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RESEARCH NOTE

Impact of Service on Customers' Demand and Members' Profit in Supply Chain

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ABSTRACT

This paper investigates the impact of provided service by the retailers and manufacturers on customers' demand and members' profit in a supply chain. It focuses on a supply chain structure with one manufacturer and a common retailer. The demand of customers depends on retailer price and service level. A game-theoretic framework is applied to obtain the equilibrium solutions for each entity in supply chain. In order to investigate the impact of service on the demand and supply chain members' profit when the manufacturer is a leader, we derive and compare equilibrium solutions for the supply chain under three different scenarios. These scenarios include the case that manufacturer and retailer do not provide any service to customers; the case that retailer provides service to customers; and the case that manufacturer provides service to customers. We compare results from these three scenarios and provide the best scenario for the proposed problem.

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1. INTRODUCTION

Due to increasing competition, the centralized supply chain or members of one decentralized supply chain must compete with more effective strategies than pricing strategy. On the other hand, manufacturers must not compete solely on price and they should focus on using non-price factors such as advertising, services, quality, delivery time, guarantee and quality level that can influence the demand for the products. These factors show the scope of efforts that must be taken by manufacturers to distinguish themselves from their competitors.

Yue et al. [1] studied the coordination of cooperative advertisement in a manufacturer–retailer supply chain when the manufacturer offers price reductions to customers. Szmerekovsky et al. [2] considered the pricing decisions and two-tier advertising levels between one manufacturer and a common retailer where customer demand depends on the retail price and advertisement by a manufacturer and a retailer. They solved a Manufacturer Stackelberg game with price sensitive customer demand and a linear wholesale contract. They showed that cost sharing of local advertising does not work well. It is better for the manufacturer to advertise nationally and offer the retailer a lower wholesale price. Shabnam Rezapour et al. [3] designed a multi-tier chain operating in markets under deterministic price-depended demands and with a rival chain present. In their paper, they used von Stackelberg model. Yugang et al. [4] proposed how a manufacturer and its retailers interact with each other in order to optimize their individual net profits by adjusting advertising and pricing and inventory policies in an information-asymmetric vendor managed inventory. They have modeled their problem as a Manufacturer Stackelberg game. Seyed Esfahani et al. [5] considered vertical advertising along with pricing decisions in a supply chain; this supply chain consists of a manufacturer and a retailer where demand is influenced by both price and advertisement. They have solved three non-cooperative games including Nash, Manufacturer Stackelberg and Retailer Stackelberg, and one cooperative game. Xie and Neyret [6] considered advertising and pricing strategies in distribution channels consisting of a manufacturer and a retailer. They have examined four different models which have based on three non-cooperative including Nash, Manufacturer Stackelberg and Retailer Stackelberg, and one cooperative game. They determined optimal

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advertising and pricing strategies for both firms mostly analytically; but, they had to resort to numerical simulations in one case.

It was mentioned above that one of the non-price factors is the service level. Heretofore, many researchers have used various definitions of service in their studies. For example, Hall and Porteus [7] used customer service capacity. They studied a finite multiple-period problem in which two firms compete by investing in capacity that is used to provide goods or services to their customers. They assumed that there is a fixed total market of customers whose demands for the goods or service is random. They obtained results for both single-period and finite-horizon problems. So [8] used delivery time guarantee as the other non-price factor. He studied the problem where several heterogeneous service firms use delivery time guarantees to compete for customers in the marketplace. Winter [9] and Iyer [10], both provided detailed representation of individual customer behavior in terms of the value of service and disutility of travel, and from this infer properties of each retailer`s demand curve. Iyer [10] examined a channel with one manufacturer and two retailers who compete on both price and non-price factors. Kurata and HyunNamb [11] considered a manufacturer offers basic warranty available to all customers who buy the product, while a retailer offers optional after-sales service that is available only to customers who pay for the option. Perry and Porter [12] focused on a type of service that unlike ours has a positive externality effect across the retailers.

Our definition of the service is similar to the definition used in McGahan and Ghemawat [13], Tsay and Agrawal [14], Xiao and Yang [15]. They studied a distribution system in which a manufacturer supplies a common product to two independent retailers. In this paper, they analyzed the effects of the retailers' risk sensitivity on the players' optimal strategies while each supply chain consists of one risk-neutral supplier and one risk-averse retailer. They also studied the effects of the wholesale prices and the service investment efficiencies on the retail price–service level decisions of the retailers.

As mentioned, service is one of the non-price competitive factors that affect customers' demand. So, we investigate the competition in the supply chain under the service factor. In this research, service is defined as any action which the provider takes to enhance the convenience of the customer while he is using the product and persuade the customer to pay more for the product. Examples of services include post-sale customer support, improved quality, on-time product delivery, responsive product repair and etc. In the last literature there is not a mathematical model that used nonlinear profit function for descending rate of return of service in order to prove the impact of services on demand and supply chain members' profits. In this paper, we proposed a mathematical model to investigate the impact of services provided by manufacturers and retailers on the demand and supply chain members' profit.

The rest of the paper is organized as follows: Section 2 describes the basic model. Section 3 introduces three types of Stackelberg game and related equations. Finally, section 4 concludes the paper.

2. MODEL ASSUMPTIONS

In our supply chain structure, there is one manufacturer that provides the demand of retailer, who in turn fulfills the demand of end customers. We assumed that there are only one retailer and one manufacturer in the area. We also supposed that the distance between each retailer and each manufacturer is so long that there is no competition among retailers and there is no competition among manufacturers. This may be a strong assumption for some markets. However, it allows us to focus on the vertical competition between manufacturers and retailers.

In this supply chain, there is not cooperation between members of the supply chain and all channel members try to maximize their own profit and behave as if they have perfect information of the demand and the cost structure of other channel members. In this model, we investigate the following three scenarios:

- The manufacturer and the retailer do not provide any service to customers.
- The retailer provides service to customers.
- The manufacturer provides service to customers.

In the first scenario, the manufacturer must decide on wholesale price for its products, while the retailer controls the retail price of products. In the second scenario, the manufacturer must decide on his product's wholesale price, while the retailer controls the retail price of products and service level must be provided to customers. In the third scenario, the manufacturer must decide on his products' wholesale price and service level must be provided to customers, while the retailer controls the retail price of both products.

We also assumed that customers' demand for each product in the first scenario is only sensitive to the retail price and in the second scenario is sensitive to retail price and service level must be provided by the retailer. In the third scenario customers' demand is sensitive to retail price and provided service the manufacturer. In this model, we supposed that the manufacturer have more bargaining power than the retailer. Thus, the manufacturer in the supply chain is the leader. The total strategic interactions among members of the supply chain have been examined in the single period, and the demand functions are deterministic.

3. STACKELBERG GAME

We investigated strategic interactions among members of the supply chain using game theory. Since in this model the manufacturer is the leader and the retailer is the follower, there are three Stackelberg games.

In these games, the leader in each scenario makes his decisions to maximize his own profit, conditioned on the follower's response function. The problem can be solved backwards. We begin solving the reaction function of the follower when he has observed the leader's decisions. For example, in the first scenario, the retailer reaction function is derived first, given that the retailer has observed the decisions made by the manufacturer. The manufacturer also solves his problem given that he knows how the retailer would react to his decisions.

3. 1. First Scenario. In this scenario, the manufacturer and the retailer do not provide any service to customers.

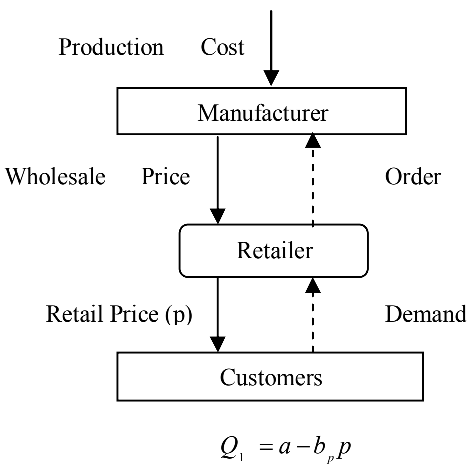


Figure 1. Schematic illustration of the first scenario

3. 1. 1. Demand Function The demand function for the manufacturer and common retailer in this scenario is as follows:

$$Q_1 = a - b_p p \tag{1}$$

This demand function is deterministic and linear; this function is known as Alfred Marshall.

We assume, parameters a , b_p, b_s, η, c in three scenarios are symmetric. All notations used in three scenarios are given in Table 1.

TABLE 1. List of variables and parameters

Variables and Parameters	Definition
p	Retail price
w	Wholesale price
Q_i	Demand of scenario i
a	Market base
b_p	Sensitivity of retailer's demand to its own retail price
b_s	Sensitivity of demand to retailer service in second scenario and Sensitivity of demand to manufacturer service in third scenario
S	The service level provided by retailer and manufacture in the second and the third scenarios
π_{iM}	Manufacture profit function in scenario i
π_{iR}	Retailer profit function in scenario i
c	Manufacture unit cost
η	Service cost factor in the second and the third scenarios

3. 1. 2. Profit Functions In this scenario, the manufacturer can influence the demand by setting the wholesale price and the retailer can influence the retail price. The manufacturer and common retailer try to maximize their own profit.

According to the demand function, retail price and wholesale price, the retailer's profit function can be described by the following equation:

$$\pi_{1R} = (p - w)Q_1 = (p - w)(a - b_p p) \tag{2}$$

And according to the demand function, production cost and wholesale price, the manufacturer's profit function can be described by the following equation:

$$\pi_{1M} = (w - c)Q_1 = (w - c)(a - b_p p) \tag{3}$$

3. 1. 3. Stackelberg Game-1 In this game, the manufacturer must decide on the wholesale price to maximize his profit, and announces wholesale price to the retailer. Then, in response to the manufacturer's announcement, the retailer decides the retail price and ordering quantity of product that maximize his expected profit. Retailer's ordering quantities become incoming demand for manufacturer.

In this scenario, the retailer reaction function is derived first and the retailer observed the decision made by the manufacturer on wholesale price. Then, manufacturer solves his problem knowing how the retailer would react to his decisions.

3. 1. 4. Retailer Reaction Function The retailer in this game must choose retail price P^* to maximize his equilibrium profit. That is,

$$p^* \in \arg\max_{p} \pi_{1R}(p|w) \tag{4}$$

where, $\pi_{1R}(p|w)$ denotes the profit of the retailer at this stage when he sets retail price p , given earlier decision by the manufacturer is w . The first order condition can be shown as.

$$\frac{\partial \pi_{1R}}{\partial p} = a - 2b_p p + wb_p = 0 \tag{5}$$

The second order condition can be shown as.

$$\frac{\partial^2 \pi_{1R}}{\partial p^2} = \ 2b_p \tag{6}$$

Assuming that $b_p > 0$, hence, the retailer profit function, π_{1R}, is concave in p . Therefore, the p which has been calculated above are the optimal reaction function for the retailer.
From Equation (5), the retailer's reaction function can be derived as:

$$p = \frac{a + wb_p}{2b_p} \tag{7}$$

3. 1. 5. Manufacturer Decisions Using the retailer's reaction function (7), the manufacturer's equilibrium wholesale price can be derived from the following first-order condition of the respective manufacturer's profit maximization problem that is shown in Equation (3):

$$\begin{gathered} \pi_{1M} = (w-c)(a - b_p \frac{a + wb_p}{2b_p}) \\ \frac{\partial \pi_{1M}}{\partial w} = \frac{a}{2} - b_p w + \frac{b_p c}{2} = 0 \end{gathered} \tag{8}$$

The second order condition can be shown as

$$\frac{\partial^2 \pi_{1M}}{\partial w^2} = -b_p \tag{9}$$

Assuming that $b_p > 0$, hence, the manufacturer profit function, π_{1M}, is concave in w . Therefore, the W has been calculated above are the optimal reaction function for the manufacturer.
Thus, from Equation (8), the manufacturer's equilibrium wholesale price can be derived:

$$w^* = \frac{a + b_p c}{2b_p} \tag{10}$$

And the retailer's equilibrium retail price can be obtained from Equations (7) and (10):

$$p^* = \frac{3a + b_p c}{4b_p} \tag{11}$$

by substituting p^* into Equation (1), we get:

$$Q_1^* = \frac{a - b_p c}{4} \tag{12}$$

by substituting w^* and Q_1^* into manufacturer profit function, π_{1M}, and substituting Q_1^*, p^* and w^* into retailer profit function, π_{1R}, we get:

$$\pi_{1M}^* = (w^* - c)Q_1^* \Rightarrow \pi_{1M}^* = \frac{(a - b_p c)^2}{8b_p} \tag{13}$$

$$\pi_{1R}^* = (p^* - w^*)Q_1^* \Rightarrow \pi_{1R}^* = \frac{(a - b_p c)^2}{16b_p} \tag{14}$$

3. 2. Second Scenario In this scenario, the retailer provides service to customers and customers' demand for each product is sensitive with respect to retail price and provided service by the retailer.

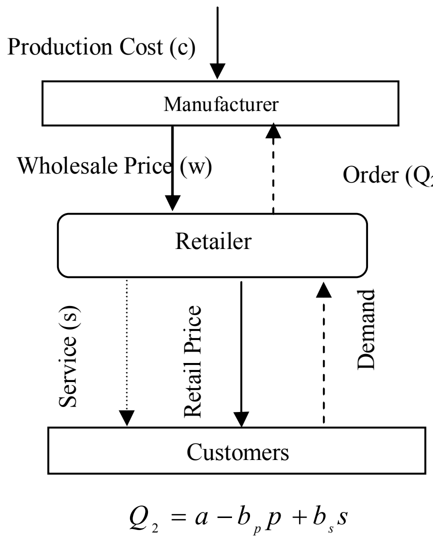


Figure 2. Schematic illustration of the second scenario

The demand function for the manufacturer and common retailer in this scenario is:

$$Q_2 = a - b_p p + b_s s \tag{15}$$

3. 2. 1. Profit Functions In this scenario, the manufacturer can influence the demand by setting the wholesale price and the retailer can influence the demand by setting the retail price and service level. The manufacturer and retailer try to maximize their own profit. The retailer's profit function can be described by the following equation:

$$\pi_{2R} = (p - w)Q_2 - \frac{\eta s^2}{2} \tag{16}$$

where, the service cost function of retailer is $\eta s^2/2$ for service level. This function has a diminishing return property on service expenditure. The next dollar which is invested would produce less unit of service than the last dollar. It becomes more expensive to provide the next unit of service. This function is also used by Xiao and Yang [15]; Tsay and Agrawal [14].

According to the demand function, production cost and wholesale price, the manufacturer's profit function can be described by the following equation:

$$\pi_{2M} = (w - c)Q_2 \tag{17}$$

3. 2. 2. Stackelberg Game-2 In this game, first, the manufacturer must decide on the wholesale price to maximize his profit; then, the manufacturer reveals offered wholesale price to retailer. After that, the retailer decides the retail price, service level and ordering quantity based on wholesale price that maximize his expected profit.

3. 2. 3. Retailer Reaction Function The retailer in this game must choose retail price p^* and service level s^* to maximize his equilibrium profit. That is,

$$p^* \in \arg\max_p \pi_{2R}(p, s^* | w) \tag{18}$$

$$s^* \in \arg\max_s \pi_{2R}(p^*, s | w) \tag{19}$$

where, $\pi_{2R}(p, s|w)$ denotes the profit of retailer at this stage when he sets retail price p and service level S, the earlier decision made by the manufacturer is w, The first order condition can be shown as below:

$$\frac{\partial \pi_{2R}}{\partial p} = a - 2b_p p + b_s s + w b_p = 0 \tag{20}$$

$$\frac{\partial \pi_{2R}}{\partial s} = p b_s - w b_s - \eta s = 0 \tag{21}$$

For which the Hessian matrix is

$$H = \begin{bmatrix} \frac{\partial^2 \pi_{2R}}{\partial p^2} & \frac{\partial^2 \pi_{2R}}{\partial p \partial s} \\ \frac{\partial^2 \pi_{2R}}{\partial s \partial p} & \frac{\partial^2 \pi_{2R}}{\partial s^2} \end{bmatrix} = \begin{bmatrix} -2b_p & b_s \\ b_s & -\eta \end{bmatrix} \tag{22}$$

Assuming that $b_p > 0$, $b_s > 0$, $\eta > 0$, $\det(H) = 2b_p\eta - b_s^2 > 0$, we have a negative definite Hessian. Hence, the retailer profit function, π_{1R} is concave in p and s. Therefore, p and s calculated above are the optimal reaction functions for the retailer. From Equations (20) and (21), the retailer's reaction functions can be derived:

$$p = \frac{a\eta + w b_p \eta - w b_s^2}{2\eta b_p - b_s^2} \tag{23}$$

$$s = \frac{a b_s - w b_p b_s}{2\eta b_p - b_s^2} \tag{24}$$

3. 2. 4. Manufacturer Decisions Using the retailer's reaction functions (23) and (24), the manufacturer's equilibrium wholesale price can be derived from the following first-order condition that is shown in Equation (17) as follows.

$$\pi_{2M} = (w - c)(a - b_p p + b_s s)$$

$$\frac{\partial \pi_{2M}}{\partial w} = \frac{1}{2\eta b_p - b_s^2}\left[a\eta b_p - 2b_p^2 \eta w + b_p^2 \eta c\right] = 0 \tag{25}$$

The second order condition can be shown as

$$\frac{\partial^2 \pi_{2M}}{\partial w^2} = \frac{-2b_p^2 \eta}{2\eta b_p - b_s^2} \tag{26}$$

Assuming that $\eta > 0$, $2b_p\eta - b_s^2 > 0$, hence, the manufacturer profit function, π_{1M}, is concave in w. Thus, from Equation (25), the manufacturer's equilibrium wholesale price can be derived:

$$w^* = \frac{a + b_p c}{2b_p} \tag{27}$$

The retailer's equilibrium retail price and service level can be obtained from Equations (23), (24) and (27):

$$p^* = \frac{3a\eta b_p + c\eta b_p^2 - a b_s^2 - c b_p b_s^2}{b_p(4\eta b_p - 2b_s^2)} \tag{28}$$

$$s^* = \frac{a b_s - b_p b_s c}{(4\eta b_p - 2b_s^2)} \tag{29}$$

by substituting p^* and s^* into Equation (15), we get:

$$Q_2^* = a - b_p p^* + b_s s^* = \frac{a\eta b_p - c\eta b_p^2}{4\eta b_p - 2b_s^2} \Rightarrow$$

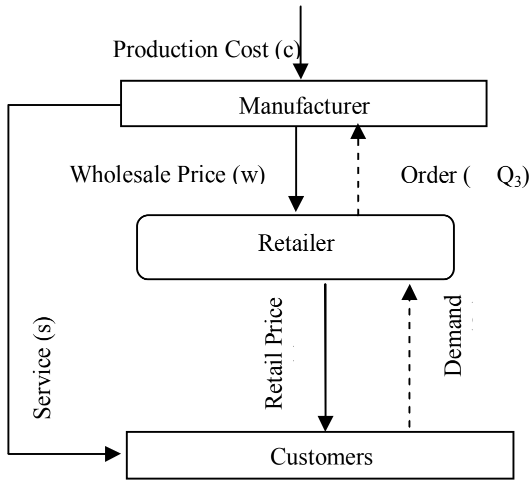
$$Q_2^* = \frac{a\eta b_p - c\eta b_p^2}{4\eta b_p - 2b_s^2} \tag{30}$$

by substituting w^* and Q_1^* into manufacturer profit function, π_{1M}, and Q_1^*, p^* and w^* into retailer profit function, π_{1R}, we get:

$$\pi^*_{2M} = (w^* - c)Q^*_2 \Rightarrow \pi^*_{2M} = \frac{\eta}{2} \times \frac{(a - b_p c)^2}{4\eta b_p - 2b_s^2} \quad (31)$$

$$\pi^*_{2R} = (p^* - w^*)Q^*_2 - \frac{\eta s^{*2}}{2} \Rightarrow \pi^*_{2R} = \frac{\eta}{4} \frac{(a - b_p c)^2}{(4\eta b_p - 2b_s^2)} \quad (32)$$

3. 3. Third Scenario In this scenario, the manufacturer provides service to customers and customer demand for each product is sensitive to two retail price and service have been provided by the manufacture. Figure 3 shows the schematic illustration of the third scenario.



$$Q_3 = a - b_p p + b_s s$$

Figure 3. Schematic illustration of the third scenario

3. 3. 1. Demand Function In this scenario the demand function for the manufacturer and retailer is as follows.

$$Q_3 = a - b_p p + b_s s \quad (33)$$

Other components of this scenario have been described in next sections.

3. 3. 2. Profit Functions In this scenario, the manufacturer can effects on the demand by determining the wholesale price and service level in other hand the retailer can also influence the demand by setting the retail price.

According to the demand function, retail price, wholesale price and retailer's profit function can be described by the following equation:

$$\pi_{3R} = (p - w)Q_3 \quad (34)$$

and according to the demand function, production cost, wholesale price and service level provided by the manufacturer, the manufacturer's profit function can be formulated by the following equation:

$$\pi_{3M} = (w - c)Q_3 - \frac{\eta s^2}{2} \quad (35)$$

where, the service cost function of retailer is $\eta s^2/2$. This function has a Descending return property on service expenditure.

3. 3. 3. Stackelberg Game-3 In this game manufacturer determines the wholesale price and service level. According to manufacturer declaration the retailer decides on the retail price and ordering quantity.

In this scenario, the reaction function of retailer is calculated first and manufacturer solves his problem by knowing how the retailer would react to his decisions.

3. 3. 4. Retailer Reaction Function The retailer in this game has to determine retail price p^* to maximize his profit. That is,

$$p^* \in \arg\max_p \pi_{3R}(p|w,s) \quad (36)$$

where, $\pi_{3R}(p|w,s)$ denotes the retailer profit when he sets retail price p, given earlier decision by the manufacturer is w and s, The first order condition can be shown as

$$\frac{\partial \pi_{3R}}{\partial p} = a - 2b_p p + b_s s + w b_p = 0 \quad (37)$$

The second order condition is shown as follows.

$$\frac{\partial^2 \pi_{3R}}{\partial p^2} = -2b_p \quad (38)$$

Assuming that $b_p > 0$, Hence, The retailer profit function, π_{3R}, is concave in p Therefore, the p calculated above is the optimal reaction function for the retailer. From Equation (37) the retailer's reaction function can be formulated as below:

$$p = \frac{a + b_s s + w b_p}{2b_p} \quad (39)$$

3. 3. 5. Manufacturer Decisions Using the retailer's reaction function (39), the manufacturer's equilibrium wholesale price and service level can be derived from the following first-order condition of the respective manufacturer's profit maximization problem that is shown in Equation (35):

$$\frac{\partial \pi_{3M}}{\partial w} = \frac{a}{2} - \frac{b_s s}{2} - b_p w + b_s s + \frac{b_p c}{2} = 0 \quad (40)$$

$$\frac{\partial \pi_{3M}}{\partial s} = -\frac{b_S w}{2} + b_S w + \frac{b_S c}{2} - b_S c - \eta s = 0 \quad (41)$$

For which the Hessian matrix is

$$H = \begin{bmatrix} \frac{\partial^2 \pi_{3M}}{\partial w^2} & \frac{\partial^2 \pi_{3M}}{\partial w \partial s} \\ \frac{\partial^2 \pi_{3M}}{\partial s \partial w} & \frac{\partial^2 \pi_{3M}}{\partial s^2} \end{bmatrix} = \begin{bmatrix} -b_p & \frac{b_s}{2} \\ \frac{b_s}{2} & -\eta \end{bmatrix} \quad (42)$$

Assuming that $b_p > 0$, $b_s > 0$, $\eta > 0$, $\det(H) = b_p \eta - \frac{b_s^2}{4} > 0$, we have a negative definite hessian. Hence, The manufacturer profit function, π_{3M}, is concave in w and s. Therefore, w and s calculated above are the optimal reaction functions for the manufacturer.

Thus, from Equations (40) and (41), the manufacturer's equilibrium wholesale price and equilibrium service level can be derived as follows:

$$w^* = \frac{b_s B - 2\eta A}{b_s^2 - 4b_p \eta} \quad (43)$$

$$s^* = \frac{2b_p B - Ab_s}{b_s^2 - 4b_p \eta} \quad A = a + b_p c \quad , \quad B = b_s c \quad (44)$$

And the retailer's equilibrium retail price can be obtained from Equations (39), (43) and (44):

$$p^* = \frac{a + b_s s^* + w^* b_p}{2b_p} = \frac{3a\eta + c\eta b_p - b_s^2 c}{4\eta b_p - b_s^2} \quad (45)$$

by substituting p^* and s^* into Equation (33), we get:

$$Q_3^* = a - b_p p^* + b_s s^* \Rightarrow Q_3^* = \frac{a\eta b_p - c\eta b_p^2}{4\eta b_p - b_s^2} \quad (46)$$

By substituting w^* and Q_3^* into manufacturer profit function, π_{3M}, and Substitute Q_3^*, p^* and w^* into retailer profit function, π_{3R}, we get:

$$\pi_{3M}^* = (w^* - c)Q_3^* - \frac{\eta s^{*^2}}{2} \Rightarrow \pi_{3M}^* = \frac{\eta}{2} \times \frac{(a - b_p c)^2}{(4\eta b_p - b_s^2)} \quad (47)$$

$$\pi_{3R}^* = (p^* - w^*)Q_3^* \Rightarrow \pi_{3R}^* = b_p \eta^2 \left(\frac{a - b_p c}{4\eta b_p - b_s^2}\right)^2 \quad (48)$$

3. 4. Results With solving the games, equilibrium solutions have been achieved and after comparing solutions of these scenarios six following results have been concluded:

1) Providing service always increases demand, whether the service is provided by the manufacturer or the retailer.
2) Providing service by the retailer increases the demand more than the manufacturer.
3) Providing service always increases the manufacture and retailer profit, whether the service is provided by the manufacturer or the retailer.
4) Manufacturer profit in the second scenario is more than the other scenarios.
5) Retailer profit in the second scenario is more than the other of scenarios.
6) Retailer earns the most profit when provides service by himself.

Proofs of all comparison results (1) to (6) have been given in Appendix A.

4. CONCLUSION AND FUTURE WORKS

We studied competition in supply chain under pricing and service level. The supply chain consists of one manufacturer and one retailer, where they compete in retail price and service level. In this paper, we mathematically proved the impact of services provided by manufacturer and retailer on the demand and supply chain members' profit.

We solved three manufacturer Stackelberg games. In two games, demand function is nonlinear and customer demand is sensitive to both retail price and service level provided by the manufacturer and the retailer. The optimal decisions of pricing and providing service in these three games are derived and results of three scenarios are compared.

There are several directions for future research. First of all, it will be appealing to use uncertain demand functions. Secondly, the supply chain structure can be changed. Thirdly, service investment sharing between the manufacturer and the retailer can be considered.

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APPENDIX A

Proofs of Scenarios comparison results:

Proof of Result 1. According to the equilibrium ordering quantities of product in the first and the second scenario, the difference between Q_1^* and Q_2^*, can be expressed as follows:

$$Q_2^* - Q_1^* = \frac{a\eta b_p - c\eta b_p^2}{4\eta b_p - 2b_s^2} - \frac{a - b_p c}{4} = \frac{b_s^2(a - b_p c)}{2(4\eta b_p - 2b_s^2)} \quad (49)$$

By assuming that $p > c$, we obtain:

$$p > c \Rightarrow -p < -c \Rightarrow -b_p p < -b_p c \Rightarrow 0 < a - b_p p < a - b_p c$$

$$\Rightarrow (a - b_p c) > 0 \quad (50)$$

From Equation (50) and $b_s^2 > 0$, then:

$b_s^2(a - b_p c) > 0$

Since, the optimal second-order condition in the second scenario is $4\eta b_p - 2b_s^2 > 0$, then

$$Q_2^* - Q_1^* > 0 \Rightarrow Q_2^* > Q_1^* \quad (51)$$

According to the equilibrium ordering quantities of product in the first and the third scenario, the difference between Q_1^* and Q_3^*, can be expressed as follows:

$$Q_3^* - Q_1^* = \frac{a\eta b_p - c\eta b_p^2}{4\eta b_p - b_s^2} - \frac{a - b_p c}{4} = \frac{b_s^2(a - b_p c)}{4(4\eta b_p - b_s^2)} \quad (52)$$

Similarly, $(a - b_p c) > 0$ and $b_s^2 > 0$ then:

$b_s^2(a - b_p c) > 0$

Since, the optimal second-order condition in second scenario is $4\eta b_p - 2b_s^2 > 0$, then

$$Q_3^* - Q_1^* > 0 \Rightarrow Q_3^* > Q_1^* \quad (53)$$

From Equations (51) and (53), then:

$Q_3, Q_2 > Q_1$

Proof of Result 2. According to the equilibrium ordering quantities of product in the second and the third scenario, the difference between Q_2^* and Q_3^*, can be expressed as follows:

$$Q_3^* - Q_2^* = \frac{-4\eta b_p b_s^2(a - b_p c)}{4(4\eta b_p - b_s^2)(4\eta b_p - 2b_s^2)} \quad (54)$$

Since, $4\eta b_p b_s^2 > 0$ and the optimal second-order condition in the second scenario is $4\eta b_p - 2b_s^2 > 0$ and the optimal second-order condition in third scenario is $4\eta b_p - b_s^2 > 0$, then:

$$Q_3^* - Q_2^* = \frac{-4\eta b_p b_s^2(a - b_p c)}{4(4\eta b_p - b_s^2)(4\eta b_p - 2b_s^2)} < 0 \Rightarrow Q_3^* < Q_2^*$$

Proof of Result 3. According to the manufacturer optimal profit functions in the first and the second scenario (i.e. π_{1M}^* and π_{2M}^*), the difference between π_{1M}^* and π_{2M}^*, can be expressed as follows:

$$\pi_{2M}^* - \pi_{1M}^* = \frac{\eta}{2} \times \frac{(a - b_p c)^2}{4\eta b_p - 2b_s^2} - \frac{(a - b_p c)^2}{8b_p} = \frac{b_s^2(a - b_p c)^2}{4b_p(4\eta b_p - 2b_s^2)} \quad (55)$$

Since, $b_s^2(a - b_p c)^2 > 0$ and the optimal second-order condition in the second scenario is $4\eta b_p - 2b_s^2 > 0$, then:

$$\pi_{2M}^* - \pi_{1M}^* > 0 \Rightarrow \pi_{2M}^* > \pi_{1M}^* \quad (56)$$

According to the manufacturer optimal profit functions in the first and the third scenario (i.e. π_{1M}^* and π_{3M}^*), the difference between π_{1M}^* and π_{3M}^*, can be expressed as follows:

$$\pi_{3M}^* - \pi_{1M}^* = \frac{\eta}{2} \times \frac{(a - b_p c)^2}{(4\eta b_p - b_s^2)} - \frac{(a - b_p c)^2}{8b_p} = \frac{b_s^2(a - b_p c)^2}{8b_p(4\eta b_p - b_s^2)} \quad (57)$$

Similarly, $b_s^2(a - b_p c)^2 > 0$ and $4\eta b_p - b_s^2 > 0$, then:

$$\pi^*_{3M} - \pi^*_{1M} > 0 \Rightarrow \pi^*_{3M} > \pi^*_{1M} \tag{58}$$

From Equatins (56) and (58), then:

$\pi_{3M}, \pi_{2M} > \pi_{1M}$

According to the retailer optimal profit functions in the first and the second scenario (i.*e.* π^*_{1R} and π^*_{2R}), the difference between π^*_{1R} and π^*_{2R}, can be expressed as follows:

$$\pi^*_{2R} - \pi^*_{1R} = \frac{\eta}{4} \times \frac{(a-b_p c)^2}{(4\eta b_p - 2b_s^2)} - \frac{(a-b_p c)^2}{16 b_p} = \frac{b_s^2 (a-b_p c)^2}{8 b_p (4\eta b_p - 2b_s^2)} \tag{59}$$

Since, $b_s^2 (a - b_p c)^2 > 0$ and the optimal second-order condition in the second scenario is $4\eta b_p - 2b_s^2 > 0$, then:

$$\pi^*_{2R} - \pi^*_{1R} > 0 \Rightarrow \pi^*_{2R} > \pi^*_{1R} \tag{60}$$

According to the retailer optimal profit functions in the first scenario and in the third scenario *(i.e.* π^*_{1R} and π^*_{3R}), the difference between π^*_{1R} and π^*_{3R}, can be expressed as follows:

$$\pi^*_{3R} - \pi^*_{1R} = b_p \eta^2 \frac{(a-b_p c)^2}{(4\eta b_p - b_s^2)^2} - \frac{(a-b_p c)^2}{16 b_p} = \tag{61}$$

$$\frac{(a-b_p c)^2 (8\eta b_p b_s^2 - b_s^4)}{16 b_p (4\eta b_p - b_s^2)^2}$$

Since, $(8\eta b_p b_s^2 - b_s^4) > 0$ and the optimal second-order condition in the third scenario is $4\eta b_p - b_s^2 > 0$, then:

$$\pi^*_{3R} - \pi^*_{1R} > 0 \Rightarrow \pi^*_{3R} > \pi^*_{1R} \tag{62}$$

From Equations (60) and (62), then

$\pi_{3R}, \pi_{2R} > \pi_{1R}$

Proof of Result 4. According to the manufacturer optimal profit functions in the second and the third scenario *(*i.e. π^*_{2M} and π^*_{3M}), the difference between π^*_{2M} and π^*_{3M}, can be proposed as follows:

$$\pi^*_{3M} - \pi^*_{2M} = \frac{\eta}{2} \times \frac{(a-b_p c)^2}{(4\eta b_p - b_s^2)} - \frac{\eta}{2} \times \frac{(a-b_p c)^2}{(4\eta b_p - 2b_s^2)} \tag{63}$$

$$\pi^*_{3M} - \pi^*_{2M} = \frac{-\eta b_s^2 (a-b_p c)^2}{2(4\eta b_p - b_s^2)(4\eta b_p - 2b_s^2)} \tag{64}$$

Since, $\eta b_s^2 (a - b_p c)^2 > 0$ and the optimal second-order condition in second scenario is $4\eta b_p - 2b_s^2 > 0$, and the optimal second-order condition in the third scenario is $4\eta b_p - b_s^2 > 0$, then:

$$\pi^*_{3M} - \pi^*_{2M} < 0 \Rightarrow \pi^*_{3M} < \pi^*_{2M} \tag{65}$$

Proof of Result 5. According to the retailer optimal profit functions in the second and the third scenario (i.e. π^*_{2R} and π^*_{3R}), the difference between π^*_{2R} and π^*_{3R}, can be calculated as follows:

$$\pi^*_{3R} - \pi^*_{2R} = \frac{b_p \eta^2 (a-b_p c)^2}{(4\eta b_p - b_s^2)^2} - \frac{\eta}{4} \frac{(a-b_p c)^2}{(4\eta b_p - 2b_s^2)} \tag{66}$$

$$\pi^*_{3R} - \pi^*_{2R} = \frac{-\eta b_s^4 (a-b_p c)^2}{4(4\eta b_p - 2b_s^2)(4\eta b_p - b_s^2)^2} \tag{67}$$

Since, $\eta b_s^2 (a - b_p c)^2 > 0$ and the optimal second-order condition in second scenario is $4\eta b_p - 2b_s^2 > 0$, and the optimal second-order condition in third scenario is $4\eta b_p - b_s^2 > 0$, then:

$$\pi^*_{3R} - \pi^*_{2R} < 0 \Rightarrow \pi^*_{3R} < \pi^*_{2R} \tag{68}$$

Impact of Service on Customers' Demand and Members' Profit in Supply Chain

RESEARCH NOTE

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چکیده

در این مقاله اثر خدمات ارائه شده توسط تولیدکننده و خرده فروش بر روی تقاضا و سود اعضای زنجیره تامین بررسی شده است. ساختار زنجیره تامین مورد نظر شامل یک تولیدکننده و یک خرده فروش می‌باشد و تقاضای مشتریان به قیمت خرده فروشی و سطح خدمات وابسته است. برای به‌دست آوردن جواب‌های بهینه از چارچوب نظریه بازی‌ها استفاده شده است. ما در این مقاله جواب‌های بهینه را در حالتی که تولیدکننده رهبر بازار است تحت سه سناریوی مختلف به‌دست آورده‌ایم. این سناریوها شامل مواردی است که تولیدکننده و خرده‌فروش هیچ‌کدام هیچ‌گونه خدماتی به مشتری ارائه نمی‌کنند. مورد دیگر اینکه، خرده فروش به مشتریان خدمات ارائه می‌کند و در سناریوی آخر، تولیدکننده به مشتریان خدمات ارائه می‌کند. ما تمام نتایج سناریوها را با هم مقایسه کرده و بهترین حالت را برای هریک از اعضای زنجیره تامین مشخص نموده‌ایم.

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