model, the manufacturer is the leader and the retailer acts as a follower. The manufacturer would like to maximize his profit according to the constraints of retailers [Mir Bahadur (2008)] and [Abad and Jaggi (2003)]. Thus the problem reduces to

Maximize

$$\Pi s = qD - C_s\, D - A_s\, \frac{D}{Q} - 0.5z\, H_s\, \frac{z}{d}\frac{D}{Q} - 0.5(Q-z)\frac{(Q-z)}{d}\frac{D}{Q}S \tag{10}$$

s.t.

$$p = \frac{\alpha(q + A_b\, Q^{-1})}{(\alpha-\beta-1)} \tag{11}$$

$$m = \frac{\beta(q + A_b\, Q^{-1})}{(\alpha-\beta-1)} \tag{12}$$

$$Q = \sqrt{\frac{2\, A_b\, D}{iq}} \tag{13}$$

3.2. Retailer-Stackelberg model

Most works on supply-chain management studied the Manufacturer-Stackelberg model. But power can also be shifted from manufacturer to retailer according to Mir Bahadur *et al.* (2008). So in Retailer-Stackelberg model retailer works as the leader and manufacturer as a follower. The retailer then would like to maximize his profit according to constraints of the manufacturer, and the model reduces to-

Maximize

$$\Pi b = kp^{-\alpha+1}m^{\beta} - qkp^{-\alpha}m^{\beta} - kp^{-\alpha}m^{\beta+1} - A_b\, \frac{kp^{-\alpha}m^{\beta}}{Q} - 0.5iqQ \tag{14}$$

s.t.

$$z = \frac{QS}{S + H_s} \tag{15}$$

$$q = R\left(C_s + \frac{A_s}{Q} + 0.5z^2\, H_s\, \frac{1}{d}\frac{1}{Q} + 0.5(Q-z)^2\frac{1}{d}\frac{1}{Q}S\right) \tag{16}$$

for some R >1.

4. Cooperative model

In the modern competitive environment, manufacturer and retailers both want to increase their profit. If the loss occurs to one player, it also will be a loss of the second player. It is also necessary for manufacture and retailer to cooperate to fight with rivalry companies. If both parties work cooperatively, both can increase their profit. Using a cooperative approach, both work together to determine decision variables. The researcher will apply the Pareto efficiency approach to find decision variables so that both can increase their profit.

Maximizing [Abad & Jaggi (2003)].

$\Pi = \lambda\Pi s + (1-\lambda)\Pi b$ $\quad\quad$ $0<\lambda<1$

i.e.

$$\Pi = \lambda\left[qD - C_s\, D - A_s\, \frac{D}{Q} - 0.5z\, H_s\, \frac{z}{d}\frac{D}{Q} - 0.5(Q-z)\frac{(Q-z)}{d}\frac{D}{Q}S\right] + (1-\lambda)\left[pD - qD - mD - A_b\, \frac{D}{Q} - 0.5iqQ\right]$$

Or

$$\Pi = qD(2\lambda - 1) + D(p - m - AbQ^{-1}) + \lambda D(m - p - C_s - A_s Q^{-1} + A_b Q^{-1} - 0.5 H_s z^2 d^{-1} Q^{-1} - 0.5S(Q-z)^2 d^{-1} Q^{-1} + 0.5iqQ(\lambda - 1) \quad (17)$$

The first-order condition for maximizing Π with respect to q yields

$$\frac{\partial \Pi}{\partial q} = 0$$

$$\lambda = \frac{(D + 0.5iQ)}{(2D + 0.5iQ)} \quad (18)$$

which gives λ lying between 0 and 1 as is desired.

First-order conditions with respect to z, Q, p and m further yield

$$\frac{\partial \Pi}{\partial z} = 0, \frac{\partial \Pi}{\partial Q} = 0, \frac{\partial \Pi}{\partial p} = 0, \frac{\partial \Pi}{\partial m} = 0$$

$$z = \frac{QS}{S + H_s} \quad (19)$$

$$Q = \sqrt{\frac{D\left[2\lambda d A_s + 2d A_b (1-\lambda) + \lambda z^2 (S + H_s)\right]}{[iqd(1-\lambda) + \lambda DS]}} \quad (20)$$

$$p = \frac{\alpha\left\{q(2\lambda-1) - m - A_b Q^{-1}(\lambda-1) + \lambda m - \lambda C_s - \lambda A_s Q^{-1} - 0.5\lambda H_s z^2 d^{-1} Q^{-1} - 0.5\lambda S(Q-z)^2 d^{-1} Q^{-1}\right\}}{(\lambda-1)(\alpha-1)} \quad \text{(c)}$$

$$m = \frac{\beta\left\{-q(2\lambda-1) - p - A_b Q^{-1}(\lambda-1) + \lambda p + \lambda C_s + \lambda A_s Q^{-1} + 0.5\lambda H_s z^2 d^{-1} Q^{-1} + 0.5\lambda S(Q-z)^2 d^{-1} Q^{-1}\right\}}{(\lambda-1)(\beta+1)} \quad \text{(d)}$$

Solving equations (c) and (d) simultaneously for p and m we get

$$p = \frac{\alpha\left\{q(2\lambda-1) + A_b Q^{-1}(\lambda-1) - \lambda C_s - \lambda A_s Q^{-1} - 0.5\lambda H_s z^2 d^{-1} Q^{-1} - 0.5\lambda S(Q-z)^2 d^{-1} Q^{-1}\right\}}{(\lambda-1)(\alpha-\beta-1)} \quad (21)$$

$$m = \frac{\beta\left\{q(2\lambda-1) + A_b Q^{-1}(\lambda-1) - \lambda C_s - \lambda A_s Q^{-1} - 0.5\lambda H_s z^2 d^{-1} Q^{-1} - 0.5\lambda S(Q-z)^2 d^{-1} Q^{-1}\right\}}{(\lambda-1)(\alpha-\beta-1)} \quad (22)$$

Manufacturer and retailer can fix q in the cooperative model and d equations (18), (19), (20), (21) and (22) are solved simultaneously to obtain optimum values λ^*, z^*, Q^*, P^*, and m^* for a fixed q.

5. Computational results

Numerical examples are considered in this section to verify the mathematical model. The following examples give the results for Manufacturer-Stackelberg, Retailer-Stackelberg and cooperative models. We can solve all the examples by using LINGO software. In all of the following examples we consider data of Esmaeili M et al. (2009).

k=3500, A_b=20\$ A_s=80\$, C_s=1.5\$, H_s=0.15\$, S=.5\$, i=10%, R=1.1, d=10, α=2.0, β=0.15.

5.1. Example1 The Manufacturer-Stackelberg model: The Manufacturer-Stackelberg model produces the following optimal values:

q=4.96\$, Q=41.35, z=31.81, p=12.8\$, m=0.96\$, D=21.23 , Π_s= 27.31\$, Π_b=125.55\$.

5.2. Example2 The Retailer-Stackelberg model: The Retailer-Stackelberg model gives the following optimal values

p=7.84\$, m=0.588\$, q=3.1499\$, Q=108.19, z=83.22, D=52.58, Π_s =15.05\$, Π_b=188.93\$.

From these two examples, we find that marketing expenditure m, as well as the manufacturer's selling price q, are less in the Retailer-Stackelberg model in comparison to the Manufacturer-Stackelberg model. Besides, selling price charged by the retailer p is reduced more in the Retailer-Stackelberg model than in the Manufacturer-Stackelberg model. We can also see that the retailer is in a much stronger position in the Retailer-Stackelberg model in comparison to the Manufacturer-Stackelberg model. Annual demand is also greater in the Retailer-Stackelberg model than in the Manufacturer-Stackelberg model, and this is due to lower selling price charged by the retailer to the consumer. Also, the manufacturer is a follower in this model so he prefers more lot size and inventory level.

5.3. Example3: The cooperative model: In this section, we consider a condition where manufacturers and retailers agree to work together, so a Pareto efficient solution will be obtained by assuming that manufacturer and retailer have negotiated an agreement on manufacturer price q=3\$. Equations (19), (20), (21) (22) are used to solve z, Q, p, m, and λ is obtained using (18).The cooperative model gives the following optimal values of decision variables

p=5.93\$, m=0.445\$, q=3\$, Q=61.30, z=47.15, D=88.14, Π =81.99\$.

From the above examples, we can see that the manufacturer's profit is more in a cooperative model in comparison to the non-cooperative model. So the cooperative model will be preferred by the manufacturer. But retailer's profit is less in a cooperative model so the retailer would like to go for a non-cooperative model.

5.4. Sensitivity Analysis:

In this section, the researcher investigates the effects of different values of parameters α and β on p, m, q, Q and z with the same parametric values as considered in Chan et. al (2007). Results are summarized in Tables 1-6 for both non-cooperative and cooperative models.

Table 1. Sensitivity analysis of the Manufacturer-Stackelberg model with respect to α when β (0.15) is fixed

α	**2.0**	**2.2**	**2.3**	**2.4**	**2.5**
p	12.8	10.5	9.72	9.11	8.64
m	0.96	0.715	0.634	0.569	0.518
q	4.96	4.52	4.36	4.23	4.13
Q	41.35	40.84	40.01	38.85	37.4
Z	31.81	31.42	30.77	29.89	28.77
D	21.23	18.84	17.47	16.01	14.45
Π_S	27.31	15.55	11.01	7.15	3.97

Table 2. Sensitivity analysis of the Manufacturer-Stackelberg model with respect β when α (1.8) is fixed

β	**0.07**	**0.09**	**0.11**	**0.13**	**0.15**
p	14.31	14.92	15.57	16.293	17.06
m	0.556	0.746	0.952	1.176	1.422
q	5.366	5.43	5.5	5.577	5.66
Q	45.62	44	42.49	41.07	39.72
Z	35.09	33.84	32.68	31.59	30.56
D	27.93	26.29	24.86	23.52	22.35
Π_S	51.64	48.85	46.55	44.52	42.85

Table 3. Sensitivity analysis of the Retailer-Stackelberg model with respect to α when β (0.15) is fixed

β	**0.07**	**0.09**	**0.11**	**0.13**	**0.15**
p	14.31	14.92	15.57	16.293	17.06
m	0.556	0.746	0.952	1.176	1.422
q	5.366	5.43	5.5	5.577	5.66
Q	45.62	44	42.49	41.07	39.72
Z	35.09	33.84	32.68	31.59	30.56
D	27.93	26.29	24.86	23.52	22.35
Π_S	51.64	48.85	46.55	44.52	42.85

Table 4. Sensitivity analysis of the Retailer-Stackelberg model with respect β when α (1.8) is fixed

β	**0.07**	**0.09**	**0.11**	**0.13**	**0.15**
p	8.19	8.42	8.675	8.93	9.21
m	0.318	0.421	0.53	0.645	0.768
q	3.14	3.146	3.1466	3.147	3.1474
Q	113.05	112.39	111.78	111.2	110.66
Z	86.96	86.45	85.98	85.54	85.12
D	73.33	69.93	66.81	64.23	61.83
Π_b	316.31	309.26	304.42	300.99	298.77

Table 5. Sensitivity analysis of the Cooperative model with respect to α when β (0.15) is fixed

α	**2.0**	**2.2**	**2.3**	**2.4**	**2.5**
p	5.93	8.24	9.66	11.43	13.95
m	0.445	0.562	0.63	0.714	0.837

q	3	3	3	3	3

Table 6. Continued

α	2.0	2.2	2.3	2.4	2.5
Q	61.3	58.41	55.8	52.08	47.01
Z	47.15	44.93	42.92	40.06	36.16
λ	0.508	0.522	0.5365	0.559	0.6
D	88.14	31	17.72	9.61	4.68
Π	81.99	56.73	40.32	25.82	14.01

Table 7. Sensitivity analysis of the Cooperative model with respect β when α (1.8) is fixed

β	0.07	0.09	0.11	0.13	0.15
p	4.55	4.42	4.3	4.17	4.05
m	0.177	0.221	0.262	0.301	0.337
q	3	3	3	3	3
Q	62.36	62.39	62.42	62.46	62.49
Z	47.97	47.99	48.01	48.04	48.07
λ	0.5038	0.50368	0.5035	0.5033	0.5032
D	202.77	210.52	218.69	229.1	239.76
Π	86.66	72.06	57.65	41.51	25.17

5.5. Graphical representation of the effects of α and β on decision variables:

The graphical representation of the effect of α and β on decision variables are respectively shown in Figure. 1-5 of subsection 5.5.1 and Fig. 6-10 of subsection 5.5.2.

5.5.1. Graphical representation of the effect of α parameter on all the decision variables p, m, q, Q, z: Each graphical representation of Fig.1-5 shows the effect of α parameter on all the decision variables for the Manufacturer-Stackelberg, Retailer-Stackelberg, and cooperative model.

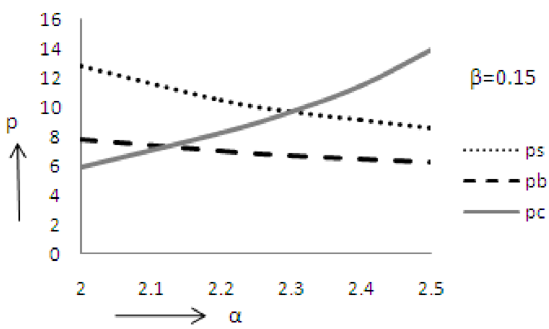

Figure 1. The effect of parameter α on p

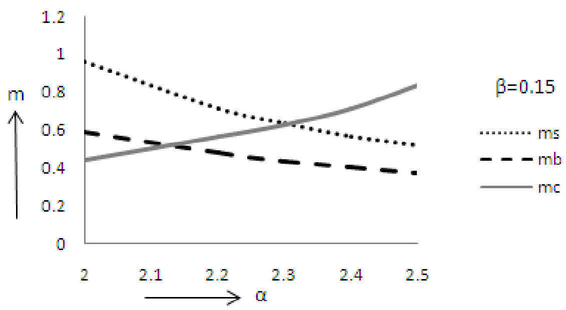

Figure 2. The effect of parameter α on m

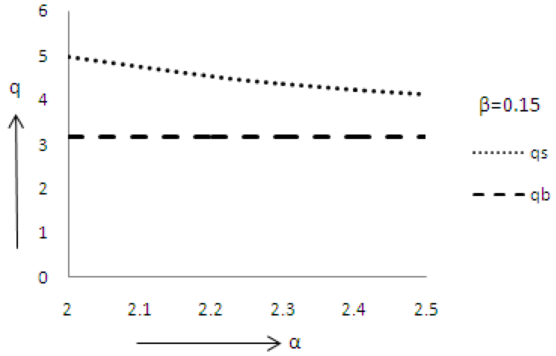

Figure 3. The effect of parameter α on q

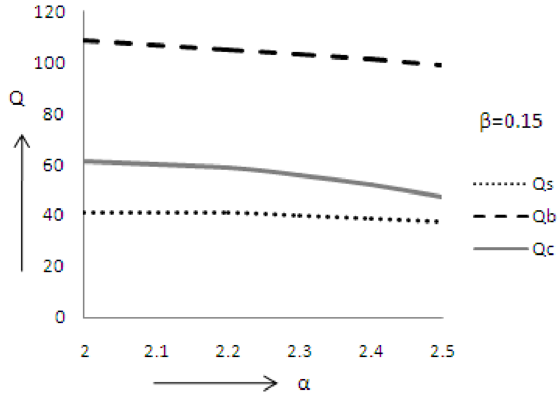

Figure 4. The effect of parameter α on Q

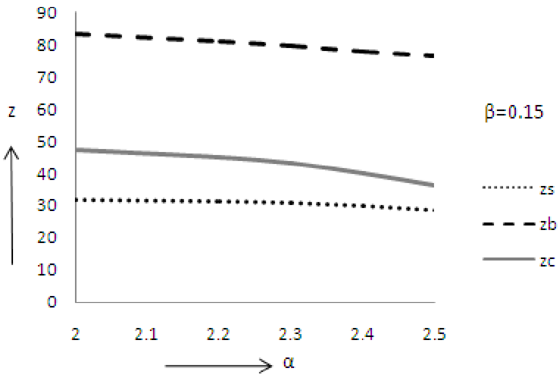

Figure 5. The effect of parameter α on z

From Fig 1-5 we can see that with increasing values of α manufacturer's selling price q decreases for the manufacturer-Stackelberg model while it increases for the Retailer-Stackelberg model. Inventory level z decreases for all the three models. Retailer's marketing expenditure m, selling price p decreases for the non-cooperative model while these values increase for the cooperative model. Retailer's lot size Q decreases for both non-cooperative and cooperative models.

5.5.2. Graphical representation of the effect of β parameter on all the decision variables: The effect of parameter β on the decision variables for the Manufacturer-Stackelberg, Retailer-Stackelberg, and cooperative model is shown below:

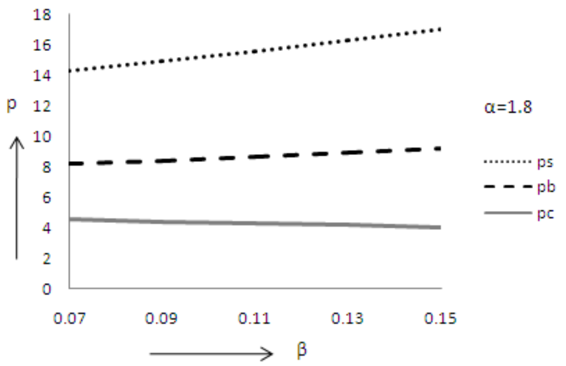

Figure 6. The effect of the β parameter on p

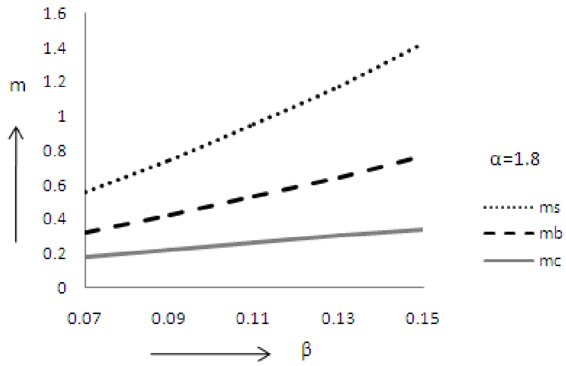

Figure 7. The effect of the β parameter on m

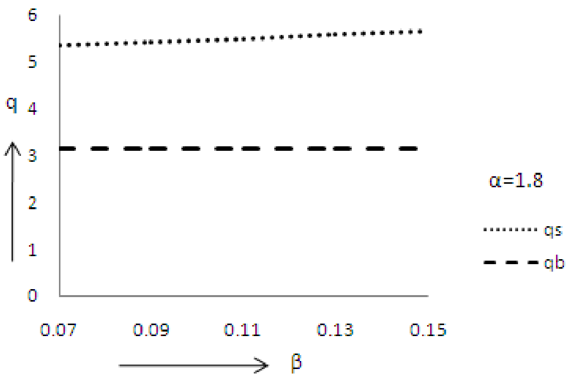

Figure 8. The effect of the β parameter on q

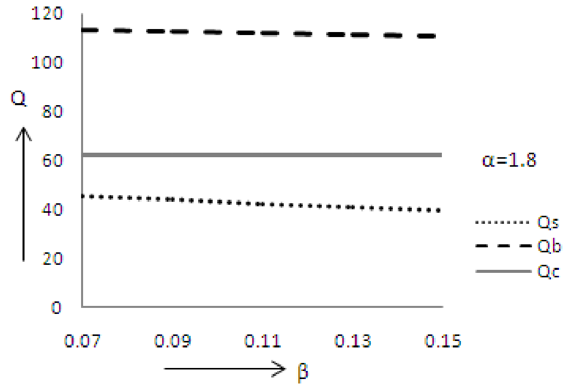

Figure 9. The effect of the β parameter on Q

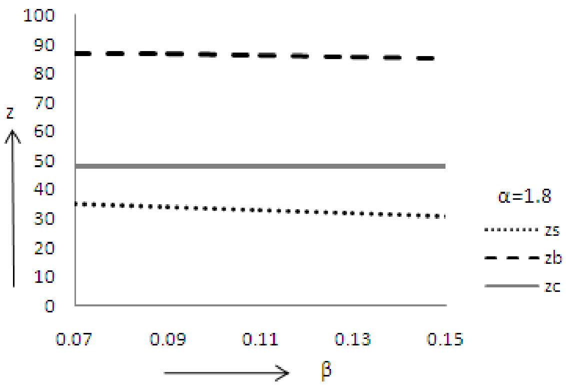

Figure 10. The effect of the β parameter on z

From F.ig 6-10 we can see that with increasing values of β manufacturer's selling price q increases for the non-cooperative model, while inventory level z decreases for the non-cooperative model and increases in the cooperative model. Retailer's selling price p increases for the non-cooperative model while it decreases for the cooperative model. Lot size Q decreases for the non-cooperative model while its value increases for the cooperative model. And marketing expenditure m increases for both non-cooperative and cooperative model.

6. Conclusion

In this paper, manufacturer-retailer relationships for supply chain management for both the non-cooperative and cooperative models with the shortage was investigated. In a non-cooperative game, the researcher considered two types of games when a manufacturer is a leader (Manufacturer-Stackelberg model) and when the retailer works as a leader (Retailer-Stackelberg model). It was assumed that production is done by the manufacturer and product is provided to the retailer, with an infinite rate of production and planned for the shortage. Demand is sensitive to marketing expenditure and unit price. From the numerical examples, the researcher found optimal solutions for both models, which shows that the profit of the manufacturer is larger in the cooperative model in comparison to the non-cooperative model. So the manufacturer prefers the cooperative model while for retailer profit is more in the non-cooperative model so the retailer prefers the non-cooperative model. The effect of two parameters on manufacturer's and retailer's decision variables is also investigated through sensitivity analysis. Future work also can be done, for example, with incorporating advertising expenditure and sharing it between retailers and manufacturers. We can also investigate lot size of retailers and when a shortage may come from the side of the retailer. The case of pricing discount together with shortage can be investigated as the future scope of the study. Here the production rate considered was infinite, so in further studies we can consider finite production rate.

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