Research on Green Supply Chain Optimization in Accommodation Industry Based on Stackelberg Model

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ABSTRACT
As market competition intensifies, the importance of dual-channel supply chain in the green accommodation industry is becoming more and more prominent. The merchant model is the main operating model in the hospitality industry when implementing a dual-channel green supply chain. However, a lot of news and facts show that there are a lot of channel conflicts and free-riding behaviors in the dual-channel supply chain when implementing the merchant model for operation. For this reason, how to resolve these channel conflicts and free-rider behavior becomes the key to improve the efficiency and greenness of hotel operations. This study uses the Stackelberg model and numerical simulation experiments with Matlab software to explore the optimization of a green dual-channel supply chain consisting of a hotel and an online travel agency under the influence of channel preference and free-rider behavior in the merchant mode of operation. The results show that channel preference and free-rider behavior reduce the greenness and operational efficiency of the supply chain. In this case, enhancing cooperation between hotels and online travel agencies and allowing them to make joint decisions can effectively address these issues. The results of the study can help the hotel industry develop an effective dual-channel distribution model to optimize revenue and product greenness.

Keywords: hotel green supply chain; dual-channel, Stackelberg game, numerical simulation

1. INTRODUCTION

There are two main forms of cooperation between hotels and OTA: agency model and merchant model. In the agency model, the hotel pays commission to OTA, which sells hotel products to the hotel as an agent. Under the wholesaler model, OTA buys rooms from hotels at wholesale prices and sells rooms independently as a retailer.

Working with OTA allows hotels to establish a dual-channel supply chain in order to expand their market and gain more profit, but there are also some problems. Under the agency model, hotels can control all the sales process, but they need to pay high commissions. With the formation of OTA oligopoly, commissions are increasing. Meanwhile, as more and more hotels choose OTA to showcase and sell their products. Nowadays, in order to get more attention and clicks, hotels have to buy the top ranking positions on online travel agency websites by bidding for them.

In the business model, the conflict between hotels and OTA has become more intense. Since OTA is a retailer under the wholesaler model, hotels cannot control the sales process of OTA, and there are problems such as channel competition, price competition, and free-rider behavior between OTA and hotels [6] [10]. Therefore, it is crucial to understand how hotels can cooperate with OTA and optimize the cooperation mechanism.

On the other hand, with the increase of society's demand for environmental sustainability, the environmental issues of hotels have been paid attention to. Green supply chain management, as an important means to achieve green production and sustainable development, has received wide attention from the hotel industry. How to build a "green supply chain" has become a new challenge for the hotel industry

A survey by Booking.com shows that in 2018, more than 68% of consumers prefer eco-stay hotels. Meanwhile, more than 48% of hotels claimed they were eco-friendly in 2013. Kang et al (2010) [5] found that consumers are now willing to pay more for eco-friendly hotels and that the green supply chain has become a core competency for hotels. How to introduce dual-channel distribution channels into the green supply chain and optimize green supply chain management has become a growing concern.

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The environmental friendliness of a green product is usually expressed by the degree of greenness of the product. For green products, the demand is not only related to the price, but also related to the greenness of the product. In a two-channel green supply chain under the merchant model, the green innovation efforts and green costs of room service are paid by the hotel. For online travel agencies, they can independently set the price of their products and enjoy the "green dividend" for free. Therefore, it is difficult to maximize the revenue of hotels in the supply chain while ensuring the maximum greenness of the product.

To fill this gap and to make some suggestions on the dual-channel green supply chain in the hospitality industry under the merchant model. In this paper, we propose the game model of Stackelberg game to explore the dual-channel green supply chain consisting of hotel and online travel agency (OTA) under the merchant model, and further try to understand the problem of greenness optimization, price conflict and free-rider behavior to finally maximize the profit of hotel and online travel agency.

2. NOTIONS AND HYPOTHESIS

2.1 Notions and basic model

Consider a hotel A with capacity T can offer its rooms only through two different channels: the offline channel and online channel. offline channel is a tradition channel controlled by hotel, and the online channel is operated by an independent OTAs.In the dual-channel green supply chain, hotel A choices merchant model to cooperate with OTAs. Under merchant model, hotel is a leader and decide the green degree of rooms, wholesale price. OTAS is a follower, decide whether to purchase a room according to green degree of rooms and wholesale price, meanwhile set an online channel price according to the price of offline channel.

Green products and green services will attract customers with green needs. According to Wang et al (2020) [9], it is assumed that green products attract the same number of green consumers online and offline. Meanwhile, green product promotion is a key part of the green supply chain. From Guo et al (2014) [4], OTA has strong promotion capability. Meanwhile, the promotion ability of OTA is the main reason for hotels to cooperate with it. Therefore, the online channel of online travel agency is the main body to implement promotional behaviors.

Assuming that ota undertakes all the promotion efforts, hotels can enjoy the results of ota's promotion (free-rider behavior), and the reality is the same. Hotel free-rider behavior is reflected in the transfer of some of the market demand inspired by the online channel promotion by hotels to the offline channel. All parameters used in this paper are shown in Table 1.

Table 1. Definition of the parameters.

Parameter	Description
T	The capacity of hotel H
H	Number of travelers browsing through OTA during the sales cycle
μ	The rooms wholesale price set by hotel for OTAS
p_H	The rooms price on offline channel set by hotel
p_O	The rooms price on online channel set by OTAS
k	Discount rate ($0 < k < 1$)
θ	The consumer channel preferencedegree of offline channel ($0 < \theta < 1$)
ϵ	The green product promotion effort level
σ	Promotion cost coefficient
β	Greenproduct development cost coefficient
α_{gre}	Elasticity of demand to green degree
α_{pro}	Elasticity of demand to promotion level
r	The Free-riding degree ($0 < \mathrm{r} < 1$)
τ	The green degree of supply chain

Assume that the sales cost of both online and offline retailers is zero, which can be extended to the case of non-zero. Consider only the green effort cost and green promotion cost. The green effort cost and the green promotion cost are related to the actual results with a quadratic function, that is $S(\epsilon) = \frac{\sigma\epsilon^2}{2}$ and $h(\tau) = \frac{\beta\tau^2}{2}$.

According to the studies about OTAS price strategy [8], OTAs will refer to offline room prices and give a discount when set the online price. Where $p_O = kp_H$ and $k \in (0,1)$. Dan, Xu and Liu (2012) [3] thought the demand of OTAs is related to price. The studies of Chan (2013) [2] show that the room green degree and promotion of green product also will impact the demand of dual-channel supply chain. Refer to the above literatures, we assume the demand function of offline channel and online channel is D_H and D_O, where $D_H =$

$r\alpha_{pro}\epsilon + \alpha_{gre}\tau + \varepsilon$ and $D_O = d_O == (1-k)H + (1-r)\alpha_{pre}\epsilon + \alpha_{gre}\tau$.

To simplify the equation, assume that the elasticity of demand to green degree and promotion $\alpha_{gre} = \alpha_{pro} = 1$, which can be extended to other cases. Refer to related research, we think the stochastic demand ε is the main demand for offline channel, which represents a part of loyal customers and no booking consumers of the hotel. They are price-insensitive and willing to pay a higher price to secure a room. The research of Amiri point that the analytical solution obtained from uniform distribution does not affect the research conclusion [1]. So, we assume ε is distributed uniformly on $[-u, u]$.

Meanwhile, considering when hotel development of green effort and OTAs implement promotion, there will be a part of the new demand about green demand is attracted, they are also price-insensitive. Those new demands reflected by d_{H}. For demand function D_O, assume that in a sales cycle, there are H travelers browsing the hotel through OTAs. $(1-k)H$ reflects the changes in OTAs demand after consideration of price competition, which is a deterministic exponential sales response function. $r\epsilon$ reflects the increased demand of OTAs considering promotion behavior and free-riding behavior.

2.2 Hypothesis

Consider real-life scenario situations, this study investigated based on the following assumptions.

Assumption 1. Refer to existing literatures, assumes the price of offline channel is an exogenous variable.

Assumption 2. Assumes that the capacity of hotel A can accommodate all consumer and will give priority to customers booking through OTAs channel.

Assumption 3. Assumes all the notions are positive numbers and the OTAS channel prices are always lower than hotel channel prices, this hypothesis is very common in reality. Meanwhile, for all stakeholder, the sale price is bigger than the cost, otherwise the deal will not exist. So, there is $c_H < \mu < p_O < p_H$.

Assumption 4. Consider the reality and related studies, because the high green innovation cost and high promotion cost of lodging industry, there are $\sigma > 1$ and $\beta > 1$.

3. THE MODEL DEVELOPMENT AND ANALYSIS

Numerous studies have shown that different decision-making models have an important impact on the optimal strategy choice of supply chain members. Therefore, this section will focus on analyzing the development of a dual-channel green supply chain in the accommodation industry under decentralized and centralized decision making models.

Here, we using π^{DC}response to decentralized decision mode, π^{C}response to centralized decision mode, and π^* is the optimization solution.

3.1 The analysis under decentralized decision mode

The dual-channel green supply chain in the hospitality industry under the discrete decision-making model represents the current state of the dual-channel green supply chain in most hotels. In this state, each member of the supply chain decentralizes decision making and optimizes its own profit.

Numerous studies have shown that there are distinct leaders and followers in the dual-channel supply chain, and the channel optimization of the supply chain is essentially a Pareto optimal state between leaders and followers. As shown in Figure 1, in the merchant model, hotels are clearly in the dominant position. Therefore, Stackelberg game theory becomes the main method to study channel coordination.

Using Stackelberg game to analyze this situation, the optimal strategy of channel members can be obtained. The game sequence is: follower makes decision according to leader's behavior, and leader optimizes his decision according to follower's behavior.

Consider hotel is the leader and OTAS is the follower. Meanwhile assume all the participants are bounded rational, information symmetry and aim to maximize their own interests. We get the objective profit functions of hotel and OTAS under decentralized decision mode will be ${\pi_H}^{DC} = p_H E[min(Q_H, D_H)] + \mu Q_o - \hbar(\tau)$ and ${\pi_O}^{DC} = (p_O - \mu)Q_O - S(\epsilon)$.

Due to the capacity of hotel A is T, and OTAs purchase D_O rooms from hotel, so $Q_H = T - D_O$ and $Q_O = D_O$.

At the same time, ε is distributed uniformly on $[-u, u]$. It is easy to know $E[min(Q_H, D_H)] = \int_{d_H-u}^{Q_H} xf(x)dx - \int_{Q_H}^{d_H+u} Q_H f(x)dx$.

As a follower OTAs can make decision according to hotel's behavior. So, we use backward induction to determine the optimal solution of OTAs. Because ${\pi_O}^{DC}$ is a function of k and ϵ, firstly find the Hesse matrix $H({\pi_O}^{DC})$ of ${\pi_O}^{DC}$. Then analyze the leading principle minor of $H({\pi_O}^{DC})$. It is easy to know, when $H > \frac{p_H}{2\sigma}$, $({\pi_O}^{DC})$ is a negative definite matrix.

Therefore π_O is a strictly concave function of k and ϵ, there exist the optimal strategy of OTAs. From the first order optimal condition $\frac{\partial {\pi_O}^{DC}}{\partial k} = 0$ and $\frac{\partial {\pi_O}^{DC}}{\partial \epsilon} = 0$, we can get the optimal discount (k^{DC*}) and optimal promotion effort (ϵ^{DC*}) of OTAs:

$$k^{DC*} = \frac{p_H(r-1)^2\mu - \sigma(\tau p_H + H(p_H+\mu))}{p_H(p_H(r-1)^2 - 2\sigma H)} \tag{1}$$

$$\epsilon^{DC*} = \frac{(r-1)((\tau+H)p_H - \mu H)}{p_H(r-1)^2 - 2\sigma H} \tag{2}$$

Then hotel A determine their own optimal strategy based on OTAS behavior. ${\pi_H}^{DC}$ is the function of μ, τ. So, we can find the Hessian matrix $H({\pi_H}^{DC})$ of ${\pi_H}^{DC}$ with respect to μ, τ, and leading principle minor of $H({\pi_H}^{DC})$.

Similar with $H({\pi_O}^{DC})$, it is easy to know, when $H > \frac{p_H+\sigma u}{3\sigma}$, $({\pi_H}^{DC})$ is a negative definite matrix. Combine the negative definite conditions of $H({\pi_O}^{DC})$, if there is a global optimal solution of supply chain, there should be $H > max\,\{\frac{p_H+\sigma u}{3\sigma}, \frac{p_H}{2\sigma}\}$. That mean only when the user base of the OTAs is large enough, the cooperation of hotels and OTAs if effectively. That is why most hotels will choose to partner with well-known and large OTAs.

Further, can get the optimal wholesale price (μ^{DC*}) and optimal green degree (τ^{DC*}) of hotel:

$$\mu^{DC*} = \frac{\begin{matrix} A1 + \sigma^2 H\big(2p_H(3H+2T+u) + \beta H(H-T+7u)\big) \\ -\sigma p_H(r-1)(A2+A5) \end{matrix}}{H(A3+\beta A4)} \tag{3}$$

$$\tau^{DC*} = \frac{\sigma p_H\big(5\sigma H + p_H((5-3r)r-2)\big)(T+u)}{A3+\beta A4} \tag{4}$$

where $A1 = {p_H}^2(r-1)^2 r\beta\big(Hr-(r-1)(T+u)\big)$; $A2 = p_H(2r-1)(2H+T+u)$; $A3 = 2\sigma p_H\Big(p_H\big((3-2r)r-1\big) + \sigma(3H-u)\Big)$; $A4 = (\sigma H - p_H(r-1)r)^2 + 4\sigma(2\sigma H - p_H(r-1)^2)u$; $A5 = H\big(T - 3u + 2r(H-T+u)\big)\beta$.

Further, we can get the k^{DC*} and ϵ^{DC*}.

$$\epsilon^{DC*} = \frac{p_H(r-1)(T+u)\big(p_H(1-r)r\beta + \sigma(p_H+\beta H)\big)}{A3+\beta A4} \tag{5}$$

$$k^{DC*} = \frac{p_H\begin{pmatrix} A1 + \sigma^2 H\big(p_H(6H+3T+u) + \beta H(H-2T+6u)\big) \\ -\sigma p_H(r-1)\big(A2+A5-r\beta H(T+u)\big) \end{pmatrix}}{H(A3+\beta A4)} \tag{6}$$

Finally, we can get the Optimal revenue of ${\pi_O}^{DC*}$, ${\pi_H}^{DC*}$ and ${\pi_S}^{DC*}$.

$${\pi_O}^{DC*} = \frac{\sigma p_H\big(2\sigma H - p_H(r-1)^2\big)\big(r\beta p_H(r-1) - \sigma(p_H+\beta H)\big)^2(T+u)^2}{2(A3+\beta A4)^2} \tag{7}$$

$${\pi_H}^{DC*} = \frac{p_H\begin{pmatrix} \sigma^2\big((p_H 12 + 2\beta H)HT + (p_H - 4\beta H)(T-u)^2\big) + 2\beta {p_H}^2(r-1)^2 r^2 T \\ -2\sigma p_H(r-1)\big(2p_H(2r-1)T + 2r\beta HT - \beta(r-1)(T-u)^2\big) \end{pmatrix}}{2(A3+\beta A4)} \tag{8}$$

$${\pi_S}^{DC*} = {\pi_H}^{DC*} + {\pi_O}^{DC*} \tag{9}$$

3.2 The analysis under centralized decision mod

Under centralized decision mode, the hotel and OTAS are a whole, they will make decisions together. In this situation, the objective profit function of the whole supply chain is ${\pi_S}^C = p_H E[min(Q_H, D_H)] + p_O Q_o - S(\epsilon) - \hbar(\tau)$.

Due to hotel and OTAS make decisions together, there are not leader or follower. The optimal revenue of the whole supply chain can be obtained in once game.

Similarly, when $H > max\,\{\frac{p_H+\sigma u}{3\sigma}, \frac{p_H}{2\sigma}\}$, there exist the optimize strategies of hotel and OTAs. The optimal discount (k^{C*}), optimal promotion effort (ϵ^{C*}) and optimal green degree (τ^{C*}) as follow.

$$k^{C*} = \frac{\begin{matrix} \sigma\beta H(T-3u-H) - 2\sigma p_H(2H+T) \\ +p_H\big(B^2 - 2\beta rH + (r-1)(T+\beta(2r-1)u)\big) \end{matrix}}{2\sigma p_H(u-2H) - \sigma\beta H(H+4u) + p_H\big(B^2 + 2\beta((r-1)^2 u - Hr)\big)} \tag{10}$$

$$\epsilon^{C*} = \frac{p_H(T+u)\big(p_H(2r-1) - \beta H(1+r)\big)}{2\sigma p_H(u-2H) - \sigma\beta H(H+4u) + p_H\big(B^2 + 2\beta((r-1)^2 u - Hr)\big)} \tag{11}$$

$$\tau^{C*} = \frac{p_H\big(p_H(r-1)(2r-1) - 3\sigma H\big)(T+u)}{2\sigma p_H(u-2H) - \sigma\beta H(H+4u) + p_H\big(B^2 + 2\beta((r-1)^2 u - Hr)\big)} \tag{12}$$

where $B = p_H(1-2r)$.

Finally, get the Optimal revenue of ${\pi_S}^{C*}$.

$${\pi_S}^{C*} = \frac{p_H\begin{pmatrix} \sigma p_H(8HT + (T-u)^2) + 2\sigma\beta H(HT - (T-u)^2) \\ +p_H(\beta(4rHT + (r-1)^2(T-u)^2) - 2p_H(1-2r)^2 T) \end{pmatrix}}{\begin{matrix} 2\beta\big(2rHp_H - 2p_H(r-1)^2 u + \sigma H(H+4u)\big) \\ -2p_H\big(p_H(1-2r)^2 + 2\sigma(u-2H)\big) \end{matrix}} \tag{13}$$

Because the functions of ${\pi_S}^{DC*}$ and ${\pi_S}^{C*}$ are too complex to compare the analytic expression, this part compares the result by numerical simulation. From above analyzing, free-riding behavior is more obvious in merchant model. So, we focus on the gap of the whole supply chain revenue of the centralized decision mode and decentralized decision mode under different free-riding degree.

According to related researchs and considering the reality and satisfy the global optimization condition $H > \max\left\{\frac{p_H+\sigma u}{3\sigma}, \frac{p_H}{2\sigma}\right\}$. The parameters set as follows: $T = 200$, $\sigma = 2$, $\beta = 2$, $\mu = 60$, $H = 500$.

Although this paper makes offline price as an exogenous variable, while different offline price reflects the different hotel level and types. Considering the same degree free-riding behavior may cause a different effect for hotels with different level and types. To enhance the robustness and reliability of numerical simulation, refer to the actual hotel price, make $p_H \in [200,1000]$ to reflect hotels with different level and types. The numerical simulation result shows as figure 1.

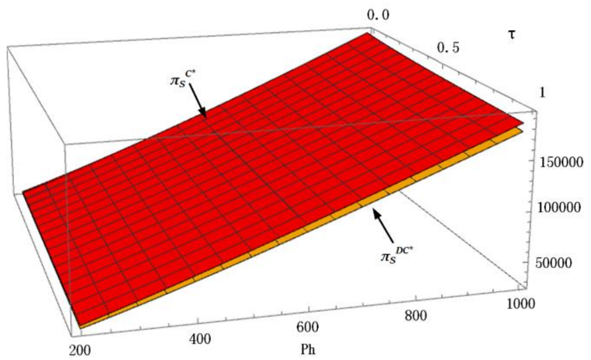

Figure 1: The contrast of the whole supply chain revenue under centralized decision mode and decentralized decision mode.

Figure 1 shows the gap between ${\pi_T}^{DC*}$ and ${\pi_T}^{C*}$. It is clear that regardless of the level and type of hotel, the benefits of the entire supply chain in a decentralized decision-making model are always lower than those in a centralized decision-making model. The presence of double marginality is one of the reasons for this phenomenon. Double marginality reflects channel barriers that result in lower transfer/delivery of products across channels. In order to maximize their own revenue, channel members, especially retailers, usually set higher selling prices to obtain higher sales revenue, which is the main reason for double marginalization. Numerous studies have proved that there is obvious double marginalization in the supply chain under the centralized decision-making model, which reduces the efficiency of the supply chain. Therefore, the efficiency of the dual-channel green supply chain in the accommodation industry is lower under the decentralized decision-making model than under the centralized decision-making model.

4. CONCLUSION

This study confirms our findings consistent with Liao and Ling's conclusion that overall hotel supply chain gains are higher under a centralized decision making model [7].

Due to double marginalization and severe free-rider behavior, the dual-channel green supply chain in the hospitality industry is inefficient and the overall supply chain revenue level is lower under the decentralized decision-making model. Centralized decision making and deep cooperation can alleviate the double marginalization and free-rider behavior. Therefore, it is clear from Figure 1 that the benefits of the entire supply chain under the centralized decision-making model are consistently higher than those under the decentralized decision-making model.

The purpose of this study is to extend dual-channel supply chain optimization and green supply chain management to dual-channel green supply chain management in the hospitality industry. Our findings lead to two main conclusions. Under the merchant model, channel preference and free-rider behavior reduce the greenness of supply and the maximum benefits to the hotel and the supply chain. Second, centralized management reduces the impact of double marginalization and free-rider behavior.

This study also has the following limitations. The existence of a coordination contract is demonstrated only hypothetically through mathematical game model analysis and simulation experiments. However, empirical data can be obtained from authoritative statistical agencies or verified through interviews, surveys, and/or questionnaires.

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REFERENCES

[1] Amiri A. (2006). Designing a distribution network in a supply chain system Formulation and efficient solution procedure. European Journal of Operational Research. 171,567-576.

[2] Chan, E. S. W. (2013). Managing green marketing: hong kong hotel managers perspective. International Journal of Hospitality Management, 34 (9),442-461.

[3] Dan B, Xu G Y, Liu C. (2012). Pricing policies in a dual-channel supply chain with retail services. International Journal of Production Economics. 139(1), 312-320.

[4] Guo X L., Zheng, X B, Ling, L Y, & Yang, C C. (2014). Online coopetition between hotels and online travel agencies: From the perspective of cash back after stay. Tourism Management Perspectives, 12, 104–112.

[5] K.H. Kang, S. Lee, C. Huh. (2010). Impacts of positive and negative corporate social responsibility activities on company performance in the hospitality industry International Journal of Hospitality Management, 29 (1), 72-82.

[6] Liao P, Ye F, Wu X L. (2019). A comparison of the merchant and agency models in the hotel industry.

International Transactions in Operational Research, 26(3), 1052-1073.

[7] Ling LY, Long X G, Chen C Y. (2014). Opening the online marketplace: An examination of hotel pricing and travel agency on-line distribution of rooms. Tourism Management, 45(11), 234–243.

[8] Long, Y, & Shi, P. (2017). Pricing strategies of tour operator and online travel agencies based on cooperation to achieve o2o model. Tourism Management, 62(11), 302-311.

[9] Wang W, Zhang Y, Zhang W S, Gao G, Zhang H. (2020). Incentive mechanisms in a green supply chain under demand uncertainty. Journal of Cleaner Production.15(8),123636.

[10] Ye, F., Zhang, L., Li, Y. (2018). Strategic choice of sales channel and business model for the hotel supply chain. J. Retailing 94 (1), 33-44.