Price and inventory policy strategy model in a price sensitive dual channel supply chain structure considering product substitution

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Abstract. Dual channel supply chain structure, which utilizes both online and traditional offline channel, is widely adopted by a lot of companies. The structure offers better market coverage and profitability. Despite the advantages, it also brings some challenges to coordinate the strategy of the channel. This paper proposes a pricing and inventory policy model to achieve better performance of the structure, where a product substitution was introduced in the offline channel. A price sensitive linear demand function was also incorporated in this EOQ model. The model then evaluated by analysing the profit in two scenarios, the Stackelberg Leadership scenario and Total Profit scenario. The results show that the total profit of this structure is higher under Total Profit scenario, in which the supply chain entities make decision simultaneously. The model also shows that the product substitution gives a positive effect to the profit and become a competitive advantage of the offline channel.

1. Introduction
The speedy information technology development has significantly improved supply chain performance in every industry. The use of internet brings many opportunities to the companies [1]. The development enables a new supply chain structure which integrates conventional selling at retail store (offline) with internet based direct selling (online) called dual channel supply chain (DCSC) [2]. Simple DCSC structure usually consists of manufacturer, retail store, and online channel. The structure can be directly managed by manufacturer. Offline consumers demands are fulfilled by inventory in retailer, while online consumers demands are fulfilled by inventory in manufacturer [3].

In DCSC structure, online and offline channels can compete with each other to attract consumers, mostly by pricing strategy. In this structure, where the supply chain consists of several entities, there is a power hierarchy that influences the decision making process [4]. In DCSC structure which consists of manufacturer and retailers, the manufacturer, which has role as the leader, usually has a higher bargaining power that decides the pricing first. The retailers have the role as followers that decide the pricing based on manufacturer price [1]. This decision making scenario is known as Stackelberg Leadership. In this scenario, each player works hard to maximize their own profit without considering the whole profit of supply chain [5]. On the other side, there is a scenario where players make decision
at the same time (simultaneous) [4] that we refer as the Total Profit scenario. In Total Profit scenario, players cooperate with each other to maximize profit of the whole supply chain [5].

Besides price, inventory also has a very important role, especially in fulfilling consumer demand to reach the required service level. The high level of inventory causes high saving cost and company’s capital is stuck in inventory form, while if the number of inventory is too low, consumer demand cannot be fulfilled and it causes loss of sales [6]. Therefore, the decision about the level of inventory becomes the main problem in minimizing inventory cost while it still maintains good service level [7].

In previous research [8], EQQ model with linear demand function is used to maximize profit from DCSC structure. It also introduced product substitution in offline channel. Product substitution plays important role especially when consumer think that main product price in both channels is too expensive and/or when there is empty inventory for the main product in both channels. The model used Stackelberg Leadership scenario. Coordination by sharing information within entities to maximize total profit of the whole supply chain, as in the Total Profit scenario explained earlier, is not considered yet. Hence this study developed pricing and inventory policy in DCSC structure by considering product substitution, and applying the two scenarios, Total Profit and Stackelberg Leadership.

2. Model
The development of the model is based on [8], which is a profit model of DCSC structure, considering product substitution, using Stackelberg Leadership scenario.

2.1. Conceptual model
The model considers a dual channel supply chain structure consisting of a central warehouse, one offline channel and one online channel (see figure 1). We assume that the product substitution only available in offline channel. Central warehouse gets its product supply from two manufacturers, Manufacturer A for the main product and Manufacturer B for the substitute product. The warehouse then distributes the product to the offline and online channel. There will be either one of the two possible scenarios which may occur. The first one is Stackelberg Leadership scenario, where central warehouse as a leader will make the prices decision first and announce the prices to offline and online channel, followed by online and offline channel sequentially. The second is Total Profit scenario, where all entities in the structure will make joint prices decision in order to maximize total profit of the structure.

![figure 1. Dual channel supply chain structure with product substitution.](image)

2.2. Notation
Parameters and variables used in this model are denoted by these following notations.

\( i \): index for product type, \( A \) for main product and \( B \) for substitute product;

\( j \): index for the structure’s entity, \( w \) for central warehouse, \( s \) for offline channel and \( o \) for online channel;

\( \beta_s \): price sensitivity in offline channel (unit/Rp);

\( \gamma_{so} \): cross-price sensitivity of offline channel to substitute online channel (unit/Rp);
$p_i^j$ : price of product $i$ for entity $j$ (Rp) (decision variable);

$Q_{ij}^*$ : optimal order quantity for product $i$ in entity $j$ (unit) (decision variable);

$T_{ij}^*$ : reorder point for product $i$ in entity $j$ (days) (decision variable);

$\rho$ : proportion of customers who prefer online than offline channel relative to the total demand;

$\sigma$ : proportion of customers who prefer substitute product over main product in offline channel;

$\beta_a$ : price sensitivity in online channel (unit/Rp);

$\gamma_{os}$ : cross-price sensitivity of online channel to substitute offline channel (unit/Rp);

$\gamma_{BA}$ : cross-price sensitivity of product $B$ to substitute product $A$ in offline channel (unit/Rp);

$D_{max}$ : maximum demand when the price is equal to zero (unit/period);

$D_i^j$ : demand of product $i$ for entity $j$ (unit/period);

$R_j$ : revenue of entity $j$;

$c_i$ : cost of product $i$ from manufacturer (Rp/unit);

$\pi_j$ : profit of entity $j$;

$h_j$ : holding cost for entity $j$ (Rp/unit/period);

$s_j$ : ordering cost for entity $j$ (Rp/order);

$O_{bj}$ : total purchasing cost for entity $j$ (Rp);

$O_{o}$ : ordering cost for entity $j$ (Rp);

$O_{hj}$ : total holding cost for entity $j$ (Rp);

$O_{Tj}$ : total inventory cost for entity $j$ (Rp);

2.3. Model development

Referring to [7], linear demand functions of this model are as follow.

$$D_A^s = \rho D_{max} - \beta_o p_A^o + \gamma_{os} p_A^o$$  \hspace{1cm} (1)

$$D_A^s = (1 - \sigma)(1 - \rho)D_{max} - \beta_s p_A^s + \gamma_{so} p_A^s$$  \hspace{1cm} (2)

$$D_A^B = \sigma(1 - \rho)D_{max} - \beta_s p_B^s + \gamma_{BA} p_A^B$$  \hspace{1cm} (3)

2.3.1. Inventory model. We use a basic EOQ model as the inventory control method. All the assumptions in EOQ model is applied in this model. According to Bahagia [9], inventory cost in EOQ model consist of purchasing cost, ordering cost, and holding cost.

$$O_{Tw} = c_A(D_A^A + D_A^S) + (c_B \times D_B^S) + s_w \left( \frac{D_A^A + D_A^S}{Q_{Aw}} + \frac{D_B^S}{Q_{Bw}} \right) + h_w \left( \frac{Q_{Aw} + Q_{Bw}}{2} \right)$$  \hspace{1cm} (4)

$$O_{Ts} = (P_A^A \times D_A^S) + (P_B^S \times D_B^S) + s_s \left( \frac{D_A^A}{Q_{As}} + \frac{D_B^S}{Q_{Bs}} \right) + h_s \left( \frac{Q_{As} + Q_{Bs}}{2} \right)$$  \hspace{1cm} (5)

$$O_{To} = (P_A^A \times D_A^S) + s_o \frac{D_A^A}{Q_{Ao}} + h_o \frac{Q_{Ao}}{2}$$  \hspace{1cm} (6)

Optimality of order quantity and reorder point are the decision variable of inventory policies in EOQ model. Formulation of optimal order quantity and reorder point for central warehouse can be expressed by the following equations.

$$Q_{Aw}^* = \left( \frac{2s_w(D_A^A + D_A^S)}{h_w} \right)^{-1}$$  \hspace{1cm} (7)

$$Q_{Bw}^* = \left( \frac{2s_wD_B^S}{h_w} \right)^{-1}$$  \hspace{1cm} (8)

$$T_{Aw}^* = \left( \frac{2s_w}{(D_A^A + D_A^S)h_w} \right)^{-1}$$  \hspace{1cm} (9)

$$T_{Aw}^* = \left( \frac{2s_w}{(D_A^S + D_A^A)h_w} \right)^{-1}$$  \hspace{1cm} (10)

Optimal order quantity and reorder point for offline channel can be expressed by the following equations.
\[ Q_{As} = \left( \frac{2s_s D_s^A}{h_s} \right)^{-1} \]  
\[ Q_{Bs} = \left( \frac{2s_s D_s^B}{h_s} \right)^{-1} \]  
\[ T_{As} = \left( \frac{2s_s}{D_s^A \times h_s} \right)^{-1} \]  
\[ T_{As}^* = \left( \frac{2s_s}{D_s^B \times h_s} \right)^{-1} \]  

Formulation of optimal order quantity and reorder point for online channel can be expressed by the following equations.

\[ Q_{A_o}^* = \left( \frac{2s_o D_o^A}{h_o} \right)^{-1} \]  
\[ T_{A_o}^* = \left( \frac{2s_o}{D_o^A \times h_o} \right)^{-1} \]  

2.3.2. Revenue model. Revenue of each entity can be obtained by multiplying demand of its product with the product’s price and can be expressed by the following equations.

\[ R_w = P_w^A (D_s^A + D_o^A) + (P_w^B \times D_s^B) \]  
\[ R_s = (P_s^A \times D_s^A) + (P_s^B \times D_s^B) \]  
\[ R_o = P_o^A \times D_o^A \]  

2.3.3. Stackelberg leadership model. Central warehouse maximized its profit by the following equation.

\[ \pi_w = (P_w^A - c_A) (D_s^A + D_o^A) + (P_w^B - c_B) D_s^B - s_w \left( \frac{D_s^A + D_o^A}{Q_{A_w}} + \frac{D_s^B}{Q_{B_w}} \right) - h_w \left( \frac{Q_{A_w} + Q_{B_w}}{2} \right) \]  

Maximization of function (20) should consider these following constraints.

\[ P_w^A \geq c_A \]  
\[ P_w^B \geq c_B \]  
\[ Q_{A_w}, Q_{B_w} \geq 0 \]  

The profit of online channel can be expressed by the following equation.

\[ \pi_s = (P_s^A - P_w^A) D_s^A + (P_s^B - P_w^B) D_s^B - s_s \left( \frac{D_s^A}{Q_{As}} + \frac{D_s^B}{Q_{Bs}} \right) - h_s \left( \frac{Q_{As} + Q_{Bs}}{2} \right) \]  

The previous variables, \( P_w^A \) and \( P_w^B \) now become parameters in function (24), where their values were determined from equation (20). Function (24) should consider the following constraint.

\[ Q_{A_w}^* \geq 0 \]  

Using the prices at central warehouse (\( P_w^A \) and \( P_w^B \)), the price at online channel (\( P_o^A \)) and the demand at online channel (\( D_o^A \)), offline channel maximized its profit.

\[ \pi_o = (P_o^A - P_w^A) D_o^A - s_o \frac{D_o^A}{Q_{A_o}} - h_o \frac{Q_{A_o}^*}{2} \]  

2.3.4. Total profit model. In this scenario, all entities in the structure will make a joint decision to maximize the entire structure’s profit. Total profit can be expressed by the following equation.
\[ \pi_{\text{total}} = \left\{ \left( (P^A - c_A)D^A + (P^O - c_O)D^O + (P^B - c_B)D^B \right) \right\} \sum_s \left( \frac{d^A}{q^A_s} + \frac{d^B}{q^B_s} + h_s \left( \frac{q^A_s + q^B_s}{2} \right) + s_o \frac{d^o}{q^o_s} + h_o \frac{q^o_s}{2} \right) \]  

(27)

3. Numerical example

Parameters in this model are adopted from [8]. There are some parameters values that were changed, price and cross-price sensitivity, because the data from previous research was not feasible in this model. Consider a DCSC structure with the following data: \( D_{\text{max}} = 84 \) units/month, \( \rho = 0.7 \), \( \sigma = 0.5 \), \( \beta_o = 0.1 \times 10^{-3} \) unit/Rp, \( \beta_s = 0.08 \times 10^{-3} \) unit/Rp, \( \gamma_{os} = 0.06 \times 10^{-3} \) unit/Rp, \( \gamma_{so} = 0.04 \times 10^{-3} \) unit/Rp, \( \gamma_{BA} = 0.05 \times 10^{-3} \) unit/Rp, \( c_A = Rp320,000/unit \), \( c_B = Rp295,000/unit \), \( s_w = Rp95,000/order \), \( h_w = Rp20,000/unit/month \), \( s_s = Rp135,000/ord \), \( h_s = Rp22,000/unit/month \), \( s_o = Rp110,000/order \) and \( h_o = Rp22,000/unit/month \). Using LINGO 11, the optimal value for the objective function and each variable in both scenarios can be obtained. The result is presented in table 1.

| Table 1. Numerical example results. |
|------------------------------------|
| Stackelberg Scenario | Total Profit Scenario |
| Central Warehouse | Offline Channel | Online Channel | Central Warehouse | Offline Channel | Online Channel |
| \( P^i_j \) | 502,143 | 383,839 | 552,143 | 452,589 | 789,286 | 338,732 | 297,976 | 477,144 | 393,215 | 664,286 |
| \( Q^i_{ij} \) | 13.78 | 8.15 | 0 | 7.01 | 11.42 | 14.46 | 6.89 | 3.50 | 7.83 | 14.49 |
| \( T^i_{ij} \) | 20.68 | 34.99 | 0 | 52.55 | 26.31 | 19.71 | 41.35 | 105.10 | 47 | 20.70 |
| \( O^i_{ij} \) | 8,903,776 | 1,689,500 | 8,083,277 | 8,941,977 | 2,078,018 | 7,432,177 |
| \( O_{\text{Total}} \) | 18,676,553 | 18,452,173 |
| \( \pi^i_j \) | 3,825,956 | 120,857 | 2,177,437 | 0 | 365,196 | 6,517,823 |
| \( \pi_{\text{Total}} \) | 6,124,250 | 6,883,019 |

4. Analysis

It can be seen from table 1 that the total profit in Total Profit scenario is higher than in Stackelberg Leadership scenario. It is also found that the prices at each entity is lower in Total Profit scenario, which shows better competitiveness.

![Figure 2. Impact of \( \rho \) to profit in Total Profit scenario.](image)

![Figure 3. Impact of \( \rho \) to profit in Stackelberg Leadership scenario.](image)

The consumer preference to online channel (\( \rho \)) influences the profits of each entity, and also the whole structure. The impact can be observed in figure 2 and figure 3. Parameter \( \gamma_{BA} \) measures cross-price sensitivity of product B to substitute product A in offline channel. In both scenarios, higher \( \gamma_{BA} \)
will give positive impact to the profit of offline channel. The impact can be observed in figure 4 dan figure 5.

![Figure 4](image1.png)  
**Figure 4.** Impact of $\gamma_{BA}$ to profit in Total Profit scenario.

![Figure 5](image2.png)  
**Figure 5.** Impact of $\gamma_{BA}$ to profit in Stackelberg Leadership scenario.

5. Conclusion and further research

This study has developed a model to accommodate price and inventory strategy in DCSC structure, implementing two scenarios namely Total Profit dan Stackelberg Leadership. The result shows that the total profit in Total Profit scenario is higher compared to Stackelberg Leadership scenario. There is a requirement to enable Total Profit scenario, which is coordination and information sharing, to get prices decision altogether. Hence, if all entities can collaborate and share information, Total Profit scenario is preferable. The study can be further developed by considering probabilistic demand and product lead time. There is also a possibility to develop application and the platform suitable, to enable the coordination. Application of the model to several different products is also interesting for further research.

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