Analysis of production-inventory decisions in a decentralized supply chain with price-dependent demand

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Abstract. In this paper, we consider a production-inventory supply chain system with single-manufacturer and single-retailer. There are many types of contract that guarantee the supply chain. However, the administrative costs of the contract are usually neglected in real situation. The additional gain from integration may not cover the extra administrative costs may not addressed to supply chain. Therefore, a Stackelberg game and RFM policy are examined in order to investigate its performance on supply chain. The RFM policy is applied because its administrative costs are lower than other policies. Although RFM policy is not capable of coordinating the channel, it leads to considerable improvements over the channel. The purpose of this research is to present a model of integrated policy, in which the goal is to maximize the whole system profit, and to evaluate decentralized-Stackelberg and RFM policies, in which individual firms in the supply chain have their own objectives and decisions to optimize.

1. Introduction

Generally, a supply chain is composed of independent members, each with its own individual costs and objectives. It is important how the members behave to manage their inventory. The integrated policy should be chosen when the take care about overall system performance. However, each member may be interested in maximizing its own profit independently. In this case, the whole channel’s performance could not necessarily be optimized, i.e. the decentralized policy. Therefore, the overall system performance may be improved by using a collaboration mechanism. Note that the channel will be collaborated under one contract if i) channel’s profit reaches its maximum as in integrated policy; and, ii) none of the members’ profit is worse compared with the decentralized policy. There is extensive research on the channel cooperation problem by means of designing efficient contracts, such as revenue sharing contracts, buyback contract, and cost sharing. The supply chain incurs some extra administrative costs by applying those contracts. The additional gain from coordination may not cover the costs. Alaei et al. [1] considered the production-inventory problem in a two level supply chain which is formulated as a Stackelberg game. They examined the retail fixed mark-up (RFM) in order to investigated its performance on supply chain. In the Stackelberg approach, two firms play a game to obtain Stackelberg equilibrium. The equilibrium is a pair of policies in which each firm maximizes its own profit assuming the other player sets his equilibrium policy. Furthermore, in RFM policy, the manufacturer determines the wholesale price first, that is equivalent to setting the retail price. In this policy, only the retail price must be monitored. Thus, the administrative costs related to this type of contract are lower than those of other contracts. In many industries fixed mark-ups are used such as electronics industry, gasoline dealers, and grocers. Moreover, RFM is also investigated in marketing environent. Li and Atkins [8]
consider RFM policy for operation sections and marketing in a single firm. Liou et al. [10] proposed multy-period inventory models. They studied the problem under the Stackelberg approach to achieve the optimal policies. Furthermore, several mult-echelon inventory systems are analyzed by using Stackelberg game.

Many integrated manufacturer-retailer inventory models assumed that the demand rate is constant and is not affected by the retail price of the product. It means that the demand remains the same over the changing of the retail price. Rad and Khoshalhan [11] proposed the integrated inventory model with backorder and assumed that the demand rate is constant. Shah et al. [13] developed the integrated inventory model with the influence of availability of stock goods under the constant demand rate. However, according to Within [14], retail price is one of the important decision variable which influences. Within [14] developed the economic order quantity (EOQ) model with pricing for a buyer that has a price dependent demand with a linear function. Many researchers are encouraged by his work to investigate joint ordering and pricing problems. The focus of these models has been on demand functions (e.g., Lau and Lau [7]), on quantity discount (e.g., Lin and Ho [9]), or on perishable inventories (e.g., Khanra et al. [5]). Chung and Wee [3] proposed joint ordering and pricing problems in which multiples companies in a supply chain coordinate with each other. Kim et al [6] developed a supply chain consisting of a single manufacturer and a single retailer under joint ordering and pricing policies for price-dependent demand. Chung and Liao [2] also introduced the integrated inventory model that involve price-sensitive demands. Recently, Rad et al. [12] discussed the integrated inventory model that considers operations and pricing decisions, where the demand rate has an iso-elastic function of the selling price.

To the best of knowledge, none of the above-mentioned decentralized models focused on the effects of decentralized policies on the performance of the supply chain comparing to integrated production-inventory models, especially when the demand rate has an iso-elastic function of the selling price. Therefore, in this paper, we consider a supply chain with a single manufacturer and a single retailer in a production-inventory system. An outside supplier supplies raw material to the vendor with zero lead time, and the vendor produces a product, and supplies it to a buyer who in turn supplies it to the consumers. Furthermore, it is assumed that the buyer faces price-dependent demand. End customer demand is assumed to be an iso-elastic function of the selling price to account for the impact of price changes on customer demand. The buyer uses EOQ inventory policy for controlling his costs. The vendor operates on a make-to-order basis and uses a lot-for-lot policy. The research conducted in this paper presents a model of (1) integrated policy, in which the goal is to maximize the whole system profit, and (2) to evaluate decentralized-Stackelberg and decentralized-RFM (Retail Fixed Mark-up) policy, in which individual firms in the supply chain have their own objectives and decisions to optimize.

2. Notations and Assumptions
To develop the proposed model, the following notations and assumptions are introduced.

2.1. Notations
\[A\] : Retailer fixed ordering cost
\[S\] : Manufacturer fixed setup cost
\[h\] : Retailer unit holding cost per unit time
\[H\] : Manufacturer unit holding cost per unit time
\[T\] : Cycle time
\[D\] : Price-dependent annual market demand
\[p\] : Retail price per unit (decision variable), \(p > 0\)
\[w\] : Wholesale price per unit (decision variable), \(c < w < p\)
\[c\] : Procurement price per unit, \(0 < c < w\)
\[k_1\] : Time-dependent production cost per unit time
\[k_2\] : Technology development cost, per one unit increasing on the production rate
\[l\] : Lead time
2.2. Assumptions
1. There are single-manufacturer and single-retailer for a single product in this model.
2. Shortage is not allowed.
3. For each unit of product, the manufacturer spends $c$ in production and receives $w$ from retailer. After that, the retailer sell it by $p$ to its customer. The relationship between them is $p > w > c$.
4. The demand rate is a decreasing function of the retail price, $D(p) = \gamma p^{-\beta}$, where $\gamma > 0$ is a scaling factor and $\beta > 1$ is the index of price elasticity. This type of demand function, which has been used by researchers such as Hays and DeLurgio (2009), Lin and Ho [4] and Rad et al. [6], for example, is commonly referred to as iso-elastic demand function. For notational simplicity, $D(p)$ and $D$ will be used interchangeably in this article.

3. Model Formulation
In this section, the retailer’s and the manufacturer’s inventory model are derived.

3.1. Retailer’s total profit
We assume that the retailer uses the EOQ inventory policy as shown in Figure 1 for controlling his costs. The retailer’s total profit includes the profit of the products, average ordering cost, and average holding cost. Thus the total annual profit of the retailer is given by

$$TP_r(p, Q) = \text{sales revenue of retailer} - \text{ordering cost} - \text{purchasing cost} - \text{holding cost}$$

$$= (\gamma p^{-\beta}) \left( p - \frac{A}{Q} - w \right) - \frac{hQ}{2}$$.  \hspace{1cm} (1)

![Figure 1. Retailer’s inventory level](image)

3.2. Manufacturer’s Total Profit.
The manufacturer’s inventory level is shown in Figure 2. The manufacturer’s total profit consists of sales revenue, holding cost, setup cost, and time-dependent production cost. The setup cost is divided into two parts: one part is fixed for every production period, and another one is an increasing function of the production rate. For instance, assume an assembly line that has the technology for assembling a set of parts that are supplied by a supplier. In this assembly line, time-dependent production cost coincides with the daily production cost. It is necessary to enhance the technology when the production rate exceeds a specific limit. Therefore, it is assumed that the manufacturer incurred a cost called technology development cost for every increasing unit on the production rate. For example, if the
manufacturer incurred $400 for increasing 200 units on the production rate, then the unit technology development cost will be $2.

![Figure 2. Manufacturer’s inventory level](image)

The manufacturer operates on a make-to-order basis using a lot for-lot policy, hence, the manufacturer begins to produce a batch of $Q$ at the rate of $\mu$, as soon as he receives an order and delivers it to the retailer after the lead time. It is assumed that the manufacturer has to produce the product with minimum possible production rate during the lead time, so we have $\mu = Q/l$. Thus, the total annual profit of the manufacturer can be expressed by

$$TP_m(p, Q) = \text{sales revenue of manufacturer} - \text{setup cost} - \text{time-dependent production cost} - \text{holding cost}$$

$$= (yp^{-\beta}) \left( w - c - \frac{S}{Q} - \frac{k_1}{l} - \frac{k_2}{l} - \frac{Hl}{z} \right).$$

(2)

4. Policies

4.1. Integrated Policy

In this policy, the goal is maximizing the joint total profit ($JTP$) which is the sum of the total annual profit for retailer ($TP_r$) and manufacturer ($TP_m$). Then the problem to be solved is to maximize

$$JTP(p, Q) = (yp^{-\beta}) \left( p - c - \frac{(S+A+k_1)}{q} - \frac{Hl}{z} - \frac{k_2}{l} \right) - \frac{hQ}{2}.$$ 

(3)

Where retail price ($p$) and order quantity ($Q$) are decision variables.

**Proposition 1.** The integrated order quantity $Q^*$ is one of the positive roots of the following equation:

$$h(Q)^2 - 2^{1+\beta}y(S + A + k_1l) \left( \frac{p^2(2(S+A+k_1l)+2k_2Q+2c+Hl))}{lQ(\beta-1)} \right)^\beta = 0.$$ 

(4)

And, the integrated retail price is

$$p^* = \frac{\beta(C(S+A+k_1l)+Hl/2+k_1l)}{\beta-1}.$$ 

Proof. The optimal retail price, $p^*$, is obtained from $\frac{\partial JTP(p,Q)}{\partial p} = 0$. Similarly, from $\frac{\partial JTP(p,Q)}{\partial Q} = 0$, the optimal order quantity is $Q^* = \frac{1}{\beta}2^{1+\beta}y(S + A + k_1l)$, and Equation (4) can be achieved by simultaneously considering $p^*$ and $Q^*$. It can be proved that this form of equations either has two positive roots or have no one. Furthermore, the Hessian matrix of $JTP(p,Q)$ is

$$H = \begin{pmatrix} \frac{\partial^2 JTP(p,Q)}{\partial p^2} & \frac{\partial^2 JTP(p,Q)}{\partial p \partial Q} \\ \frac{\partial^2 JTP(p,Q)}{\partial Q \partial p} & \frac{\partial^2 JTP(p,Q)}{\partial Q^2} \end{pmatrix},$$

where
The Stackelberg’s retail price is obtained from the following system of equations:

\[
\frac{\partial^2 JTP(p,Q)}{\partial p^2} = -\frac{1}{2\ell q} p^{-2-\beta} \gamma \beta (2l(S + A + k_1 l) + 2k_2 Q + l(2c + Hl + 2p) Q + (2l(S + A + k_1 l) + 2k_2 Q + l(2c + Hl + 2p) Q) \beta),
\]

\[
\frac{\partial^2 JTP(p,Q)}{\partial Q \partial p} = \frac{\partial^2 JTP(p,Q)}{\partial Q p} = -\gamma \beta p^{-\beta - 1} (S + A + k_1 l),
\]

\[
\frac{\partial^2 JTP(p,Q)}{\partial Q^2} = -\frac{2 \gamma \beta}{Q^3} (S + A + k_1 l).
\]

Checking the sign of the first and second principal minor determinant of \(H\), we get

\[
|H_{11}| = \frac{\partial^2 JTP(p,Q)}{\partial p^2} < 0
\]

\[
|H_{22}| = \frac{1}{4q^2} (S + A + k_1 l) p^{-2(1+\beta)} \beta y^2 (2l(S + A + k_1 l) + 2k_2 Q + l(2c + Hl + 2p) Q + (2k_2 Q + l(S + A + k_1 l) + 2c + Hl) Q) \beta) > 0.
\]

Therefore, the Hessian matrix is a negative definite matrix, so \(JTP(p,Q)\) is a concave function in \(p\) and \(Q\). Therefore, \((p^*, Q^*)\) maximizes the integrated inventory model.

### 4.2. Decentralized (Stackelberg policy)

In Stackelberg policy, manufacturer and retailer are classified as leader and follower, respectively. The manufacturer chooses a strategy first, and then the retailer observes this decision and makes his own strategy. It is necessary to assume that each enterprise is not willing to deviate from maximizing his profit. In other words, each player chooses his best strategy. The manufacturer determines his wholesale price, and acts as a leader by announcing it to the retailer in advance, and the retailer acts as a follower by choosing his retail price and order quantity based on the manufacturer’s strategy.

**Proposition 2.** The Stackelberg’s order quantity and wholesale price are achieved by solving the following system of equations:

\[
(i) \quad h(Q^*)^2 - 2 A \gamma \left(\frac{(A + Q^* w)^\beta}{Q^*(\beta - 1)}\right)^{-\beta} = 0, \quad \text{and}
\]

\[
(ii) \quad \left(\frac{(A + Q^* w)^\beta}{Q^*(\beta - 1)}\right)^{-\beta} \left(2l(A + Q^* w) y + (2k_2 Q^* + l(2S + 2k_1 l + Q^*(2c + Hl + 2w)) \gamma \beta)\right) = 0,
\]

and the Stackelberg’s retail price is

\[
p^* = \frac{A \beta + Q^* w \beta}{Q^*(\beta - 1)}.
\]

**Proof.** We need the retailer’s reaction function \((p^*, Q^*)\) for given \(w\). It can be proved that the Hessian matrix of \(TP_r\) is a negative definite matrix, so \(TP_r\) is concave in \(p\) and \(Q\). Therefore, the optimal retail price and the optimal order quantity are obtained from \(\frac{\partial TP_r(p,Q)}{\partial p} = 0\) and \(\frac{\partial TP_r(p,Q)}{\partial Q} = 0\). We get

\[
p = \frac{A \beta + Q w \beta}{Q(\beta - 1)}
\]

and

\[
Q = \left[\frac{2 A \gamma p^{-\beta}}{h}\right].
\]

By simultaneously considering equations (7) and (8), we obtain Equation (5). Further, by substituting \(p\) to the manufacturer’s total profit, we have

\[
TP_m = \left(\gamma \left(\frac{A \beta + Q^* w \beta}{Q^*(\beta - 1)}\right)^{-\beta}\right) \left(w - c - \frac{s}{Q} - \frac{k_1 l}{Q} - \frac{k_2}{l} - \frac{Hl}{2}\right).
\]

The optimal wholesale price is achieved by maximizing Equation (9) with respect to \(w\) or equivalently \(\frac{\partial TP_m}{\partial w} = 0\). Then we get Equation (6).
4.3. Decentralized (RFM policy)
In RFM policy, the wholesale price is determined first by the manufacturer. Next the retailer sets his order quantity. The retailer receives a fixed mark-up ($\alpha = 1 - w/p$). Hence, setting the wholesale price by manufacturer is equivalent to choosing the retail price. Then, the retailer only chooses on value of order quantity and the manufacturer decides the retail price. Note that, the value of $\alpha$ is assumed to be exogenously given, and, not to be endogenously determined. It is important to specify that for which values of $\alpha$, the RFM policy will be desirable for both members. By substituting $w = (1 - \alpha)p$ to equations (1) and (2), we obtain the total profits of two firms under RFM as below:

$$TP_r(p, Q) = (y p^{-\beta} \left( ap - \frac{A}{q} \right) - hq - \frac{q}{z})$$

and

$$TP_m(p, Q) = (y p^{-\beta} \left( p - ap - c - \frac{c}{q} - \frac{Hi}{q} - \frac{k_1 l - k_2}{l} \right).$$

Proposition 3. RFM’s order quantity and retail price are achieved by solving the following system of equations:

(i) $\frac{h(q)}{z^2} - y (p)^{-\beta} = 0$, and

(ii) $p^{1-\beta} y \left( 2k_2 Q^\beta + l^2(2k_1 + HQ)\beta + 2l((S + cQ)\beta + pQ(\beta - 1)(\alpha - 1)) \right) = 0$. (13)

Proof. Similar to previous section, the retailer’s reaction, $Q$, is obtained from $\frac{\partial TP_r(p, Q)}{\partial q} = 0$. We have

$$Q = \sqrt{\frac{2Ap^{-\beta}}{h}}.$$

The manufacturer maximizes his total profit by taking the retailer’s reaction into account. Furthermore, simplifying $\frac{\partial TP_m(p, Q)}{\partial p} = 0$ results the Equation (13). Moreover, it can be proved that the profit function is concave.

5. Numerical example
Numerical examples given below are for illustrating the feasibility of the above policies. Moreover, the Pareto-improvement region through a numerical study is illustrated. Next, a sensitivity analysis is performed by changing the values of major parameters. We consider the retailer’s and the manufacturer’s inventory systems with the following data: $D(p) = 300000 p^{-1.25}$ units per year, $A = $80 per order, $c = $13 per unit, $S = $300, $k_1 = $1000, $k_2 = $0.0002, $l = 0.02$, $h = $1.2, $H = $1. In RFM, we assume that $\alpha$ is equal to 0.32.

| Table 1. Solutions of integrated policy, Stackelberg policy and RFM policy. |
|---|
| \(Q^*\) | \(w^*\) | \(p^*\) | \(TP_r\) | \(TP_m\) | \(JTP(p, Q)\) |
| Integrated policy | 1021 | - | 67.059 | - | 83256 |
| Stackelberg policy | 152 | 77.768 | 391.479 | 53865 | 10792 | 64657 |
| RFM policy | 351 | 69.667 | 102.452 | 29754 | 51297 | 81051 |

The solutions of integrated policy, Stackelberg policy and RFM policy are summarized in Table 1. The table shows that the manufacturer’s profit is higher in RFM policy comparing to Stackelberg policy. The opposite results occurs in retailer’s profit. However, we can see that RFM profit is higher than Stackelberg profit. Furthermore, we define the competition penalty ($\rho$) as the difference between the integrated profit and Stackelberg/RFM profit measured as a fraction of the integrated profit. For RFM policy, this value is equal to 3% but increased to 23% in Stackelberg policy. It is important to determine an interval ($\alpha_{min}, \alpha_{max}$) in which both retailer and manufacturer can benefit from RFM policy.
Figure 3 shows the manufacturer’s and retailer’s profit functions with respect to $\alpha$ under the Stackelberg and RFM policies. It can be seen that the retailer’s profit function is concave and has a maximum value. However, the manufacturer’s profit function is convex and decreasing in $\alpha$. There exists a $\alpha_{\text{max}}$ such that if $\alpha \leq \alpha_{\text{max}} = 0.83$, the manufacturer can benefit from RFM policy comparing to Stackelberg policy. Similarly, there exist $\alpha_{\text{min}}$ and $\alpha_{\text{max}}$ such that if $0.74 = \alpha_{\text{min}} \leq \alpha \leq \alpha_{\text{max}} = 0.83$, the retailer can benefit from RFM policy comparing to Stackelberg policy. Furthermore, we can see that in the interval $(\alpha_{\text{min}}, \alpha_{\text{max}}) = (0.74, 0.83)$, both the manufacturer and the retailer will always prefer RFM policy to stackelberg policy. The interval $(0.74, 0.83)$ is a Pareto efficient strategy for the given data. Next, we investigate this Pareto-improving region numerically. The variation of this region with respect to retailer fixed ordering cost, $A$, and scaling factor of demand rate, $y$, is illustrated in Figure 4. From the figure, the higher the ordering cost, the longer the interval of Pareto efficient strategy. However, the opposite results occurs in the scaling factor of demand rate.

6. Sensitivity Analysis

The sensitivity analysis is performed by changing the values of major parameters. Table 2 illustrates the sensitivity analysis of the parameters and the competition penalty ($\rho$) for RFM policy with three different retail fixed mark-up rates. In the table, $\Delta_r$ is defined as the retailer’s percentage improvement.
of RFM policy comparing to Stackelberg policy. Similarly, \( \Delta_m \) is defined for the retailer's. Negative values shows that the retailer's/manufacturer's profit in RFM policy is lower than that of Stackelberg's. The RFM is not a Pareto efficient strategy if either \( \Delta_r \) or \( \Delta_m \) is negative. Moreover, the variations of decision variables for integrated, Stackelberg, and RFM policies with three different retail fixed mark-up rate are illustrated in Table 3.

| Parameters ↓ | Solutions | RFM (0.74) | RFM (0.76) | RFM (0.78) |
|--------------|-----------|------------|------------|------------|
| RFM          | c         | 7          | 23         | 17         | 41.489     | 0.369 |
|              | \( \rho \) | 18          | 22         | 17         | 40.664     | -0.128 |
| \( \gamma \) | 150000    | 23          | 18         | 17         | 41.834     | 0.577 |
| \( \beta \)  | 1.08      | 15          | 5          | 6          | 294.158    | -10.368 |
| \( A \)      | 40        | 23          | 18         | 40.88      | 0.073      | 20    |
| \( S \)      | 150       | 21          | 19         | 41.364     | 0.192      | 22    |
| \( h \)      | 1         | 22          | 17         | 40.724     | -0.0924    | 18    |
| \( H \)      | 0.5       | 22          | 17         | 40.915     | 0.022      | 20    |
| \( k_1 \)    | 500       | 22          | 17         | 40.887     | 0.002      | 18    |
| \( k_2 \)    | 0.0001    | 22          | 17         | 40.915     | 0.022      | 18    |
| \( l \)      | 0.1       | 23          | 18         | 41.128     | 0.177      | 19    |

We solve 101 problems and drive conclusions about the results. To evaluate the RFM policy, we set \( \alpha \) to 0.74, but other parameters generated randomly from the intervals as below:

- \( c \in [7,18] \), \( \gamma \in [150000,500000] \), \( \beta \in [1.08,1.6] \), \( A \in [40,200] \), \( S \in [150,600] \),
- \( h \in [1,3] \), \( H \in [0.5,1.2] \), \( k_1 \in [500,2000] \), \( k_2 \in [0.0001,0.001] \), \( l \in [0.01,0.1] \).

Next, we compare the competition penalty for these problems. The penalty's histogram for RFM and Stackelberg policies can be seen in Figure 5. The figure shows that the highest and the lowest frequency of the competition penalty of Stackelberg policy are \( \rho \in [22\%, 22.5\%] \) and \( \rho < 21\% \), respectively. The highest frequency of competition penalty of RFM policy is \( \rho \in [17\%, 18\%] \); whereas the lowest one is \( \rho < 15\% \) and \( \rho \in [15\%, 16\%] \).
Table 3. Two approach solutions under variation of major parameters.

| Parameters | Integrated | Stackelberg | RFM (0.74) | RFM (0.76) | RFM (0.78) |
|------------|------------|--------------|------------|------------|------------|
| $c$        | 7          | 1495 36.438 216 221.8 43.9 | 268 158.032 41.088 | 253 172.617 41.428 | 239 190.097 41.821 |
| $\gamma$   | 150000     | 717 67.892 102 423.511 83.918 | 127 298.895 77.712 | 120 326.819 78.436 | 113 360.346 79.276 |
| $\beta$    | 1.08       | 851 182.116 80 3286.44 242.437 | 175 771.221 200.517 | 167 840.384 201.692 | 159 922.895 203.04 |
| $A$        | 40         | 970 66.957 104 412.35 82.062 | 127 298.895 77.712 | 120 326.819 78.436 | 113 360.346 79.276 |
| $S$        | 150        | 811 66.643 158 364.969 72.489 | 193 267.382 69.519 | 183 90.649 69.755 | 173 318.309 70.28 |
| $h$        | 1          | 1121 66.886 168 385.118 76.647 | 205 280.477 72.924 | 194 305.65 73.355 | 183 335.701 73.854 |
| $H$        | 3          | 639 68.231 90 437.296 86.565 | 112 305.349 79.390 | 106 334.259 80.222 | 100 369.032 81.187 |
| $k_1$      | 0.5        | 1022 67.034 152 391.34 77.74 | 186 283.473 73.703 | 176 309.093 74.182 | 166 339.71 74.736 |
| $k_2$      | 1.2        | 1021 67.108 152 391.536 77.79 | 186 283.618 73.740 | 176 309.251 74.220 | 166 339.883 74.774 |
| $l$        | 2000       | 1046 67.108 151 395.189 78.507 | 185 285.826 74.314 | 175 311.789 74.829 | 165 342.836 75.424 |
| $\alpha$   | 0.001      | 0.001 1022 67.037 152 391.34 77.74 | 186 283.473 73.703 | 176 309.093 74.182 | 166 339.71 74.736 |
|            | 0.01       | 0.01 1019 67.263 151 392.598 77.991 | 186 284.407 73.945 | 176 310.109 74.426 | 166 340.823 74.981 |

Figure 5. Histogram of (a) Stackelberg policy’s penalty and (b) RFM policy’s penalty.

Figure 6 illustrates the variations of total profit, retailer’s profit and manufacturer’s profit respect to the retailer’s fixed ordering cost. It can be seen that total profit of the RFM policy is higher than that of Stackelberg policy. Moreover, it is shown that greater value of $\alpha$ leads to lower profit for the manufacturer, but greater profit for the retailer. It is obvious that with $\alpha = 0.74$ is preferred by the retailer. However, manufacturer may choose $\alpha = 0.6$ to maximize his profit.
Figure 6. (a) Total profit, (b) retailer profit, and (c) manufacturer profit respect to retailer fixed ordering cost.

The variations of retail price and order quantity respect to the procurement cost are illustrated in Figure 7. We examine four different values of fixed mark-up, $\alpha$. It can be seen that the greater the procurement cost, the greater the retail price, but the lower the order quantity. Moreover, the retail price of Stackelberg policy is greater than that of integrated policy. However, the order quantity of integrated policy is greater than those of Stackelberg and RFM policies.

Figure 7. (a) Retail price and (b) order quantity respect to the procurement cost.

7. Conclusions

In this paper, we consider a production-inventory supply chain system with single-manufacturer and single-retailer. The decentralized policies (i.e. Stackelberg and RFM) are examined with the goal of
coordinating the channel. There are many types of contract that guarantee the supply chain. However, the administrative costs of the contract are usually neglected in real situation. The additional gain from integration may not cover the extra administrative costs and may not be addressed to supply chain. Therefore, RFM policy is used it has minor administrative costs comparing to the other policies. With properly designed RFM policy, Pareto improvement is obtained over the Stackelberg policy. Although the RFM policy is not capable of coordinating the channel, it leads to considerable improvements over the channel. Possible extensions for future research could be by considering other general demand function with more efficient inventory models. Furthermore, it is also interesting to consider the administrative costs of the integration contracts in the objective function of the members.

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