Environmental factor analysis of green supply chain based on pricing decision

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Abstract. With facing an increasing challenging of environmental pollution and climate change, the whole society, including manufacturer factories, transportation enterprises, retailers and customers, etc. are all have responsibility for controlling pollutant discharge and environmental protection. This paper focus on a model of green supply chain which consisting of one manufacturer and two retailers. Unlike the traditional supply chain, the green supply chain pay more attention to achieve sustainable development and long term profit by reducing pollutants and carbon emissions. The results of analysis indicate that when customers’ awareness of environmental protection increased, accordingly, the manufacturer would strive to increase the development of green product, in order to expand the market influence and raise the green product demand.

1. Introduction
It is obvious that the challenging of earth pollution and environmental pressure becomes more and more severe and difficult in last decade. In order to face this increasing severe challenge, it is necessary to investigate the green supply chain, which is environmentally friendly and conducive to the suppression of environmental pollution [1]. In this paper, we consider green supply chain consisting of one manufacturer and two retailers that develop and sell a type of green product to customers with different environmental awareness. In order to analyze the decision process of supply chain members, we construct a Stackelberg game model with consideration of consistent /inconsistent pricing strategy and different demand functions.

2. Literature Review
In the paper we review literatures with two streams related to our research, (1) analysis about the pricing decision process, and (2) the impact of external factors such as government intervention or information transparency on supply chain members.

Zu, Chen and Fan [1] studied a green supply chain composed of one supplier and one retailer and analyzed optimal strategy by differential game model. Liu, Anderson and Cruz [2] focused the impact factors between supply chain members’ profit coordination and customers’ different levels of environmental awareness. Zhu and He [3] investigated designing problem of green environmental protection product with considering the competition between supply chain members, and get the conclusion of the optimal balance of green product design is dependent on the competitive strength of the supply chain members. Jamali and Barzoki[4] considered the competition problem between an environmental green product and a traditional non-green product in a compound supply chain
consisting of two suppliers and two retailer with direct internet channels and traditional sale channels, and a coordination model between centralized system and decentralized system was researched. Basiri and Heydari[5] investigated negotiation and coordination problem in a green supply chain which an environmental green product and a traditional non-green product are designed and sold at the same time. Different types of products’ demand rely on several factors such as retail prices and green degree of them. Zhang, Wang and You [6] focused on the choosing of environmental green product and traditional non-green product within a green supply chain consisting of one supplier and one retailer.

Xu, Qi and Bai[7] studied the mixed channel supply chain with traditional channel and network sells channel and take carbon emission cap regulation into consideration. When the carbon emission cap regulation is fully satisfied, the impact of supplier’s profit is more than retailer’s. Chernonog and Avinadav[8] researched the timing-saving product and its production and distribution system by using contract theory, in which consisting of one supplier and one retailer. Madani and Barzoki[9] studied the competition between the government and two different types of supply chain, one is traditional non-green supply chain, another one is environmental green supply chain. Mahmoudi and Barzoki[10] built a mathematics model to describe the government’s important coordination and guiding role in the green product supply chain. The results demonstrate that the government’s carbon emissions policy has a significant impact on manufacturer and consumers. Dukes, Esther and Geylani[11] researched the mechanism about the degree of symmetry and transparency of information have a positive or negative effect on the profit level of the supply chain members.

3. Modeling
In this section, we construct the model of supply chain consisting of one manufacturer and two retailers. The manufacturer is the leader of the supply chain and the driver of green product innovation. The decision process of a stackelberg game decentralized model is studied. Firstly, the manufacturer determines the wholesale prices \(w_1\) and \(w_2\) with considering the reaction of the two retailers to maximize his profit. Secondly, the retailers determine their retail prices \(p_1\) and \(p_2\) with considering the reaction of consumers to maximize their profit respectively. The demand functions of retailers are monotonous incremental linear function of retail prices and green degree of products. The mathematics model can be formulated as following

\[
\begin{align*}
\max \pi_m(w_1, w_2, \theta) = (w_1 - c_1)q_1 + (w_2 - c_2)q_2 - k\theta^2 \\
\text{subject to } \max \pi_1(p_1, p_2) = (p_1 - w_1)q_1 \\
\max \pi_2(p_1, p_2) = (p_2 - w_2)q_2
\end{align*}
\]

Where the demand functions of two retailers are as following

\[
q_1(p_1, p_2) = a_1 - bp_1 + ep_2 \\
q_2(p_1, p_2) = a_2 - bp_2 + ep_1
\]

Using the backward sequential decision making approach, optimal solutions can be calculated as follows:

\[
\begin{align*}
p_1^* &= \frac{2a_1b + a_2e + 2b^2w_1 + bew_2}{4b^2 - e^2} \\
p_2^* &= \frac{2a_2b + a_1e + 2b^2w_2 + bew_1}{4b^2 - e^2} \\
w_1^* &= \frac{c_1b^2 + a_1b - c_1e^2 + a_2e}{2(b^2 - e^2)} \\
w_2^* &= \frac{c_2b^2 + a_2b - c_2e^2 + a_1e}{2(b^2 - e^2)}
\end{align*}
\]

Substitute the optimal solution \(w_1^*, w_2^*, p_1^*, p_2^*\) into profit function \(\pi_m, \pi_1, \pi_2\), the optimal profit of them can be calculated.

In the situation of \(w_1 = w_2, p_1 \neq p_2\), the model can be formulated as
Using the backward sequential decision making approach, optimal solutions is calculated as follows:

\[
\begin{align*}
\max_{p_{21} \geq 0} & \quad \Pi_{21} = (w_2 - c_1)q_1 + (w_2 - c_2)q_2 \\
\text{subject to } & \quad \max_{p_{21} \geq 0} \Pi_{21} = (p_{21} - w_2)q_1 \\
\max_{p_{22} \geq 0} & \quad \Pi_{22} = (p_{22} - w_2)q_2
\end{align*}
\] (4)

Substitute the optimal solution \(w_2^*, p_{21}^*, p_{22}^*\) into profit function \(\Pi_{1m}, \Pi_{11}, \Pi_{12}\), the optimal profit of them can be calculated.

\[
\max \Pi_{p_1^*, p_2^*} - \max \Pi_{p_1 = p_2^*} = \frac{(a_i - a_2 + bc_1 - bc_2 + ec_1 - ec_2)^2}{8(b + e)} \geq 0
\] (5)

4. Case Study

In this section, a numerical example is studied to show the relationship between the profits of the supply chain members and some parameters. We use the model in section 3 and specify the parameters as following: \(a_1 = a_2 = 10\), \(b = 3\), \(c = 0.5\). The results for the total supply chain and the manufacturer are presented in Figure 1.

5. Conclusions

In this paper, a pricing decision model of green product supply chain with consistent and inconsistent wholesale prices strategy is analyzed. The results indicate that the profit of the total supply chain in inconsistent wholesale prices strategy is more than the profit in consistent strategy. In order to maximize the total profit, a coordination scheme should be carried out. So, further research can consider the coordination and negotiation between consistent and inconsistent wholesale price strategy in green product supply chain model.
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