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PRICING DECISION AND COORDINATION CONTRACT IN LOW-CARBON TOURISM SUPPLY CHAINS BASED ON ALTRUISM PREFERENCE

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Abstract

The optimal pricing strategies and coordination contract of providers of low carbon tourism products and services (TCP) and an online travel agency (OTA) are discussed based on altruism preference of decision makers. A competition model is established to compare and analyze the revenue, pricing strategies and coordination conditions in Stackelberg game model. According to the study and comparison results, altruism preference can directly influence decision-makers' decisions and supply chain. Meanwhile, information symmetry can determine decision making. If altruism preference of TCP increases, the overall profit of the supply chain will be enhanced in spite of the information symmetry. When Altruism Preference of OTA platform increases, the overall profit of the supply chain will decrease in the case of information symmetry. As for information asymmetry, the overall supply chain profit will decease with increasing altruism preference. Moreover, numerical examples are taken to analyze the profits of OTA and TCP in revenue coordination. Finally, some suggestions are proposed for the establishment of coordination contract.

Keywords: altruism preference, consumer low-carbon preference, online travel agency, Sackelberg game, tourism supply chains

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1. Introduction

Tourism has achieved considerable evolution and modernization in the past twenty years (Calina et al., 2017; Zhang et al., 2009). According to the World Travel and Tourism Council, the value of tourism will increase to $10,986.5 billion by 2026, accounting for 10.8% of the global GDP (World Travel & Tourism Council, 2016). In the face of the severe competition in the industry, tourism firms have to explore new strategies to improve their competitive advantages. For example, tourism firms can implement effective tourism supply chain management (TSCM) to improve their competitiveness (Zhang et al., 2009). Tourism supply chain management is an emerging topic in the tourism industry. With the development of economy, the components of tourism have broken the traditional concept of tourism products, and expanded to tourism services. The structure of tourism supply chains is no longer limited to dining, accommodation, transportation or tourist attractions, and transforms to various service providers including restaurants, transportation companies, travel agencies and hoteliers (Huang, 2018; Lambert and Cooper, 2000). Due to the increasing supply chain participants and higher complexity, the traditional tourism supply chain decision-making has become extremely complex. Therefore, decision making and coordination between product channels and service suppliers play important roles in TSCM (Nouri et al., 2017).

The existing literature discussed some issues about decision making and supply chain coordination in tourism. For instance, by studying the coordination performance and competition in a tourism supply chain, Yang et al. (2009) found that integration with

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accommodation providers can benefit destinations.

Guo et al. (2013) studied players' decision making process, finding the coordination with a third party website is the optimal pricing strategy for the online channel operation of hotels. Shi et al. (2016) discussed the coordination of a two-echelon tourism supply chain (TSC) involving a tour operator and a hotel, and determined the optimal ordering policies for the integrated and Stackelberg game models which is a Price Leadership Model with risk neutral and loss-averse tour operator. Picazo et al. (2018) examined the information of 15 tourist destinations in Cyprus, Malta, Egypt, Turkey and Spain from the perspective of hedonic pricing, finding obvious differences among the analyzed destinations. The study included tour operators, accommodations and destinations to improve their negotiation.

Some scholars have also discussed the decision making and coordination of multi-channel tourism supply chains. Information technology has developed rapidly, which has laid a foundation for e-commerce. Suppliers break the tradition and establish direct distribution channels. Researchers begin to pay more attention to multi-channel issues in tourism management. The variations of marketing channel will inevitably lead to the change of supply chain structure, decision-making, coordination, etc. Guo et al., (2013) proposed the coordination with a third party website is the optimal pricing strategy for the operation of online distribution channel according to Stackelberg game methods. Ye et al., (2018) established a dual-channel supply chain model composed of hotels and online travel agencies, and developed two coordination models of agency model and merchant model. According to the study results, larger hotels have greater contributions to the increase of market size with the OTA channel. They have low commission rate, and the Agency model is preferred. Otherwise the Merchant model will be preferred by hotels. Based on the nature of the relationship between hotels and OTAs, Lee et al. (2013) analyzed online reviews between boutique hotel international and Expania.com and found that hotels must find the most effective way to make the most of existing technology and distribution channels. It may even form a consortium to share information about third-party distribution channels. Ling Liuyi et al. (2014) established a sequence game model. In this paper, the optimal decision is derived on the unit commission of hotels and the optimal response of the OTA to commission and noted management implications. Before opening online marketing, occupancy rate of a hotel is an important metric for the coordination with an OTA. Yang et al. (2016) investigated a two-echelon tourism supply chain composed of an online travel agency and a hotel. In the case of low wholesale price, the Stackelberg game can benefit the online travel agency and the hotel more significantly compared with the Bertrand game. Zhang & Ye (2018) studied the coordination between a hotel and an independent OTA. In their coordination, the business model—the Merchant model or the Agency model would be further selected. According to the equilibrium strategy of the hotel, more OTA channels cannot increase the profit for hotels with small capacity, market size and consumer acceptance. They found both option contract and two-stage ordering contract can enhance the profits for both hotels and supply chain. However, with the development of tourism, its environmental pollution problem is becoming more and more serious.

It has become a global consensus to emphasize the sustainability, low-carbon tourism supply chain. For instance, Goffi et al. (2019) examined whether tourism destination competitiveness can be influenced by sustainability in developing countries. Empirical results demonstrate the positive correlation between sustainability factors and competitiveness indicators as dependent variables in the regression model, which supports the hypothesis that sustainability can foster the competitiveness of tourism destinations. There are also some studies focus on analyzing carbon emissions constraints influences. Hua et al. (2016) considered perishable inventory control with freshness-dependent demand under carbon emissions constraints and had maximized the profit per unit time. Balamurugan et al. (2018) created a modification in the considered two-stage inventory routing problem to minimize the total amount of carbon dioxide emission in the network by reducing the total distance travelled by all the vehicles to meet the demand. From the point of view of the life cycle of tourism area, Tang et al. (2017) presented a factor decomposition model for analyzing the carbon emissions of energy consumption in tourism industry from the point of view of life cycle of tourism area. The results show that the growth of tourist scale and the scale of tourism output will lead to the rapid growth of carbon emissions. Du et al. (2018) estimated of vehicle emissions along mainline freeways under various ramp metering strategies and significantly improved for the integrated ramp metering strategy. Zha et al. (2018) established an evaluation framework of the direct and indirect CO_2 emissions from tourism, and included the CO_2 emission factor in the efficiency evaluation framework on the basis of SBMUn desirable model. According to the results of efficiency measurement, the overall efficiency of low-carbon tourism economy is on a rather low level and varies significantly among the cities. Untapped potentials exist with internal productive factors in the economic system of urban tourism. The role of low carbon in the supply chain cannot be underestimated. Similarly, the preference of decision makers also has a great impact on the supply chain.

Decision-maker preference has an important impact on supply chain decision-making and coordination. The traditional study of tourism service supply chain management regards the decision-maker as a "rational economic man" who is purely self-interested, and emphasizes the maximization of his own interests, and seldom considers the interests of other members in the supply chain（Zhao et al., 2019; Zhao et al., 201). As a result, the optimal supply chain performance cannot be realized in practice, and the harmonious and stable supply chain coordination relationship is difficult to continue. Studies in psychology and behavioral economics show that people are not purely self-interested and usually have some behavioral preferences or even cognitive biases which will significantly affect people's decision outcomes (Gino and Pisano, 2008). The common preference of decision makers is fair preference and risk aversion. Most previous studies are focus on fairness preference in supply chain (Bertsimas, Farias, and Trichakis, 2012). According to Du et al. (2014), if both parties have fairness concern preferences, the total channel efficiency will decrease. Zhang & Wang (2018) examined the influence of vertical and horizontal fairness concerns on the three-party supply chain coordination.

Another literature is associated with risk aversion. The risk avoidance attitude of supply chain members has become an important factor affecting their decision-making behavior. From the point of view of research methods, we usually use Mean Variance, VaR (Value at Risk) and CVaR (Conditional Value at Risk) to measure the risk return of decision makers and analyze the influence of risk aversion decision maker's behavior and decision-making deviation on supply chain coordination mechanism (Choi et al, 2018; Li et al, 2018, 2016; Kim et al, 2014). For example, Zhuo et al. (2018) studied the meaning of risk considerations for option contracts in a two-echelon supply chain of the mean–variance framework. When the threshold is public information, the supplier with a higher risk tolerance prefers to reduce the exercise price in a unique equilibrium. As a result, the order quantity of retailers will increase. Jasmine J. Lim et al. (2014) applied Var to avoid possible risks, which allowed firms to carry out "what-if" analysis on potential risk management and minimize the influence of risks on supply chain in disruptions. Compared to other key thresholds, retailers' risk-averse behavior can significantly influence the retail price, wholesale price, green degree and order quantity of green products.

Decision makes with altruistic preference not only show altruism preference, but also maximize the benefits in decision making. Decision makers with altruistic preference tend to help others to reduce their own pain. For instance, David K. Levine (1998) examined a simple altruism theory, where the payoffs of players are linear in their monetary income and their opponents. Ge and Hu (2012) interpreted the cooperative incentive of firms as their altruism, and characterized firms in the supply chain by introducing altruistic preferences. According to the study results, the supply chain considering altruism has better performance than scenarios under integration and decentralization.

Although abundant research results (Choi et al., 2018; Li et al, 2018, 2016; Kim et al., 2014; Bertsimas, Farias and Trichakis, 2012) of supply chain decision-making and coordination considering risk aversion and fair preference have been achieved, supply chain decision-making or coordination is seldom reported under the consideration of altruistic preference. In addition, most scholars we mentioned above study supply chain decision-making and coordination based on decision makers' preferences, fairness preference and risk aversion information symmetry. However, the decision makers' fair preference information is private information, while information asymmetry is common.

This paper has the following contributions: (a) Driven by sustainability, a two-echelon supply chains model composed of low-carbon tourism products and services (TCP) and OTA network platform was built. (b) The decentralized and centralized decision making of low carbon tourism supply chain was discussed considering both information symmetry and information asymmetry and altruism. (c) The influence of low carbon preference on supply chain decision was explored. (d) The coordination of revenue sharing contracts in low carbon tourism supply chain was explored considering information symmetry, information asymmetry and altruism.

The remaining sections are structured as follows: Section 2 introduces Hypothesis and Modeling. In Section 3, the influence of the optimal pricing strategies with decision makers' (TCP&OTA) altruism preference is affected. Section 4 discusses the influence of low carbon preference. In Section 5, the Coordination Contract is constructed. Section 6 reports the empirical results. Finally, Section 7 draws the conclusions and gives recommendations for future research.

2. Materials and methods

2.1. *Hypothesis and modeling*

In consideration of the two-stage tourist service supply chain consisting of Providers of Low Carbon Tourism Products and Services (hereinafter abbreviated as TCP) and Online Travel Agency (OTA) (hereinafter abbreviated as OTA), TCP sells low-carbon tourism products or services to OTA and OTA provides consumers with low-carbon tourism products or services as shown in Fig. 1.

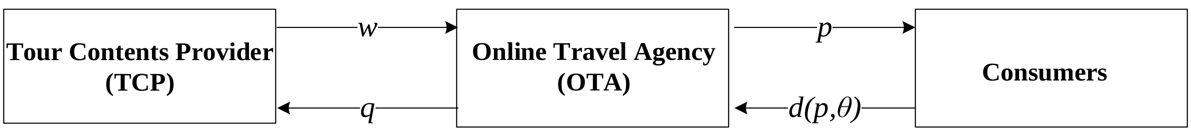

Fig. 1. Schematic diagram of the low-carbon tourism supply chain structure

Game decision point between TCP and OTA is the price of low-carbon tourism products or services, namely the two parties realize maximization of their own benefits by determining the optimal price. On this basis, the following hypotheses are proposed:

Hypothesis 1: prices and costs of the two parties. The wholesale price of per unit low-carbon tourism product or service provided by TCP (hereinafter expressed by subscript s) is assumed as w and apportioned unit cost as c_s. Sale price of per unit low-carbon product or service provided by OTA (hereinafter expressed by subscript r) is assumed as p and sale cost as c_r. Without loss of generality, $p > c_s + c_r$ is assumed.

Hypothesis 2: demand function and consumer low-carbon preference for tourism products or services. With a reference to practices of Dada and Patruzzi (1999), multiplicative demand function is adopted to depict random demand of the tourism market, namely $d(p,\theta)$: $d(p,\theta) = y_0 p^{-k}\theta\varepsilon$, where $d(p, \theta)$ is market demand, θ is consumer preference coefficient for low-carbon tourism products or services, and $\theta \in (0,1]$. Consumer preference is closely related to market demand. Under the same sale price, the higher the consumer low-carbon preference degree, the greater the market demand. When $\theta = 0$, consumers will not consider products sold through the OTA channel at all. When $\theta = 1$, consumers will take paramount consideration of products sold through the OTA channel. y_0 is measurement of market scale and ε is a continuously distributed random factor with mean value of 1. Probability density function (PDE) and probability distribution function (CDF) are $f(x), F(x)$ respectively. k is demand sensitivity to price. As consumers are very sensitive to the price given by OTA, $k > 1$ is set.

Hypothesis 3: The game order between two parties. In the two-stage tourism product or service supply chain consisting of TCP and OTA, market positions of the two game parties decide the power structure in the supply chain. Assuming TCP is the dominant power and OTA is the follower. Typical Stackelberg master-slave game structure exists between TCP and OTA. Before the sales cycle, TCP decides wholesale price w of low-carbon tourism products or services, and then OTA decides quantity ordered q. After the sales cycle starts, OTA provides consumers with low-carbon tourism products or services according to the quantity ordered.

Hypothesis 4: Altruism preference features of decision subjects and information symmetry between them. Behavioral economic study shows that when making decisions, decision subjects not only consider their own economic benefits but also concern others' revenues, concretely manifested by altruism preference of decision subjects. When making decisions, OTA will consider TCP interests.

In a similar way, TCP will consider OTA interests when making decisions. In the decision-making interaction between OTA and TCP, the following information states exist: TCP and OTA are clear about their mutual altruism preferences and are willing to consider their mutual altruism preferences in the decision-making process; TCP and OTA are clear about each other's altruism preference but are not willing consider their mutual altruism preferences; TCP and OTA are unclear about their mutual altruism preference. As both parties have altruism preferences, the result under the second state is identical with that under the third state.

Hypothesis 5: OTA will not supplement low-carbon tourism products or services before the ending of the sales cycle. According to the above related hypotheses, utility functions of TCP and OTA are established in consideration of their altruism preference features. With a reference to descriptions given by Loch and Wu (2008) regarding altruism preference, the utility functions are expressed respectively as given by Eqs.(1, 2):

$$U_s = \pi_s + \delta_s \pi_r \tag{1}$$

$$U_r = \pi_r + \delta_r \pi_s \tag{2}$$

where δ_s is altruism preference degree of TCP to OTA; δ_r is altruism preference degree of OTA to TCP, and $\delta_s, \delta_r \in [0,1]$. When δ_s、$\delta_r = 0$, altruism preference degree of TCP or OTA is 0, namely being under a complete self-interest state, $U_s = \pi_s$, $U_r = \pi_r$ and this belongs to a decentralized supply chain structure. When $\delta_s, \delta_r = 1$, the decision maker is completely altruistic, maximization of overall supply chain value is taken as the objective, and at the time $U_s = U_r = \pi_r + \pi_s$, and it is a centralized supply chain structure.

2.2. Optimal decision under the decentralized supply chain

When $\delta_s, \delta_r = 0$, TCP and OTA are both under a complete self-interest state, $U_s = \pi_s, U_r = \pi_r$ at the time, it belongs to a decentralized supply chain and the two are under a complete competitive state. Before the sales cycle starts, TCP firstly determines wholesale price w of low-carbon tourism products or services, then OTA decides quantity of low-carbon tourism products or services ordered and formulates sales price p, and then expected profits of OTA and TCP can be expressed by Eqs. (3, 4).

$$\pi_r = pE\{\min(d(p,\theta),q)\} - (c_r + \omega)q \tag{3}$$

$$\pi_s = qw - c_s q \tag{4}$$

First of all, the optimal decision of OTA is analyzed. With a reference to the practice of Dada and Patruzzi (1999), Stocking Factor is defined as $z := q / y_0 p^{-k}\theta$.

Decision variable (*q*, *p*) is transformed into a definite optimal (*q*, *z*). $p = (zy_0\theta / q)^{1/k}$ is substituted into Eq. (3), and then:

$$\pi_r = pE\left\{\min(d(p,\theta), q)\right\} - (c_r + w)q$$
$$= (zy_0\theta / q)^{1/k} E\left\{\min(d(p,\theta), q)\right\} - (c_r + w)q$$
$$= (zy_0\theta)^{1/k} q^{1\text{-}1/k} z[1 - \int_0^z (1 - \frac{x}{z}) f(x)dx] - (c_r + w)q$$

According to the literature of Dada and Patruzzi (1999), it can be easily known that:

Lemma 1 Optimal stocking factor z_0 of OTA is decided by Eq. (5).

$$\int_0^z (k-1)xf(x)dx = z[1 - F(z)] \qquad (5)$$

When $xf(x)/x\bar{F}(x)$ increases progressively relative to x and $\lim_{x\to\infty} x\bar{F}(x) = 0$, optimal stocking factor z_0 is sole, where $\bar{F}(x) = 1 - F(x)$.

At the time optimal quantity ordered of OTA is (Eq. 6):

$$q^* = y_0\theta z_0\left[\frac{1 - F(z_0)}{(c_r + \omega)}\right]^k \qquad (6)$$

In order to simplify the formula, $\Phi = y_0\theta z_0[1 - F(z_0)]^k$ is set, and then equation (Eq.6) can be expressed as $q^* = \frac{\Phi}{(c_r + w)^k}$.

Therefore, optimal sales price p^* and optimal expected profit π_r^* of OTA given by Eqs. (7, 8).

$$p^* = (y_0\theta z_0 / q^*)^{1/k} = (c_r + w)/(1 - F(z_0)) \qquad (7)$$

$$\pi_r^* = \frac{\Phi}{(k-1)(c_r + w)^{k-1}} \qquad (8)$$

The optimal decision of TCP is analyzed. As the profit of TCP is $\pi_s = qw - c_s q$, which is jointly decided by quantity ordered q and wholesale price w, π_s is substituted into Eq. (6) to obtain (Eq. 8).

$$\pi_s = q^*(w - c_s) = \frac{\Phi}{(c_r + w)^k} \qquad (9)$$

First-order derivative of π_s relative to w is solved, $\frac{d\pi_s}{dw} = \frac{\Phi}{(c_s + w)^k}\left[1 - \frac{k(w - c_s)}{c_r + w}\right]$. As $k > 1$, $\frac{\Phi}{(c_s + w)^k}$ decreases progressively relative to w, $1 - \frac{k(w - c_s)}{c_r + w} = \frac{c_r + kc_s + (1-k)w}{c_r + w}$ and $1 - \frac{k(w - c_s)}{c_r + w} = \frac{c_r + kc_s + (1-k)w}{c_r + w}$, and then $\frac{d\pi_s}{dw}$ decreases progressively relative to w. It's easily known that π_s is a concave function, so optimal wholesale price w^*, which realizes maximization of π_s, exists. Setting $\frac{d\pi_s}{dw} = 0$ and then $w^* = \frac{c_r + kc_s}{k-1}$. The optimal quantity ordered can be obtained by substituting w^* into Eq. (6).

$$q^* = (k-1)^k y_0\theta z_0\left[\frac{1 - F(z_0)}{k(c_r + c_s)}\right]^k = \Phi\left[\frac{k-1}{k(c_r + c_s)}\right]^k \qquad (10)$$

The optimal sales price $p^* = \frac{k(c_r + c_s)}{(k-1)[1 - F(z_0)]}$ can be further obtained, and the optimal profit of TCP is $\pi_s = \frac{\Phi(k-1)^{k-1}}{k^k(c_r + c_s)^{k-1}}$.

2.3. Optimal decision under the centralized supply chain

When TCP and OTA have complete altruism preferences (namely $\delta_s, \delta_r = 1$), the two are under a complete cooperative state, then a centralized decision is made with revenue maximization of the supply chain taken as the objective, and $U_s = U_r = \pi_r + \pi_s$. Therefore, the expected profit π_t of the centralized supply chain can be determined, and expressed as follow:

$$\pi_c = pE\left\{\min(d(p,\theta), q)\right\} - (c_r + c_s)q$$

Derivative of π_c relative to q is solved. Setting $\frac{d\pi_c}{dp} = 0$ and then $q_c^* = \frac{\Phi}{(c_r + c_s)^k}$. Hence, optimal sales price and maximum profit of the supply chain are given by Eqs. (11, 12).

$$p_c^* = \frac{c_r + c_s}{1 - F(z_0)} \qquad (11)$$

$$\pi_c^* = \frac{\Phi}{(k-1)(c_r + c_s)^{k-1}} \qquad (12)$$

According to $q^* = \Phi\left[\frac{k-1}{k(c_r + c_s)}\right]^k = (1 - \frac{1}{k})^k q_c^*$ and $k > 1$, $(1 - \frac{1}{k})^k < 1$, so $q^* < q_c^*$.

3. Results

3.1. The supply chain decision under dual-party information symmetry

Optimal decision when a supply chain member has altruism preference.

3.1.1. Only OTA has altruism preference

When only OTA has altruism preference, $\delta_r \in (0,1)$, $\delta_s = 0$, and utility functions of TCP and OTA are respectively:

$$U_s = \pi_s$$

$$U_r = \pi_r + \delta_r \pi_s$$

According to equations (1) and (2), the following can be easily known:

$$U_r = pE\left\{\min(d(p,\theta),q)\right\} - (c_r + w)q + \delta_r(w - c_s)q$$

$$= (y_0\theta z_0)^{1/k} q^{1-1/k} \frac{k}{k-1}[1 - F(z_0)] - (c_r + w)q + \delta_r(w - c_s)q$$

Backward induction method is used to solve the first-order partial derivative of equation (6) relative to q and to obtain:

$$\frac{dU_r}{dq} = (y_0\theta z_0)^{1/k} q^{-1/k}[1 - F(z_0)] - (c_r + w) + \delta_r(w - c_s)$$

Setting $\frac{dU_r}{dq} = 0$, the optimal quantity ordered of OTA can be obtained as $q_0^* = \frac{\Phi}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^k}$. At the time, $U_s = (w - c_s)q_0^* = \frac{(w - c_s)\Phi}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^k}$.

Furthermore, the first-order derivative of U_s relative to wholesale price w is solved, and then:

$$\frac{dU_s}{dw} = \frac{\Phi}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^{k+1}}\left[(1-k)(1-\delta_r)w + c_s\delta_r + c_r + k(1-\delta_r)c_s\right]$$

Setting $\frac{dU_s}{dw} = 0$, and then when altruism preference degree of TCP is zero, the optimal wholesale price is ω_0^* (Eq. 13)

$$w_0^* = \frac{c_s\delta_r + c_r + k(1-\delta_r)c_s}{(1-\delta_r)(k-1)} \quad (13)$$

Hence, the optimal quantity ordered q_0^* of OTA is given by Eq. (14).

$$q_0^* = \frac{\Phi(k-1)^k}{\left[k(c_s + c_r)\right]^k} \quad (14)$$

Through a comparison of optimal quantity ordered and optimal wholesale price under the model when only OTA has altruism preference and decentralized decision model of the supply chain, proposition 1 is obtained:

Proposition 1. When only OTA has altruism preference, altruism preference δ_r of OTA has no influence on the optimal quantity q_0^* of products or services ordered while having influence on the optimal wholesale price w_0^* of products or services. When only OTA has altruism preference, the optimal wholesale price of products or services is greater than the optimal wholesale price w^* when TCP has no altruism preference, and the optimal wholesale price w_0^* and altruism preference δ_r of OTA present the same change.

Proof. See Appendix A

According to proposition 1, when OTA has altruism preference, OTA will consider TCP interest and then keep the original quantity ordered to increase TCP profit when the wholesale price increases.

3.1.2. Optimal decision when only TCP has altruism preference

When only TCP has altruism preference, $\delta_s \in (0,1)$, $\delta_r = 0$ and utility functions of TCP and OTA are respectively:

$$U_s = \pi_s + \delta_s \pi_r$$

$$U_r = \pi_r$$

Calculated by the same method as 3.1.1(1), the optimal quantity ordered q_1^* of OTA is expressed by Eq. (15).

$$q_1^* = \frac{\Phi}{(c_r + w)^k} \quad (15)$$

Utility function U_s of TCP is obtained:

$$U_s = \frac{(w - c_s)\Phi}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^k}。$$

Then the optimal wholesale price ω_1^* is obtained by Eq. (16).

$$w_1^* = \frac{c_r + kc_s - c_r\delta_s}{\delta_s + k - 1} \quad (16)$$

Then the optimal quantity ordered of OTA is given by Eq. (17).

$$q_1^* = \frac{\Phi(\delta_s + k - 1)^k}{\left[k(c_r + c_s)\right]^k} \quad (17)$$

Through a comparison of optimal quantity ordered and optimal wholesale price under the model when only TCP has altruism preference, the model when only OTA has altruism preference and the centralized decision model of the supply chain, proposition 2 is obtained:

Proposition 2. When only TCP has altruism preference, only altruism preference δ_s of TCP has influence on both optimal quantity ordered q_1^* and optimal wholesale price w_1^* of low-carbon tourism products or services. Under the model when only TCP has altruism preference, the optimal quantity q_1^* of low-carbon tourism products or services ordered is greater than the optimal quantity ordered q_0^* when only OTA has altruism preference and greater than the optimal quantity ordered q^* under the decentralized decision of the supply chain but smaller than the optimal quantity ordered q_c^* under the centralized decision, namely $q_c^* > q_1^* > q_0^* = q^*$.

Under the model when only TCP has altruism preference, the optimal wholesale price w_1^* of low-carbon tourism products or services is smaller than the optimal wholesale price w^* under the decentralized decision so it is smaller than the optimal wholesale price w_0^* when only OTA has altruism preference, namely $w_1^* < w^* < w_0^*$

Proof. See Appendix B

According to proposition 2, compared with the optimal decision under the model when only OTA has altruism preference, in the optimal decision under the model when only TCP has altruism preference, TCP is more willing to lower the wholesale price in order to increase OTA cost while OTA increases quantity of low-carbon tourism products or services ordered due to decline of the wholesale price so that the whole supply chain is more coordinated, which can effectively enhance the cooperation between OTA and TCP.

3.1.3. Optimal decision when both parties have altruism preference

When both OTA and TCP have altruism preference (δ_s, $\delta_r \in (0,1)$), utility functions of OTA and TCP are respectively:

$$U_s = \pi_s + \delta_s \pi_r$$

$$U_r = \pi_r + \delta_r \pi_s$$

Calculated by the same method as 3.1.1, the optimal quantity ordered q_a^* of OTA is given by Eq. (18).

$$q_a^* = \frac{\Phi}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^k} \tag{18}$$

Utility function U_s of TCP is obtained:

$$U_s = (w - c_s)q_a^* + \delta_s\left\{(y_0\theta z_0)^{1/k}\left(q_a^*\right)^{1-1/k}\frac{k}{k-1}[1-F(z_0)] - (c_r + w)q_a^*\right\}$$

Then the optimal wholesale price w_a^* is obtained by Eq. (19).

$$w_a^* = \frac{\mathrm{E}}{(1-\delta_r)(1-k+k\delta_s\delta_r-\delta_s)} \tag{19}$$

Furthermore, the optimal quantity ordered of OTA is obtained as $q_a^* = \frac{\Phi}{\left[k(c_r+c_s)\right]^k}\left(k - \frac{1-\delta_s}{1-\delta_s\delta_r}\right)^k$.

Through a comparison of relationships of optimal quantities ordered when only TCP has altruism preference, when only OTA has altruism preference and under the centralized decision, proposition 3 is obtained:

Proposition 3. When both OTA and TCP have altruism preference, both TCP altruism preference δ_s and OTA altruism preference δ_r have influences on the optimal quantity ordered q_a^* and optimal wholesale price w_a^* of low-carbon tourism products or services. Under the model when both OTA and TCP have altruism preference, the optimal quantity q_a^* of low-carbon tourism products or services ordered is greater than the optimal quantity ordered q_0^* under the model when only OTA has altruism preference but smaller than the optimal quantity ordered q_1^* under the model when only TCP has altruism preference and smaller than the optimal quantity ordered q_c^* under the centralized decision, namely $q_0^* < q_a^* < q_1^* < q_c^*$.

Proof. See Appendix C

Proposition 3 indicates that when both TCP and OTA have altruism preference, mutual benefit and reciprocity of the two properties will improve efficiency of the supply chain. Compared with the model when only OTA has altruism preference, OTA is willing to buy more low-carbon tourism products or services. However, the optimal quantity ordered q_a^* when both TCP and OTA have altruism preference is smaller than the optimal quantity ordered q_1^* when only TCP has altruism preference so it is smaller than the optimal quantity ordered q_c^* under the centralized decision.

3.2. Decision problem under information asymmetry

3.2.1. Optimal decision when only OTA has altruism preference while TCP is uninformed

According to section 3.1.1, the optimal quantity ordered when OTA has altruism preference is $q_{2\mathrm{I}}^* = \frac{\Phi}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^k}$ (where the subscript I represents the real optimal quantity ordered q_2^* when OTA has altruism preference. However, as TCP is uninformed and doesn't consider OTA altruism preference, TCP formulates the optimal wholesale price w_2^* according to the optimal quantity ordered

$q_{2II}^* = \frac{\Phi}{(c_r + w)^k}$ when OTA doesn't have altruism preference in equation (Eq.6) in section 2.2. (where II is the situation when TCP thinks of information asymmetry of the optimal quantity ordered q_2^* of OTA) , and at the time $U_s = (w - c_s)q_0^* = \frac{(w-c_s)\Phi}{[c_r + w]^k}$ is obtained.

Then w_2^* is obtained by Eq. (20).

$$w_2^* = \frac{c_r + kc_s}{k-1} \quad (20)$$

The optimal quantity ordered $q_2^* = q_{2I}^*$ of OTA is further obtained as given by Eq. (21).

$$q_2^* = \frac{\Phi(k-1)^k}{[(k-\delta_r)(c_s + c_r)]^k} \quad (21)$$

Through a comparison of optimal quantities ordered and optimal wholesale price under the model when only OTA has altruism preference in the case of information symmetry and under the decentralized decision model of the supply chain, proposition 4 is obtained:

Proposition 4. When only OTA has altruism preference but TCP doesn't know about OTA altruism preference, OTA altruism preference has the influence on both the optimal quantity ordered q_2^* and optimal wholesale price w_2^* of low-carbon tourism products or services. At the time, the optimal quantity ordered q_2^* of OTA is greater than the optimal quantity ordered q_0^* when only OTA has altruism preference under information symmetry, but the optimal wholesale price w_2^* of TCP is smaller than the optimal wholesale price ω_0^* when only OTA has altruism preference under information symmetry.

Proof. See Appendix D

According to proposition 5, in the model when only OTA has altruism preference with information asymmetry, TCP will formulate the wholesale price firstly, so the optimal wholesale price w_2^* will not generate any influence on the optimal wholesale price w^* under the decentralized decision in the supply chain. However, as OTA has altruism preference, OTA will pay attention to TCP profit level so that quantity ordered of OTA will increase, so will the overall profit.

3.2.2.Optimal decision when only TCP has altruism preference but OTA is uninformed

Calculated by the same method as 3.2.1, the optimal quantity ordered q_3^* of OTA is obtained by Eq. (22).

$$q_3^* = \frac{\Phi}{(c_r + w)^k} \quad (22)$$

Utility function U_s of TCP is obtained: $U_s = \frac{(w-c_s)\Phi}{[c_s\delta_r + c_r + (1-\delta_r)w]^k}$

Then the optimal wholesale price w_3^* is obtained by Eq. (23).

$$w_3^* = \frac{c_r + kc_s - c_r\delta_s}{\delta_s + k - 1} \quad (23)$$

According to the obtained optimal wholesale price w_3^*, OTA obtains the optimal quantity ordered as $q_3^* = \frac{\Phi(\delta_s + k - 1)^k}{[k(c_r + c_s)]^k}$

Through a comparison of the relationship between the optimal quantity ordered and optimal wholesale price of the low-carbon tourism product or service supply chain when only OTA has altruism preference under information symmetry and information asymmetry, proportion 5 is obtained:

Proposition 5. When only TCP has altruism preference but OTA doesn't know that TCP has altruism preference, the optimal quantity ordered q_3^* and optimal wholesale price w_3^* of TCP altruism preference δ_s for low-carbon tourism products or services are respectively equal to the optimal quantity ordered q_1^* and optimal wholesale price w_1^* when only TCP has altruism preference under information symmetry.

Proof. See Appendix E

3.2.3. Optimal decision when both parties have altruism preference but both are uninformed

According to section 3.1.3, the optimal quantity ordered when OTA has altruism preference is $q_{4I}^* = \frac{\Phi}{[c_s\delta_r + c_r + (1-\delta_r)w]^k}$. But as TCP is uninformed and doesn't consider OTA altruism preference, TCP formulates the optimal wholesale price w_4^* according to the optimal quantity ordered $q_{4II}^* = \frac{\Phi}{(c_r + w)^k}$ when OTA doesn't have altruism preference as solved in section 2.1, where q_{4I}^* and $q_{4\Pi}^*$ are actual quantity ordered of OTA and the optimal quantity ordered as deemed by TCP.

Utility function U_s of TCP is obtained: $U_s = \frac{(w-c_s)\Phi}{[c_s\delta_r + c_r + (1-\delta_r)w]^k}$。

Then the optimal wholesale price w_4^* results as expressed by Eq. (24).

$$w_4^* = \frac{c_r + kc_s - c_r\delta_s}{\delta_s + k - 1} \tag{24}$$

Furthermore, the optimal quantity ordered q_4^* of OTA is solved in the form of Eq. (25).

$$q_4^* = \frac{\Phi(\delta_s + k - 1)^k}{\left[(c_r + c_s)(\delta_s\delta_r - \delta_r + k)\right]^k} \tag{25}$$

3.3. Influence of low-carbon preference on the supply chain decision

Consumer low-carbon preference will influence the demand for low-carbon tourism products or services so as to influence the supply chain decision. To focus on the study, product low-carbon cost is included in costs c_r and c_s of TCP and OTA but not studied here, and then proposition 6 is obtained:

Proposition 6 Among the above model, consumer preference for low-carbon tourism products or services will influence the optimal quantity ordered so as to influence the profit within the whole supply chain. The higher the consumer preference degree for low-carbon tourism products or services, the higher the optimal quantity ordered.

Proof. See Appendix F

According to proposition 6, if TCP and OTA want to increase their own incomes and the overall income of the supply chain, they need to elevate consumer preference, the higher the consumer preference, the higher the quantity ordered, thus generating an active influence on the supply chain.

3.4. Coordination of revenue-sharing contracts

The optimal supply chain performance requires that members on the supply chain accurately execute a series of activities, but as decentralized decision will result in a difficult-to-coordinate state of the supply chain, revenue-sharing contract is a supply chain coordination mechanism which has been studied by scholars for a long term and which can be easily implemented in practice.

Decision of the whole supply chain can be more unified by coordinating revenues of the two parties even though one part of OTA revenue will be shared to TCP. Under the revenue-sharing contract mechanism, OTA owns its sales revenue ϕ, then TCP owns $1-\phi$ of OTA revenue, so profit functions of TCP and OTA can be expressed by Eqs. (26, 27).

$$\pi_r = \phi pE\left\{\min(d(p,\theta), q)\right\} - (c_r + w)q \tag{26}$$

$$\pi_s = (1-\phi)pE\left\{\min(d(p,\theta), q)\right\} + q(w - c_s) \tag{27}$$

3.5. Coordination of revenue-sharing contracts under information symmetry of the two parties

3.5.1. Coordination of revenue-sharing contracts when neither parties has altruism preference

According to lemma 1 and Eqs. (1, 2, 19) (Eq.19), the optimal quantity ordered q_5^* of OTA can be easily obtained as Eq. (28):

$$q_5^* = \frac{\phi^k\Phi}{(c_r + w)^k} \tag{28}$$

Utility function U_s of TCP is obtained:

$$U_s = \frac{\Phi\phi^{k-1}\left[\phi(k-1)(w-c_s) + k(1-\phi)(w+c_r)\right]}{(k-1)(w+c_r)^k} 。$$

The first-order derivative of U_s relative to w is solved, and setting $\frac{dU_s}{dw} = 0$ to obtain w_5^* by Eq. (29).

$$w_5^* = \frac{(k\phi - k + \phi)c_r + k\phi c_s}{k - \phi} \tag{29}$$

The optimal quantity ordered of OTA is obtained as $q_5^* = \frac{\Phi(k-\phi)^k}{\left[k(c_r + c_s)\right]^k}$

When $q_5^* = q_c^*$, $\phi_0^* = 0$ is solved. When $\phi_0^* = 0$, overall profit of the supply chain is elevated, but OTA profit is 0, and the coordination under this situation is ineffective.

3.5.2. Coordination of revenue-sharing contracts when OTA has altruism preference

Calculated by the same method as 3.5.1. to obtain q_6^* by Eq. (30).

$$q_6^* = \frac{\Phi\left[\phi + \delta_r(1-\phi)\right]^k}{\left[c_s\delta_r + c_r + (1-\delta_r)w\right]^k} \tag{30}$$

$U_s = (1-\phi)(y_0\theta z_0)^{1/k} q^{1-1/k} \frac{k}{k-1}[1-F(z_0)] + (w - c_s)q$ is obtained by substituting q_6^* into U_s.

Then w_6^* is obtained:

$$w_6^* = \frac{c_r(k - k\phi - \phi - \delta_r + \phi\delta_r) + c_s(-\phi\delta_r - k\phi + k\phi\delta_r)}{(1-\delta_r)(\delta_r\left[1 + k\phi - (k+\phi)\right] - k + \phi)} \tag{31}$$

The following can be obtained by substituting ω_6^* into the optimal quantity ordered:

$$q_6^* = \frac{\Phi\left[\phi + \delta_r(1-\phi)\right]^k\left[\delta_r(1-k)(1-\phi) + \phi - k\right]^k}{\left\{\delta_r\left[c_s\delta_r(1-k)(1-\phi) - k(1-\phi)(c_s + c_r)\right] - k\phi(c_s + c_r)\right\}^k}$$

When $\phi = 1$, w_6^*, q_6^* and q_6^* are obtained as follows:

$$w_6^* = \frac{c_s\delta_r + c_r + k(1-\delta_r)c_s}{(1-\delta_r)(k-1)} = w_0^*$$

$$q_6^* = \Phi\frac{(k-1+\mathrm{N})^k\left[\phi+\delta_r(1-\phi)\right]^k}{\left[k(c_s+c_r)+\mathrm{M}\right]^k}.$$

where:

$$\mathrm{N} = -\left[\delta_r(1-k)(1-\phi)+\phi-k+(k-1)\right] = \left\{(1-\phi)\left[\delta_r(k-1)+1\right]\right\} > 0$$

$$\mathrm{M} = (1-\phi)\left[c_s\delta_r^2(k-1) - k(1-\delta_r)(c_s+c_r)\right]$$

According to $c_s\delta_r^2(k-1) - k(1-\delta_r)(c_s+c_r) >< 0$, $\mathrm{M} >< 0$ is obtained, so $q_6^* >< q_0^*$.

Therefore, whether the contract is effective is jointly decided by the parameter system consisting of $\delta_r, \delta_s, c_s, c_r$. This situation will be carefully discussed in the next numerical analysis.

3.5.3. Coordination of revenue-sharing contracts when TCP had altruism preference

Calculated by the same method as 3.5.1 to obtain q_7^* by Eq. (32).

$$q_7^* = \frac{\phi^k\Phi}{(c_r+w)^k} \qquad (32)$$

Utility function U_s of TCP is obtained: $U_s = \frac{\Phi\phi^{k-1}\left\{(c_r+\omega)\left[\delta_s\phi+k(1-\phi)\right]+(k-1)\phi(\omega-c_s)\right\}}{(k-1)(c_r+\omega)^k}$

Then ω_7^* is obtained using Eq. (33).

$$\omega_7^* = \frac{c_r\left[k(1-\phi)+\phi(1-\delta_s)\right]+k\phi c_s}{-k+2k\phi-\phi+\delta_s\phi} \qquad (33)$$

Furthermore, the optimal quantity ordered of OTA is solved as $q_7^* = \frac{\Phi(-k+2k\phi-\phi+\delta_s\phi)^k}{\left[k(c_r+c_s)\right]^k}$.

Setting $q_7^* = q_t^*$ to obtain $\phi_1^* = \frac{2k}{2k-1+\delta_s} > 1 (0<\delta_s<1)$, so OTA revenue-sharing contract can't be realized.

3.5.4. Coordination of revenue-sharing contracts when both parties have altruism preference

Calculated by the same method as 3.4.1 to obtain q_8^* (Eq. 34).

$$q_8^* = \frac{\Phi\left[\phi+\delta_r(1-\phi)\right]^k}{\left[c_s\delta_r+c_r+(1-\delta_r)\omega\right]^k} \qquad (34)$$

Then the optimal quantity ordered q_8^* into utility function U_s of TCP, $U = \frac{\Phi\mathrm{T}^{k-1}}{(k-1)\Gamma^k}\left\{\left[k\Phi(1-\phi)\Gamma+(\omega-c_s)\mathrm{T}\right]+\delta_s\left[k\phi\Gamma-(\omega+c_r)\mathrm{T}\right]\right\}$,

Then ω_8^* is obtained (see the Box 1).

Then the optimal quantity ordered q_8^* of OTA is obtained as:

$$q_8^* = \frac{\Phi}{\left[k(c_r+c_s)\right]^k}\left(\frac{k(1-\delta_s\delta_r)-1+\delta_s+\mathrm{N}}{1-\delta_s\delta_r+\mathrm{M}}\right)^k$$

where:

$$\mathrm{N} = (1-\phi)(-1+\delta_s+\delta_r-\delta_r\delta_s) < 0,$$

$$\mathrm{M} = (1-\phi)(-1+\delta_r\delta_s+\delta_r-\delta_r^2\delta_s) < 0$$

According to $\frac{\mathrm{N}}{\mathrm{M}} >< 1$, $\left(\frac{k(1-\delta_s\delta_r)-1+\delta_s+\mathrm{N}}{1-\delta_s\delta_r+\mathrm{M}}\right)^k >< \left(\frac{k(1-\delta_s\delta_r)-1+\delta_s}{1-\delta_s\delta_r}\right)^k$, so $q_8^* >< q_a^*$.

According to the analysis in section 3.1.2, whether the contract is effective is jointly decided by $\delta_r, \delta_s, c_s, c_r$.

3.6. Coordination of revenue-sharing contracts under information asymmetry of the two parties

3.6.1. The optimal decision when OTA has altruism preference but TCP is uninformed

Calculated by the same method as 3.1.2 to obtain: $q_{9\mathrm{I}}^* = \frac{\Phi\left[\phi+\delta_r(1-\phi)\right]^k}{\left[c_s\delta_r+c_r+(1-\delta_r)\omega\right]^k}$, $q_{9\Pi}^* = \frac{\Phi(k-\phi)^k}{\left[k(c_r+c_s)\right]^k}$, where $q_{9\mathrm{I}}^*$ and $q_{9\Pi}^*$ are the decided quantity ordered when OTA has altruism preference and the decided quantity ordered when OTA doesn't have altruism preference respectively.

Box 1.

$$\omega_8^* = \frac{c_r\left[k\phi(1-\delta_r)-k(1-\delta_r)+\phi+\delta_r(1-\phi)\right]+c_sG+c_r\delta_sH+c_s\delta_s\left[-k\phi\delta_r(1-\delta_r)-\phi\delta_r-\delta_r^2(1-\phi)\right]}{(1-\delta_r)\left[\delta_r(1-\phi)+\phi-\delta_s\delta_r^2(1-\phi)-\phi\delta_s\delta_r\right]}$$

where $G = \left[-k\phi\delta_r^2 - k\delta_r(1-\delta_r)+\phi\delta_r+\delta_r^2(1-\phi)+k\phi+k\delta_r(1-\phi)-k\delta_r^2(1-\phi)\right]$ and

$$H = \left[-k\phi(1-\delta_r)-\phi-\delta_r(1-\phi)+k\phi(1-\delta_r)+k\delta_r(1-\phi)-k\delta_r^2(1-\phi)\right]$$

At that time:

$$U_s=\frac{\Phi\phi^{k-1}\left[\phi(k-1)(\omega-c_s)+k(1-\phi)(\omega+c_r)\right]}{(k-1)(\omega+c_r)^k}$$

Then obtain the optimal wholesale price ω_9^* by Eq. (35).

$$\omega_9^*=\frac{(k\phi-k+\phi)c_r+k\phi c_s}{k-\phi} \tag{35}$$

So the optimal quantity ordered $q_9^*=q_{9I}^*$ of OTA is given by Eq. (36).

$$q_9^*=\frac{\Phi(k-\phi)^k}{\left[\phi(k-\delta_r)(c_s+c_r)+(1-\phi)(c_s+c_r)k\delta_r\right]^k} \tag{36}$$

Setting $q_9^*=q_c^*$ to obtain $\phi_2^*=\frac{k}{1+k}<1$. According to $k>1$, $\frac{1}{2}<\phi_2^*<1$

3.6.2. Optimal decision when TCP has altruism preference but OTA is uninformed

Calculated by the same method as 3.5.1 to obtain q_{10}^* (Eq. 37).

$$q_{10}^*=\frac{\phi^k\Phi}{(c_r+\omega)^k} \tag{37}$$

Utility function U_s of TCP is obtained: $U_s=\frac{\Phi\phi^{k-1}\left\{(c_r+\omega)\left[\delta_s\phi+k(1-\phi)\right]+(k-1)\phi(\omega-c_s)\right\}}{(k-1)(c_r+\omega)^k}$。

Then ω_{10}^* is obtained by Eq. (38).

$$\omega_{10}^*=\frac{c_r\left[k(1-\phi)+\phi(1-\delta_s)\right]+k\phi c_s}{-k+2k\phi-\phi+\delta_s\phi} \tag{38}$$

The optimal quantity ordered of OTA is $q_{10}^*=\frac{\Phi(-k+2k\phi-\phi+\delta_s\phi)^k}{\left[k(c_r+c_s)\right]^k}$.

Setting $q_{10}^*=q_t^*$ to obtain $\phi_3^*=\frac{2k}{2k-1+\delta_s}>1(0<\delta_s<1)$, so profit-sharing coordination of OTA can't be realized.

3.6.3. Optimal decision when both parties have altruism preference but both are uninformed

Calculated by the same method as 3.6.1 to obtain:

$$q_{11I}^*=\frac{\Phi\left[\phi+\delta_r(1-\phi)\right]^k}{\left[c_s\delta_r+c_r+(1-\delta_r)\omega\right]^k},\quad q_{11\Pi}^*=\frac{\Phi(k-\phi)^k}{\left[k(c_r+c_s)\right]^k},$$

where q_{11I}^* and $q_{11\Pi}^*$ are the decided quantity ordered when OTA has altruism preference and the decided quantity ordered when OTA doesn't have altruism preference respectively.

Then ω_{11}^* is obtained:

$$\omega_{11}^*=\frac{c_r\left[k(1-\phi)+\phi(1-\delta_s)\right]+k\phi c_s}{-k+2k\phi-\phi+\delta_s\phi}$$

The optimal quantity ordered of OTA is obtained as:

$q_{11}^*=q_{11I}^*=\frac{\Phi\left[\phi+\delta_r(1-\phi)\right]^k(-k+2k\phi-\phi+\delta_s\phi)^k}{\left\{(c_r+c_s)\left[k\phi-k\delta_r(1-\phi)-\delta_r\phi(1-\delta_s)\right]\right\}^k}$, and $q_{11}^*=\frac{\Phi\left[\phi+\delta_r(1-\phi)\right]^k\left(k-1+\delta_s+\text{N}\right)}{\left[k-\delta_r(1-\delta_s)+\text{M}\right]^k}$, where $\text{N}=(1-\phi)(1-2k-\delta_s)<1$ and $\text{M}=\left[-k(1-\phi)(1+\delta_r)+\delta_r(1-\delta_s)(1+\phi)\right]><0$.

According to $\frac{\text{N}}{\text{M}}><1$, $\frac{\Phi\left[\phi+\delta_r(1-\phi)\right]^k\left(k-1+\delta_s+\text{N}\right)}{\left[k-\delta_r(1-\delta_s)+\text{M}\right]^k}><\frac{\Phi(\delta_s+k-1)^k}{\left[k-\delta_r(1-\delta_s)\right]^k}$, so $q_{11}^*><q_a^*$.

According to the analysis in section 3.1.2, whether the contract is effective is jointly decided by $\delta_r,\delta_s,c_s,c_r$.

4. Discussion

According to the assignment specification of Dada and Patruzzi (1999), assuming that the demand function of a low-carbon tourism product or service is $d(p,\theta)=y_0p^{-k}\theta\varepsilon$, where $\varepsilon\in[0,2]$ is $y_0=20000$, OTA cost is $c_r=1$ unit, TCP cost is $c_s=4$ unit and consumer low-carbon preference is θ=0.95. Assuming that consumer sensitivity degree to the price of tourism products or services is $k=2$, the optimal stocking factor $z_0=\frac{2}{k+1}=\frac{2}{3}$ can be obtained, and then $F(z_0)=\frac{z_0}{2}=\frac{1}{3}$. Setting $\delta_r=\delta_s=0.6$, and Table 1 is obtained through the calculation using Matlab2016a:

As shown in Table 1., the optimal wholesale price w_0^* under the model when only OTA has altruism preference is the maximum, and optimal wholesale prices (w_1^*, w_3^* and w_4^*) in the model when only TCP has altruism preference under information symmetry and information asymmetry and in the model when both parties have altruism preference under information asymmetry are the minimum. The optimal quantity ordered q_c^* in the centralized decision model of the supply chain is the maximum, followed by the optimal quantity ordered q_4^* when both parties have altruism preference under information asymmetry and the optimal quantities q^* and q_0^* ordered under the decentralized decision model of the supply chain and the model when only OTA has altruism preference. Therefore, the overall supply chain revenue π_c^* in the centralized decision model of the supply chain is the maximum, thus conforming the numerical analysis results of propositions 1~6.

Table 1. Decision values under different altruism preference conditions of OTA and TCP

Corresponding section (and subscript)	***2.2***	***2.3(c)***	***3.1.1(0)***	***3.1.2(1)***	***3.1.3(a)***	***3.2.1(2)***	***3.2.2(3)***	***3.2.3(4)***
W	9.00	Not considered	16.50	5.25	9.68	9.00	5.25	5.25
Q	56	225	56	144	106	115	144	186
P	113	28	113	44	60	55	44	34
TCP utility	563	Not considered	563	901	774	804	901	1024
OTA utility	281	Not considered	704	721	851	574	721	763
Overall profit	844	1126	844	1081	1016	1034	1081	1117

Table 2. Decision values of coordination of revenue-sharing contracts under different altruism preference conditions of OTA and TCP

Corresponding section (and subscript)	***3.5.1(5)***	***3.5.2(6)***	***3.5.3(7)***	***3.5.4(8)***	***3.6.1(9)***	***3.6.2(10)***	***3.6.3(11)***
Wholesale price w	7.18	12.50	6.26	8.64	7.18	6.26	1.32
Quantity ordered q	68	74	87	110	132	87	149
Sales price p	93	86	73	57	48	73	43
Utility of TCP U_s	557	618	628	757	827	628	1173
Utility of OTA U_r	341	754	712	883	592	712	566
Overall revenue π	898	919	963	1025	1064	963	1087

In order to analyze the impact of revenue sharing contract on supply chain, assuming Revenue contract coefficient is set as $\phi = 0.9$, and other values are identical with those in Table 1, so Table 2 can be obtained. According to Table 2., after the revenue-sharing contract is adopted, the optimal wholesale price w_6^* in the model when only OTA has altruism preference is the maximum while the optimal wholesale price w_{11}^* in the model when both parties have altruism preference under information asymmetry is the minimum. The optimal quantity ordered q_{11}^* in the model when both parties have altruism preference under information asymmetry is the maximum. Therefore, the overall supply chain revenue π_{11}^* in the model when both parties have altruism preference under information asymmetry is the maximum.

Through a comparison between Table 1 and Table 2, $q^* < q_5^*$, $q_0^* < q_6^*$, $q_2^* < q_9^*$, $q_a^* < q_8^*$; $w^* > w_5^*$, $w_0^* > w_6^*$, $w_2^* > w_9^*$, $w_a^* > w_8^*$; $\pi^* < \pi_5^*$, $\pi_0^* < \pi_6^*$, $\pi_2^* < \pi_9^*$ and $\pi_a^* < \pi_8^*$. That's to say, after the revenue-sharing contract is adopted, the optimal wholesale prices reduce, optimal quantities ordered rise and overall supply chain revenues increase in the decentralized decision model of the supply chain, in the model when only OTA has altruism preference under information symmetry and information asymmetry and the model when both parties have altruism preference under information symmetry, so effective coordination can be realized. In a similar way, $q_1^* > q_7^*$, $q_3^* > q_{10}^*$, $q_4^* > q_{11}^*$; $w_1^* < w_7^*$, $w_3^* < w_{10}^*$, $w_4^* > w_{11}^*$; $\pi_1^* > \pi_7^*$, $\pi_3^* > \pi_{10}^*$ and $\pi_4^* > \pi_{11}^*$.

The optimal wholesale price rises, optimal quantity ordered reduces and overall supply chain revenue declines in the models when only TCP has altruism preference under information symmetry and information asymmetry; the optimal wholesale price reduces, so does the optimal quantity ordered and overall supply chain revenue declines in the model when both parties have altruism preference under information asymmetry. Therefore, when the above three models adopt revenue-sharing contracts, effective coordination is impossible.

4.1. Numerical analysis of the model when both parties have altruism preference under information symmetry

TCP profit π_{sa}, TCP utility U_{sa}, OTA profit π_{ra} and OTA utility U_{ra} when TCP altruism preference δ_s is taken as 0.3, 0.5 and 0.7 respectively and OTA altruism preference δ_r is within $\delta_r \in [0.1, 0.9]$ are calculated, and thus Fig. 1 and Fig. 2 are obtained.

First of all, influences of TCP altruism preference δ_s and OTA altruism preference δ_r on TCP profit π_{sa} and TCP utility U_{sa} are analyzed as shown in Fig. 1. In the model when both parties have altruism preference under information symmetry, π_{sa} reduces with δ_s but increases with δ_r; U_{sa} increases with δ_s and increases with δ_r, too.

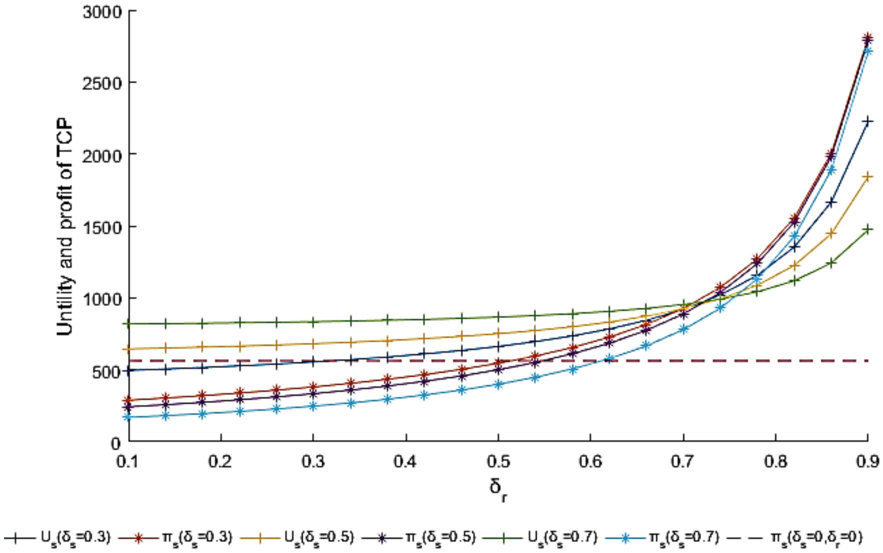

Fig. 1. Change tendency of TCP profit π_{sa} and TCP utility U_{sa} with δ_s and δ_r

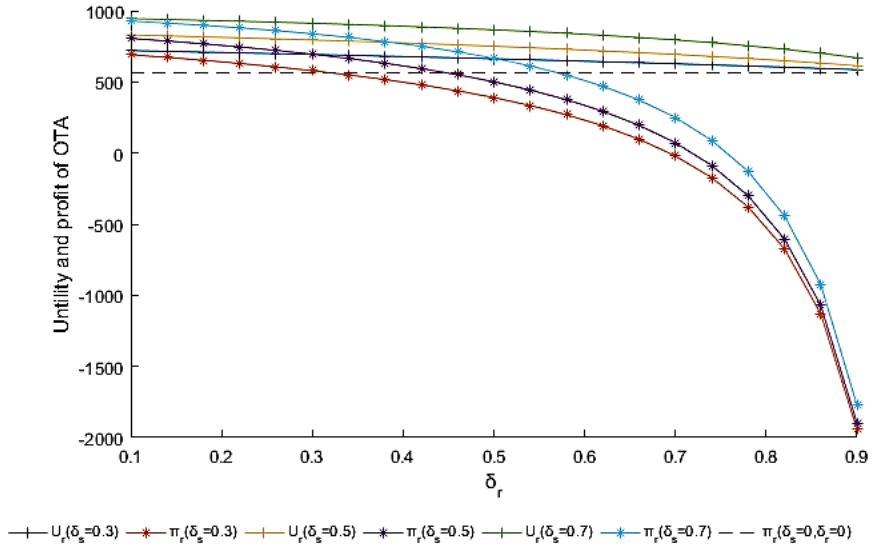

Fig. 2. Change tendency of OTA profit π_{ra} and OTA utility U_{ra} with δ_s and δ_r

Secondly, influences of δ_s and δ_r on OTA profit π_{ra} and OTA utility U_{ra} are analyzed. As shown in Fig. 2, in the model when both parties have altruism preference under information symmetry, π_{ra} increases with δ_s but reduces with δ_r, and even when $\delta_r > 0.3$, $\pi_{ra} < 0$, this situation should be avoided; U_{ra} increases with δ_s but reduces with δ_r, and U_{ra} is always greater than OTA utility U_s in the decentralized decision.

4.2. Numerical analysis of the model when both parties have altruism preference under information asymmetry

TCP profit π_{s4}, TCP utility U_{s4}, OTA profit π_{r4} and OTA utility U_{r4} when TCP altruism preference δ_s is taken as 0.3, 0.5 and 0.7 respectively and OTA altruism preference δ_r is within $\delta_r \in [0.1, 0.9]$ are calculated, and thus Fig. 3 and Fig. 4 are obtained:

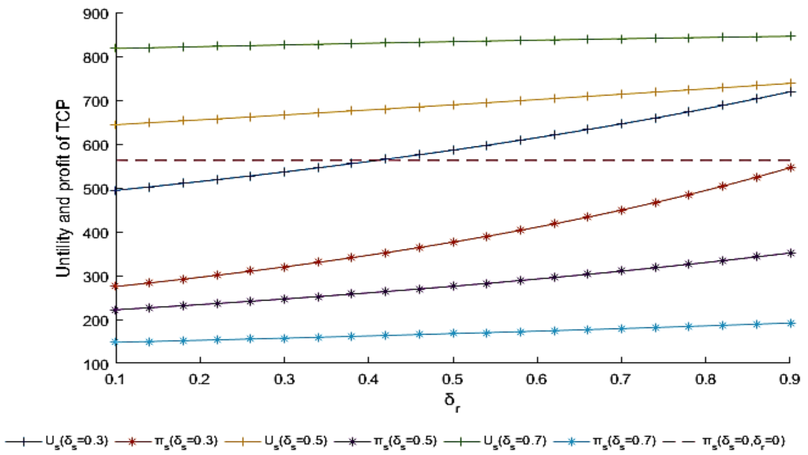

Fig. 3. Change tendency of TCP profit π_{s4} and TCP utility U_{s4} with δ_s and δ_r

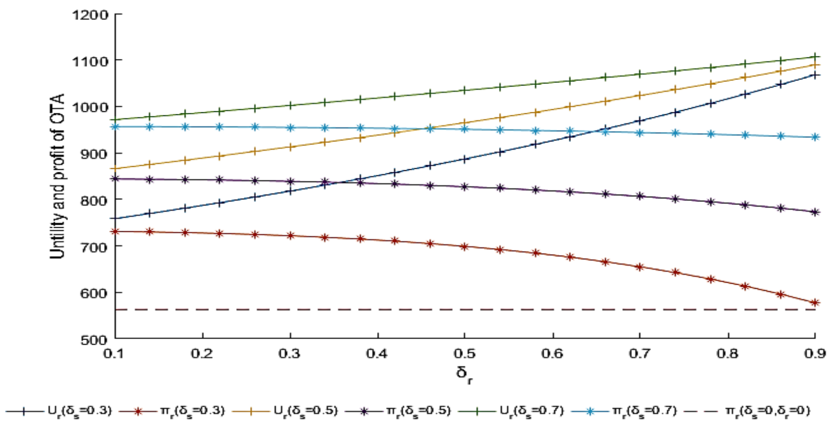

Fig. 4. Change tendency of OTA profit π_{r4} and OTA utility U_{r4} with δ_s and δ_r

Influences of TCP altruism preference δ_s and OTA altruism preference δ_r on TCP profit π_{s4} and TCP utility U_{s4} are firstly analyzed as shown in Fig. 3. π_{s4} reduces with δ_s but increases with δ_r; U_{s4} increases with δ_s and increases with δ_r, too. Secondly, influences of δ_s and δ_r on OTA profit π_{r4} and OTA utility U_{r4} are analyzed. As shown in Fig. 4, π_{r4} increases with δ_s but reduces with δ_r, but not lower than OTA profit π_r in the decentralized decision; U_{r4} increases with δ_s and also increases with δ_r.

Different from the result in the model when both parties have altruism preference under information symmetry stated in section 6.1, the whole supply chain is more coordinated and orderly on the contrary under information asymmetry, indicating that mutual concern of the two parties in the supply chain will make the overall supply chain more efficient.

4.3. Influence of revenue-sharing contracts on the supply chain

Quantities ordered (q_a, q_4, q_8 and q_{11}), wholesale prices (w_a, w_4, w_8 and w_{11}) and overall supply chain revenues (π_a, π_4, π_8 and π_{11}) in the four models-the models when both TCP and OTA have altruism preference under information symmetry and information asymmetry and models when both TCP and OTA have altruism preference and revenue-sharing contracts are adopted-are compared respectively. The influences of effectiveness of revenue-sharing contract coordination and altruism preference on quantities ordered, wholesale prices and overall supply chain revenues in the above four models are further analyzed. Quantities ordered, wholesale prices and overall supply chain revenues in the above four models when TCP altruism preference δ_s is taken as 0.5 and OTA altruism preference δ_r is within $\delta_r \in [0.1, 0.9]$ are calculated respectively, and Figs. 5, 6 and 7 are obtained.

As shown in Fig. 5, the optimal quantity q_4 is the greatest and increases with δ_r. q_8 is always higher than q_a, and both q_8 and q_a reduce with δ_r. When δ_r is small, both q_8 and q_a are greater than q_{11}, and q_{11} increases with δ_r.

According to Fig. 6, the optimal wholesale price w_a increases with δ_r and changes rapidly. When $\delta_r = 0.9$ and $\delta_r = 0.9$, the high wholesale price results in decline of quantity ordered so as to cause decline of the overall supply chain revenue. As $w_8 < w_a$, after the revenue-sharing contract is adopted, the wholesale price of the supply chain reduces and overall revenue rises, so the revenue-sharing contract can realize effective coordination. As $w_{11} > w_4$, TCP profit reduces, so does quantity ordered, which exerts an adverse effect on the supply chain. Therefore, under information asymmetry, effective coordination is impossible when the revenue-sharing contract is adopted.

As shown in Fig. 7, change tendency of the overall supply chain revenue is identical with that of the quantity ordered in Fig. 5, and Fig. 7 can intuitively show coordination results of revenue-sharing contracts. As $\pi_4 > \pi_a$, using revenue-sharing contracts can realize effective coordination under information symmetry. According to $\pi_{11} < \pi_8$, using revenue-sharing contracts can't realize effective coordination under information asymmetry.

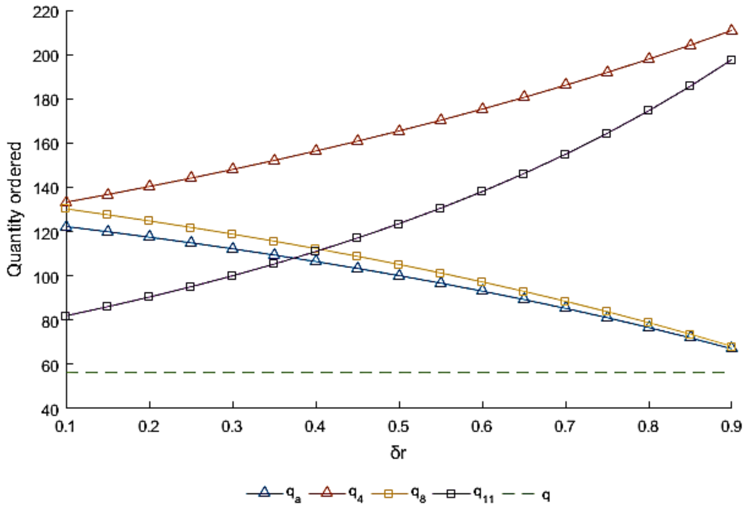

Fig. 5. Change tendency map of quantities ordered (q_a, q_4, q_8 and q_{11}) of the above four models with δ_r

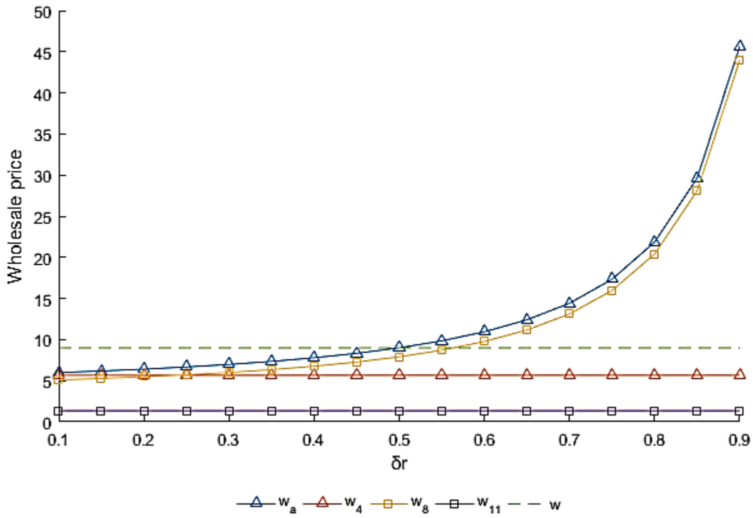

Fig. 6. Change tendency graph of wholesale prices (w_a, w_4, w_8 and w_{11}) of the above four models with δ_r

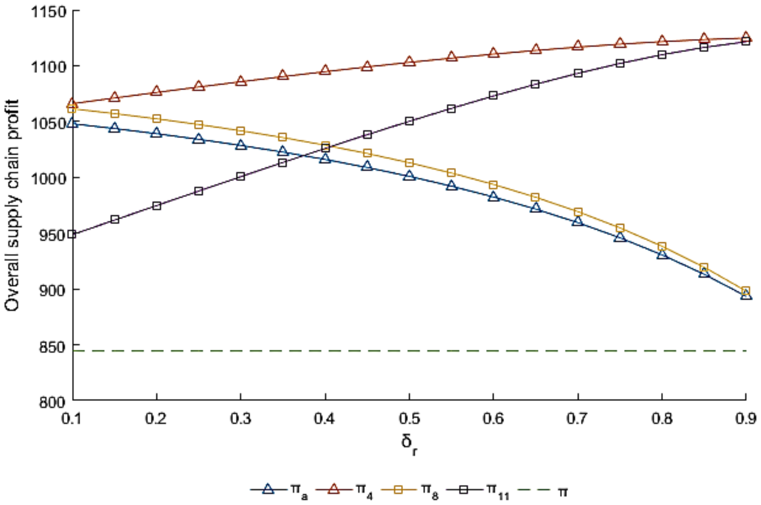

Fig. 7. Change tendency map of overall supply chain revenues (π_a, π_4, π_8 and π_{11}) of the above four models with δ_r

4.4. Influence of consumer low-carbon preference on the supply chain

The overall supply chain revenues when OTA altruism preference is $\delta_r = 0.5$, consumer low-carbon preference θ is within $\theta \in [0,1]$ and TCP altruism preference δ_s is within $\delta_s \in [0,1]$ are calculated, and then Fig. 8 is obtained.

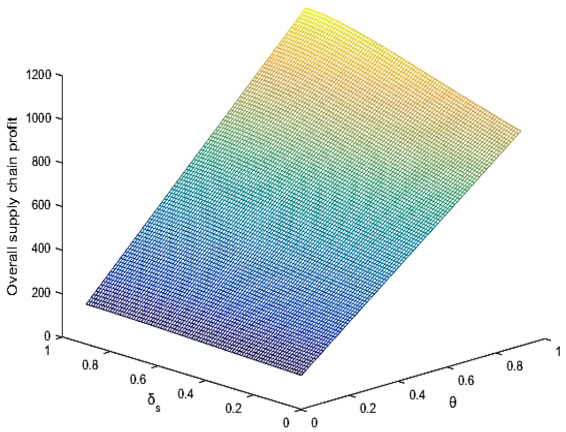

Fig. 8. Change tendency map of the overall supply chain revenue with θ and δ_s

It can be known from Fig. 8 that the overall supply chain profit increases with both θ and δ_s. This indicates that the greater the consumer low-carbon preference, the higher the overall supply chain revenue; similarly, the greater the TCP altruism preference, the higher the overall supply chain revenue. When $\theta = 1, \delta_s = 1$, the overall supply chain profit reaches the maximum.

5. Conclusions

Low-carbon tourism supply chain decision and coordination contract problems under information symmetry and information asymmetry are studied in this paper. In consideration of influences of altruism preference of the decision maker and consumer low-carbon preference on the decision, the optimal decisions for wholesale price of TCP and quantity ordered and wholesale price of OTA are examined in the Stackelberg game, and the impacts of coordination parameters on coordination condition, pricing decisions, wholesale price and quantity ordered are analyzed and compared. The influences of altruism preference and some suggestions for establishing coordination contracts are provided.

(a) Increase the altruistic preference of TCP to improve the overall profits of the supply chain. (b) Under information symmetry condition, the overall supply chain profit reduces with OTA altruism preference increases. However, under information asymmetry, the overall supply chain profit increases with OTA altruism preference increases. Therefore, when OTA platform has altruistic preference, information exchange between OTA and TCP should be increased to improve the overall income of the supply chain. (c) As the consumer low-carbon preference degree increases, the overall supply chain profit increases. Therefore, we should actively promote the concept of green and low carbon, improve consumers' awareness of low carbon and environmental protection, and play a positive role in the overall supply chain profit and the natural environment. (d) Under information symmetry condition, revenue-sharing contracts should be taken into consideration in order to increase the overall supply chain profit; under information asymmetry condition, the revenue-sharing contracts should not be taken. As the model is constructed under the hypotheses, the assumption of parameters will lead to distortion of the model, it is difficult to explore the intrinsic and profound relationship between the different parameters. For the following research, the interaction between altruistic preference and customer's low-carbon preference can be considered.

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Appendixes

Appendix A. Proof of Proposition 1

$q_0^*=q^*$ is firstly proved. According to equations (10) and (14), analytical expressions of q_0^* and q^* are equal. $w_0^*>w^*$ is proved, and then it's only necessary to prove $w_0^*-w^*>0$. According to $w_0^*\text{-}w^*=\frac{\delta_r(c_r+c_s)}{(k-1)(1-\delta_r)}>0(k>1,0<\delta_r<1)$, $w_0^*>w^*$. Moreover, as $\frac{\delta_r}{1-\delta_r}=\frac{\delta_r-1+1}{1-\delta_r}=\frac{1}{1-\delta_r}-1$, $\frac{\delta_r}{1-\delta_r}$ increases with δ_r, namely w_0^* increases with δ_r. Therefore, the proposition is proved.

Appendix B. Proof of Proposition 2

Easily proved by the same method as Proposition 1. $q_1^*-q_0^*=\frac{\Phi}{[k(c_r+c_s)]^k}[(\delta_s+k-1)^k-(k-1)^k]>0$, $q_c^*-q_1^*=\frac{\Phi}{(c_r+c_s)^k}[1\text{-}\frac{(\delta_s+k-1)^k}{k^k}]>0$ .so $q_c^*>q_1^*>q_0^*=q^*$ is proved. According to proposition 1, $w_0^*>w^*$. As $w_1^*\text{-}w^*=\text{-}\frac{k\delta_s(c_r+c_s)}{(\delta_s+k-1)(k-1)}<0$, $w_1^*<w^*<w_0^*$ is proved.

Appendix C. Proof of Proposition 3

Easily proved by the same method as Proposition 1, $q_0^*<q_a^*$ and $q_a^*<q_1^*$. According to proposition 2, $q_1^*<q_c^*$.

Appendix D. Proof of Proposition 4

Easily proved by the same method as Proposition 1. As $q_2^*-q_0^*=\frac{\Phi(k-1)^k}{(c_r+c_s)^k}[\frac{1}{(k-\delta_r)^k}-\frac{1}{k^k}]>0$. As $w_2^*=w^*$, according to proposition 1, $w^*<w_0^*$, so $w_2^*=w<w_0^*$

Appendix E. Proof of Proposition 5

Easily proved by the same method as Proposition 1, $w_3^*=\frac{c_r+kc_s-c_r\delta_s}{\delta_s+k-1}=w_1^*$; $q_3^*=\frac{\Phi(\delta_s+k-1)^k}{\left[k(c_r+c_s)\right]^k}=q_1^*$.

Appendix F. Proof of Proposition 6

$\forall q_i\,(i=0,1,2,3,4,c,a)$ and $q_i=\frac{y_0\theta z_0[1-F(z_0)]^k A_i}{B_i}$, where A_i, B_i are analytical forms not including the consumer low-carbon preference θ, and then $\forall q_i$ and θ present first-order direct proportional linear relation. Therefore, the greater the θ, the greater the q_i, and then the proposition is proved.

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