Traffic & Transportation

Cooperative Strategy for Airline Code-Share Agreements – A Comparative Analysis

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Original Scientific Paper
Submitted: 3 Nov. 2023
Accepted: 14 Jan. 2024

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Publisher:
Faculty of Transport and Traffic Sciences, University of Zagreb

ABSTRACT

Members of marketing airline alliances cooperatively book seats from the operating airline and compete with each other in the market. This paper models and discusses two types of bargaining pricing processes: representative-based and agent-based cooperative bargaining. It also considers the internal negotiation mechanism within the marketing airline alliance for representative-based bargaining. Using a cooperative bargaining approach, the effects of marketing airline mergers in code-share agreements with the operating airline are analysed. The performance of two sub-strategies under representative-based bargaining is compared with the non-cooperative case. The study con-cludes that representative-based bargaining without internal negotiation intensifies competition, while representa-tive-based bargaining with internal negotiation has the opposite effect. Cooperative bargaining with internal ne-gotiation benefits both the marketing airlines and the operating airline, whereas representative-based bargaining without internal negotiation may result in a total profit loss. The choice of which bargaining strategy to adopt depends on the bargaining power and the substitutability of different market airline brands. This research provides the basis and support for the formulation of pricing strategies in airline alliances' code-sharing.

KEYWORDS

airline alliance; code-share agreement; transfer price; cooperative bargaining; negotiation.

1. INTRODUCTION

Competition units among different enterprises have developed from one to group such as strategic alliances [1–3]. In the rapidly evolving aviation industry, airline alliances have emerged as an important mechanism of cooperation, streamlining operations and boosting competitiveness by sharing resources, optimising networks and distributing risks to reduce costs [4, 5]. The strategic collaboration allows member airlines to offer more diverse services and improved connectivity, providing passengers with more flexibility and value-added benefits [6–9]. With the rise of alliances such as Star Alliance, SkyTeam and Oneworld, code-share agreements have become one of the most common practices for collaboration, highlighting the necessity of intensely competitive global market for partnerships. Based on available seat kilometres, the three grand airline alliance passenger capacity by market share was 43 percent in 2022 and airlines non-aligned with the three largest airline alliances as a whole comprised more than half of the global market [10]. Therefore, exploring cooperative strategies between airlines is vital for understanding and optimising industry dynamics and guiding strategic decision-making, making it an issue of theoretical and practical significance.

Airline code-sharing, where multiple airlines share a single flight, allowing each to market it under its own designator and flight number, has become a fundamental operational strategy. This practice enhances network connections, boosts flight frequencies and provides comprehensive travel options for passengers. Current research focuses on leveraging code-sharing to improve operational efficiency and customer satisfaction, while also addressing the economic, regulatory and strategic aspects within the global air travel sector [11, 12]. Cooperation between airline alliance members includes complementary alliances and parallel alliances [13–17]. Several studies have examined the impact of complementary and parallel alliances on output, profit, ticket prices and social welfare etc. 18 –20]. Studies reveal that different alliance forms influence airfares in diverse ways. Research by Morrish and Hamilton, Park, Brueckner and Whalen, Oum et al., and others have explored these aspects, revealing variations in airfares and operational efficiencies attributed to different alliance structures [11, 12, 21–23]. The identity is that alliances often lead to reduced airfares [24–29] and improved performance [30–33], with implications on both supply and demand dynamics [34] and overall industry profitability. These studies indicate that airline alliances significantly influence the aviation industry's pricing strategies, operational efficiency and profit models, thereby profoundly affecting the industry's development trends and competitive landscape.

Our research is related to airline revenue management which is widely studied in the existing literature. The literature on airline revenue sharing focuses on booking system design [35], capacity sharing [36–37] and revenue sharing mechanisms [38–40]. The most related to our work is the transfer price between the operating airline and the marketing airline. Individual airlines within an alliance aim to maximise their net profits, using two primary methods for revenue sharing: a predetermined percentage payment or a transfer price paid by marketing airlines to sell seats of operating airlines. The decision to accept a booking request depends on whether the marketing airline's offered price meets the operating airline's requirements. Graf and Kimms conducted studies focusing on revenue-sharing mechanisms based on options in airline alliances, proposing methods for booking seats and optimising transfer prices [41,42]. Their research primarily addresses code-sharing between one marketing and one operating airline.

Game-theoretic models based on Nash bargaining are widely used in studies on operation management. Nagarajan and Blondiau et al. studied the behaviour of air traffic control using union bargaining, considering the bargaining power of air traffic agencies and unions [43, 44]. Bargaining power refers to a player's ability to influence bargaining terms based on possession of key resources [45]. Hsu et al. studied retailer cooperative purchasing through leader-based collective bargaining, showing that the leader is always better off under an equal price strategy [46]. Li explored supplier merging in cooperative purchasing and inventory sharing and its impact on the supply chain [47]. Wang et al. investigated the fresh food supply chain considering carbon emission trade policies and retailers merging in replenishment [48]. One representative work Zheng et al. analysed carbon offset strategies using a cooperative bargaining framework in the transportation sector, focusing on determining specific carbon offset schemes within airline alliances [49]. However, very limited studies have focused on bargaining under code-share agreements within partners. In this study, we attempt to propose different cooperative bargaining scenarios targeting the achievement of profit maximisation of the airlines.

Existing works of literature have conducted some investigations into exploring airline alliances, codeshare agreement, and their impact on airfare, airline profitability and performance. The existing studies explored how alliances influence ticket prices and enhance the operational effectiveness of airlines and the dynamics of cooperation and competition within alliances. However, most of them overlook the decision-making process regarding transfer pricing between marketing and operating carriers employing a cooperative Nash bargaining framework. Our research innovatively addresses this gap by putting forward three bargaining models for transfer pricing decisions. The contribution plays a key role in enhancing operational efficiency and offering practical decision-making tools and insights into the economic interaction within airline code-share alliances.

The rest of the paper is organised as follows: Section 2 presents the benchmark model for separate bargaining between two marketing airlines and the operating airline. Sections 3 and 4 describe and model the representative-based and agent-based cooperative bargaining, respectively. Representative-based bargaining explores transfer price strategies with and without internal negotiation. In Section 5, the performance of the different cooperative bargaining strategies presented in Sections 3 and 4 is analytically and numerically discussed. Finally, Section 6 provides the conclusions.

2. BENCHMARK: NON-COOPERATIVE BARGAINING MODEL (NC)

We consider a marketing airline alliance consisting of two marketing airlines and one operating airline, indexed by $i(i=1,2)$ and o. The marketing airlines purchase the services from the operating airline through a codeshare contract. Each marketing airline sells transport services in the market and competes with each other. To simplify the problem, we assume that the operating airline only sells seats to the marketing airlines and does not directly sell seats to passengers. Additionally, it is assumed that the seats provided by the operating airline can satisfy the total demand of both marketing airlines.

From the perspective of the marketing airlines, we only consider Cournot competition whereby the quantity offered by both airlines is determined by the ticket price. We also assume that there is only one fare class offered by the operating airline and the ticket price remains static over time. The demand quantity of the marketing airlines on the codeshare route, as well as the booking quantity from the operating airline is $p_i=\alpha-q_i-\gamma q_{-i}$, where α and p_i represent the market size and unit ticket price. γ indicates the substitution factor between the two marketing airlines where $\gamma\in[0,1]$. When $\gamma=0$, the service products of the two airlines are completely independent; when $\gamma=1$, the service products are perfect substitutes. The subscript i represents one marketing airline, while $-i$ represents the other marketing airline. This classical inverse function is commonly employed in the field of supply chain management [50–54].

In the non-cooperative case, the two marketing airlines engage in separate negotiations with the operating airline. The bargaining process is illustrated in *Figure 1*. Each marketing airline independently determines the quantity of seats required based on their respective ticket prices. They then proceed to negotiate with the operating airline regarding the transfer price that the marketing airline pays to sell the seats of the operating airline. If an agreement is reached, marketing airline i will book q_i seats from the operating airline by paying the transfer price λ_i. However, if the negotiation fails, a codeshare agreement will not be established.

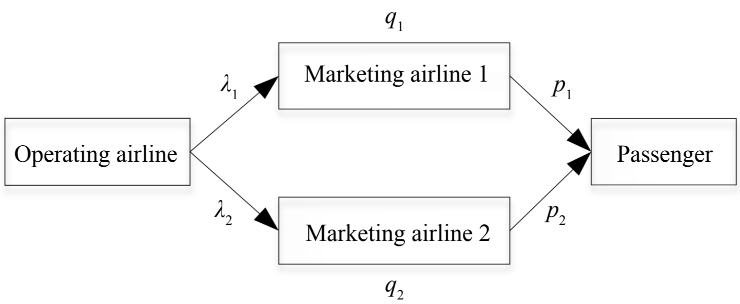


Figure 1 – Process of two marketing airlines in non-cooperative bargaining

From the perspective of the operating airline, the marginal cost of each seat is c. The profit of marketing airline i and operating airline are respectively $\pi_i=(\alpha-q_i-\gamma q_{-i}-\lambda_i)q_i$ and $\pi_0=\sum_{i=1}^{2}(\lambda_i-c)q_i$. The subscript o denotes the operating airline.

The two separate bargaining processes are independent and constitute a Nash-Nash equilibrium. This equilibrium extends the concept of a single Nash equilibrium, and the two bargaining processes are not bilateral. According to the Nash bargaining model, the following problem has a unique optimal solution:

$$\max_{x_1,x_2}(x_1-d_1)(x_2-d_2) \text{ s.t. } x_1\geq d_1,\ \ x_2\geq d_2,\ \ x_1+x_2\leq \Pi$$

where x_1 and x_2 represent the allocation results of the bargaining problem, and (d_1,d_2) is the disagreement point of the bargaining. Π represents the additional revenue gained from cooperation.

Based on the influence factor of bargaining power, the model can be expressed as follows:

$$\max_{\lambda_i}\pi_i^{\theta_{io}}[(\lambda_i-c)q_i]^{1-\theta_{io}} \tag{1}$$

where θ_{io} and $1-\theta_{io}$ represent the bargaining power of marketing and operating airline satisfying $0<\theta_{io}<1$. π_i and $(\lambda_i-c)\ q_i$ denote the profit of marketing airline i and the surplus obtained by bargaining with airline i, respectively. It is assumed that the disagreement point for each player is zero, indicating that if either of the bargaining fails, neither of the players will receive any surplus. The transfer price that marketing airline i pays and the profit of the marketing airline i are as follows:

$$\lambda_i = \theta_{io} c + (1 - \theta_{io})(\alpha - q_i - \gamma q_{-i}) \tag{2}$$

$$\pi_i = \theta_{io}(\alpha - q_i - \gamma q_{-i} - c) q_i \tag{3}$$

The optimal demand of marketing airlines can be obtained by arg max$(p_i - c)q_i$ that $q_i^s = \frac{\alpha - c}{2+\gamma}$, where the superscript s denotes that the two marketing airlines separately bargain with the operating airline. The transfer price is $\lambda_i^s = \frac{\alpha(1-\theta_{io}) + c(1+\gamma+\theta_{io})}{2+\gamma}$. The corresponding profits of marketing airline and operating airline are $\pi_i^s = \theta_{io}\left(\frac{\alpha - c}{2+\gamma}\right)^2$ and $\pi_o^s = (1 - \theta_{io} - \theta_{-io})\left(\frac{\alpha - c}{2+\gamma}\right)^2$.

3. REPRESENTATIVE-BASED COOPERATIVE BARGAINING MODEL (RC)

In this section, the cooperative bargaining dynamics between two marketing airlines are explored. One marketing airline acts as the representative and directly negotiates with the operating airline regarding the transfer price of seats. The other marketing airline follows the lead of the representative airline. Two sub-strategies are examined within representative-based cooperative bargaining, distinguished by the presence or absence of internal negotiation between the two marketing airlines.

In the context of code-share agreements, marketing airlines have two strategies for setting transfer prices: one with internal negotiation and one without. Without internal negotiation, each airline independently decides on its output and negotiates collectively for seat booking with the operating airline. With internal negotiation, marketing airlines first negotiate among themselves before the representative negotiates with the operating airline. If internal negotiation fails, the cooperative strategy collapses.

3.1 RC without internal negotiation

The bargaining process of representative marketing airline-based bargaining without internal negotiation is illustrated in *Figure 2*.

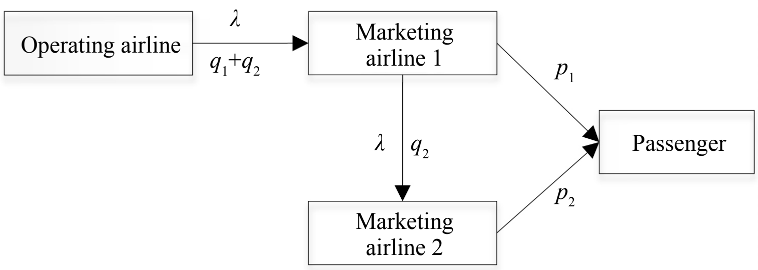


Figure 2 – Process of representative-based cooperative bargaining without internal negotiation

First, the two marketing airlines independently determine their demand quantity q_i by maximising their profits. Next, the representative marketing airline engages in bargaining with the operating airline regarding the transfer price. If they reach an agreement in the negotiation, the representative marketing airline i proceeds to book seats from the operating airline by making the necessary payment. Subsequently, the representative marketing airline resells the seats to the follower marketing airline at the same transfer price. The profits of marketing airline i and the operating airline (labelled as o) are as follows:

$$\pi_i = (\alpha - q_i - \gamma q_{-i} - \lambda) q_i, \ \pi_o = (\lambda - c)(q_1 + q_2) \tag{4}$$

By employing backward induction, the cooperative bargaining problem is expressed as follows:

$$\max_{\lambda} (\pi_i)^{\theta_i} \pi_o^{1-\theta_i} \tag{5}$$

where θ_i and 1-θ_i represent the bargaining power of the representative marketing airline and the operating airline, respectively. It is important to note that θ_i is the cooperative bargaining power of the representative marketing airline, while θ_{io} represents the separate bargaining power of marketing airline i.

By solving the bargaining problem, the transfer price, the profits of the marketing and operating airline are as follows:

$$\lambda_i = \theta_i c + (1-\theta_i)(\alpha - q_i - \gamma q_{-i}) \tag{6}$$

$$\pi_i = \theta_i(\alpha - q_i - \gamma q_{-i} - c)q_i \tag{7}$$

$$\pi_{-i} = [(\alpha - q_{-i} - \gamma q_i) - \theta_i c - (1-\theta_i)(\alpha - q_i - \gamma q_{-i})]q_{-i} \tag{8}$$

where the optimised demand quantity could be derived by solving the maximisation problem of the marketing airline's profit, $q_i^u = \frac{(\alpha-c)[2(1-\gamma)+\gamma\theta_i]}{(4+\gamma)(1-\gamma)+3\gamma\theta_i}$ and $q_{-i}^u = \frac{(\alpha-c)(1-\gamma-\theta_i)}{(4+\gamma)(1-\gamma)+3\gamma\theta_i}$. Superscript u denotes the strategy of representative-based cooperation without internal negotiation.

By substituting q_i^u and q_{-i}^u into *Equation 11–13*, the optimal solutions of transfer price and corresponding profits are as follows:

$$\begin{aligned} &\lambda^u = c + (1-\theta_i)\frac{(\alpha-c)[2(1-\gamma)+\gamma\theta_i]}{(4+\gamma)(1-\gamma)+3\gamma\theta_i},\ \pi_i^u = \theta_i\left[\frac{(\alpha-c)[2(1-\gamma)+\gamma\theta_i]}{(4+\gamma)(1-\gamma)+3\gamma\theta_i}\right]^2, \\ &\pi_{-i}^u = \frac{(\alpha-c)^2(1-\gamma-\theta_i)[(1-\gamma^2)+\gamma\theta_i^2]}{[(4+\gamma)(1-\gamma)+3\gamma\theta_i]^2},\ \pi_o^u = \frac{(1-\theta_i)(\alpha-c)^2[2(1-\gamma)+\gamma\theta_i][3(1-\gamma)+(1+\gamma)\theta_i]}{[(4+\gamma)(1-\gamma)+3\gamma\theta_i]^2} \end{aligned} \tag{9}$$

Then, we will compare the performance of representative-based cooperative bargaining without internal negotiation and non-cooperative bargaining in terms of demand quantity, marketing airline profit and operating airline profit. Thus Proposition 1 is obtained.

Proposition 1. Compared with non-cooperative bargaining, we could derive that $q_i^u > q_i^s$, $q_{-i}^u < q_{-i}^s$, and $q_i^u + q_{-i}^u < q_i^s + q_{-i}^s$.

Proposition 1 suggests that under cooperative bargaining, the demand quantity of the representative marketing airline is higher, while the demand quantity of the follower marketing airline is lower compared to the non-cooperative case. As a result, the total demand of the marketing airlines decreases.

Then we would compare the profits of the marketing airlines in the representative-based cooperative bargaining without internal negotiation and the non-cooperative case and obtain Proposition 2.

Proposition 2. Compared with the non-cooperative case, for the leader marketing airline there is always $\pi_i^u \geq \pi_i^s$. For the follower airline, when bargaining power of separate bargaining power $\theta_{-io} < \tilde{\theta}_{-io}$, $\pi_{-i}^u \geq \pi_{-i}^s$; when $\theta_{-io} > \tilde{\theta}_{io}$, $\pi_{-i}^u < \pi_{-i}^s$. For the two marketing airlines, when bargaining power of separate bargaining power $\theta_{-io} < \hat{\theta}_{io}$, $\pi_i^u + \pi_i^u > \pi_{-i}^s + \pi_{-i}^s$; when $\theta_{-io} > \hat{\theta}_{io}$, $\pi_i^u + \pi_{-i}^u < \pi_i^s + \pi_{-i}^s$.

Proposition 2 indicates that representative-based cooperation without internal negotiation is always better for the leader marketing airline than the non-cooperative case. When the separate bargaining power of the follower marketing airline is comparatively low, the profit of the follower marketing airline and the total profit of marketing airlines are higher than in the non-cooperative case. As for a comparison of the total profit of the three airlines under representative-based cooperation without internal negotiation, we have Proposition 3.

Proposition 3. There exists an interval $[\hat{\gamma}_1, \hat{\gamma}_2]$ between 0 and 1, with $0 < \hat{\gamma}_1 < \hat{\gamma}_2 < 1$, such that when $\gamma \in [\hat{\gamma}_1, \hat{\gamma}_2]$, $\pi_i^u + \pi_{-i}^u + \pi_o^u > \pi_i^s + \pi_{-i}^s + \pi_o^s$; otherwise, $\pi_i^u + \pi_{-i}^u + \pi_o^u < \pi_i^s + \pi_{-i}^s + \pi_o^s$.

Proposition 3 shows that whether the representative-based cooperation without internal negotiation is better for the three airlines' total profit depends on the substitution factor of the two marketing airlines. When the substitution factor is comparatively low or high, the representative-based cooperation without internal negotiation makes the total profit of the three airlines lower than the non-cooperative case.

The variation in total profit of the three airlines reflects the impact of cooperation compared to non-cooperation on the overall performance of all airlines in the market. Proposition 1 suggests that representative-based cooperation without internal negotiation leads to a decrease in the total demand quantity of the two marketing airlines. This can be attributed to resource allocation optimisation, as one marketing airline considers the influence of other competitors. Proposition 3 highlights the existence of an interval for the substitution factor where the total profit of the three airlines is better off under the strategy of representative marketing airline-based cooperation without internal negotiation.

3.2 RC with internal negotiation

Representative cooperative bargaining with internal negotiation involves a two-stage bargaining process within the marketing airline alliance before the negotiation between the representative airline and the operating airline. This process is illustrated in *Figure 3*.

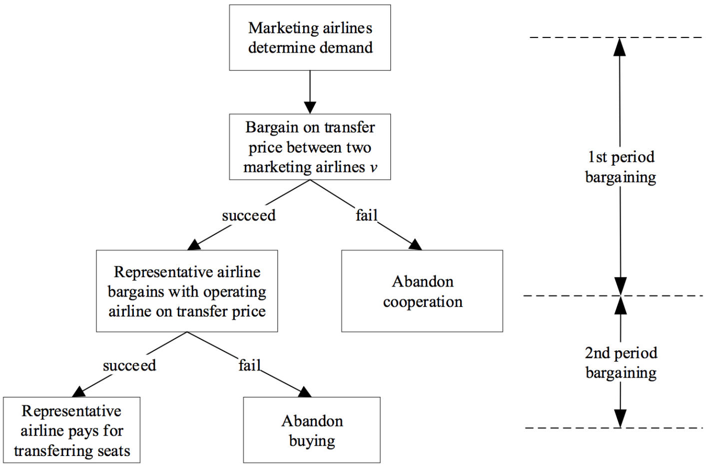


Figure 3 – Process of representative-based cooperative bargaining with internal negotiation

Two marketing airlines determine their respective service quantity. Demand quantities of the representative marketing airline and the follower marketing airline are denoted by q_i and q_{-i}. In the first period of bargaining, two marketing airlines bargain on the transfer price that the follower marketing airline pays to representative marketing denoted by v. If the negotiation between two marketing airlines fails, they would abandon cooperation and separately book from the operating airline. If the first period-bargaining has reached a deal, the second-period bargaining begins. In the second period of bargaining, the representative marketing airline engages in negotiations with the operating airline to determine the transfer price denoted as λ. If the negotiation in the second period fails, the disagreement point of the second-period negotiation is zero. If the agreement is reached, the representative marketing airline will pay the operating airline $\lambda(q_i+q_{-i})$. Additionally, the representative marketing airline will resell q_{-i} seats to the follower marketing airline at the unit transfer price v. Regarding the bargaining power, during the first-period bargaining the bargaining powers for the representative and follower airline are σ and $1\text{-}\sigma$. In the second period of negotiation, the bargaining power of representative marketing and the operating airline are θ_{io} and $1\text{-}\theta_{io}$, where $0<\sigma,\theta_{io}<1$.

The profits of the representative marketing airline, the follower marketing airline and the operating airline are as follows:

$$\pi_i=(\alpha-q_i-\gamma q_{-i}-\lambda)q_i+(v-\lambda)q_{-i},\ \pi_{-i}=(\alpha-q_{-i}-\gamma q_i-v)q_{-i}\ \text{and}\ \pi_o=(\lambda-c)(q_i+q_{-i}) \tag{9}$$

Based on backward induction, the second-period bargaining can be expressed as follows:

$$\max_{\lambda}(\pi_i)^{\theta_{io}}(\pi_o)^{1-\theta_{io}} \tag{10}$$

To solve this bargaining problem, the transfer price and profit of marketing airline are, respectively, as follows:

$$\lambda=\theta_{io}c+(1-\theta_{io})\cdot\frac{(\alpha-q_i-\gamma q_{-i})q_i+vq_{-i}}{q_i+q_{-i}} \tag{11}$$

$$\pi_i=\theta_{io}[(\alpha-q_i-\gamma q_{-i}-c)q_i+(v-c)q_{-i}] \tag{12}$$

From *Equations 11 and 12*, the transfer price of the representative marketing airline and the profit of the marketing airlines are influenced by the unit transfer price of the follower marketing airline v, which is obtained from the first period of the bargaining.

Next, in the first period of bargaining, the two marketing airlines negotiate on the transfer price that the follower marketing airline pays to the representative marketing airline. If the negotiation fails, the two marketing airlines would book from the operating airline separately, indicating that the disagreement point is (π_i^s, π_{-i}^s). However, if the negotiation is successful, the bargaining problem can be expressed as follows:

$$\max_{v} (\pi_i - \pi_i^s)^{\sigma} (\pi_{-i} - \pi_{-i}^s)^{1-\sigma} \tag{13}$$

The transfer price that the follower marketing airline pays to the representative marketing airline is obtained from solving the bargaining problem, as follows:

$$v = \sigma\left(\alpha - q_{-i} - \gamma q_i - \frac{\pi_{-i}^s}{q_{-i}}\right) + (1-\sigma)\left[\frac{\pi_i^s/\theta_{io} - (\alpha - q_i - \gamma q_{-i})q_i}{q_{-i}} + c\right] \tag{14}$$

The profits of the representative marketing airline and the follower marketing airline are, respectively, as follows:

$$\pi_i = \theta_{io}\sigma[(\alpha - q_i - \gamma q_{-i} - c)q_i + (\alpha - q_{-i} - \gamma q_i - c)q_{-i} - \pi_{-i}^s] + (1-\sigma)\pi_i^s \tag{15}$$

$$\pi_{-i} = \sigma\pi_{-i}^s + (1-\sigma)[(\alpha - q_i - \gamma q_{-i} - c)q_i + (\alpha - q_{-i} - \gamma q_i - c)q_{-i} - \pi_i^s/\theta_{io}] \tag{16}$$

Then the equilibrium demand quantity of the two marketing airlines $q_i^m = q_i^m = \frac{\alpha - c}{2(1+\gamma)}$, where the superscript m denotes the representative-based cooperation with internal negotiation (indicating multiple transfer prices).

The corresponding profits of the representative marketing airline, the follower marketing airline and the operating airline are illustrated as follows:

$$\begin{gathered}\pi_i^m = \theta_{io}(\alpha - c)^2 \cdot \left[\frac{\sigma}{2(1+\gamma)} + \frac{(1-\sigma-\sigma\theta_{-io})}{(2+\gamma)^2}\right],\ \pi_{-i}^m = (\alpha - c)^2 \cdot \left[\frac{1-\sigma}{2(1+\gamma)} + \frac{\sigma + \sigma\theta_{-io} - 1}{(2+\gamma)^2}\right] \\ \pi_o^m = \frac{(\alpha - c)^2}{2(1+\gamma)} \cdot [2 - \sigma(1+\theta_{-io})] - \left(\frac{\alpha - c}{2+\gamma}\right)^2 \cdot [1 + \theta_{io} - \sigma(\theta_{io} + \theta_{io}\theta_{-io} - \theta_{-io} + 1)]\end{gathered} \tag{17}$$

Then, we compare the performance of representative-based cooperation with internal negotiation and the non-cooperative case in terms of demand quantity, profit of marketing airlines, and the operating airline. We have Proposition 4.

Proposition 4. In the representative-based cooperation with internal negotiation cases, the demand quantities for the two marketing airlines are the same and is not more than that in the non-cooperative case, i.e. $q_i^m \le q_i^s$.

Proposition 4 implies that through internal negotiation in cooperative models, airlines might stabilise demand and reduce competition, aiding in resource optimisation and operational efficiency. However, it also suggests that cooperation might lead to reduced demand, possibly to maintain price stability or avoid the negative impacts of excessive competition.

Next, the profits of marketing airlines are compared. We find that the total profit of both marketing airlines is higher under representative-based cooperation compared to the non-cooperative case, and Proposition 5 is derived.

Proposition 5. $\pi_i^m \ge \pi_i^s$, $\pi_{-i}^m \ge \pi_{-i}^s$, i.e. the profit of both marketing airlines under representative-based cooperative bargaining with internal negotiation are higher than the non-cooperative case.

Proposition 5 indicates that in a representative-based cooperative bargaining scenario with internal negotiation, both marketing airlines achieve higher profits compared to a non-cooperative situation. This suggests that cooperative strategies lead to increased profitability for both marketing airlines. The cooperation with internal negotiation results in better coordination, more efficient resource utilisation, and possibly more favourable market conditions, which collectively contribute to enhanced profitability for the marketing airlines.

Then the profit of the operating airline under representative-based cooperation with internal negotiation is analysed and we obtained Proposition 6.

Proposition 6. When $\sigma(1-\theta_{io}) \ge 4(1-\theta_{-io})[1-\sigma(1-\theta_{io})]$, there is a substitution factor $\gamma \in (\hat{\gamma}, 1)$ that could lead

$\pi_o^m > \pi_o^s$, where $\hat{\gamma} = \dfrac{\sqrt{(1-\theta_{-io})[\sigma(1-\theta_{-io})-1][\sigma(1-\theta_{-io})^2-(1-\theta_{-io})-2\sigma(1-\theta_{io})]}-(1-\theta_{-io})[\sigma(1-\theta_{-io})-1]}{\sigma(1-\theta_{io})}$; otherwise $\pi_o^m < \pi_o^s$.

Proposition 6 indicates that when the substitution factor is comparatively higher than the threshold, the profit of the operating airline under representative-based cooperative bargaining with internal negotiation can be higher than in the non-cooperative case; when the substitution factor is comparatively low, cooperation with internal negotiation would make the operating airline benefit less than non-cooperative case.

Next, we compare the total profit of the three airlines in the case of cooperation with internal negotiation with the non-cooperation case. Proposition 7 is derived.

Proposition 7. $\pi_i^m + \pi_{-i}^m + \pi_o^m \geq \pi_i^s + \pi_{-i}^s + \pi_o^s$, i.e. the total profit of three airlines under representative-based cooperation with internal negotiation is higher than that in the non-cooperative case.

From Proposition 5, 6 and 7, it is evident that representative-based cooperative bargaining with internal negotiation is always more beneficial to each marketing airline and the total profit of the three airlines. As for the operating airline, implementing representative-based cooperative bargaining with internal negotiation would result in conditional benefits compared to non-cooperative bargaining.

4. AGENT-BASED COOPERATIVE BARGAINING MODEL (AC)

Agent-based cooperative bargaining is when the marketing airline alliance employs an external representative to negotiate with the operating airline (shown in *Figure 4*). In this approach, if the negotiation is successful, the agent receives a commission based on the total earnings.

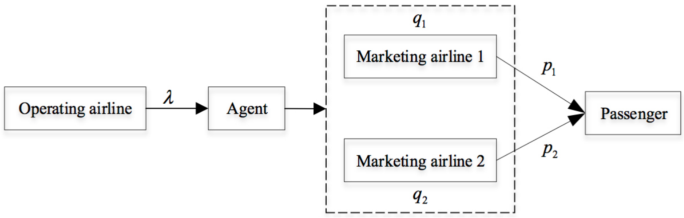


Figure 4 – Process of agent-based cooperative bargaining

Firstly, two marketing airlines independently determine their quantities. Then the agent bargains with the operating airline on wholesale transfer price λ. If the negotiation fails, the two marketing airlines will not separately book seats from the operating airline. If the negotiation reaches a deal, the agent would book a quantity of q_1+q_2 by unit transfer price λ and then the agent allocates the seats to the two marketing airlines according to their demand. The agent charges a commission of $k\lambda(q_1+q_2)$, where k is the commission rate. Subscript a denotes the agent of the marketing airline alliance. The profit of the marketing airlines, agent and the operating airline are $\pi_i=[\alpha-q_i-\gamma q_{-i}-(1+k)\lambda]q_i$, $\pi_a=k\lambda(q_1+q_2)$ and $\pi_o=(\lambda-c)(q_1+q_2)$, respectively.

Using backward induction, first we consider the bargaining problem expressed as follows:

$$\max_{\lambda}(\pi_1+\pi_2+\pi_a)^{\delta}\pi_o^{1-\delta} \tag{28}$$

where σ and 1-σ represent the bargaining power of the agent and the operating airline. The optimal transfer price is as follows:

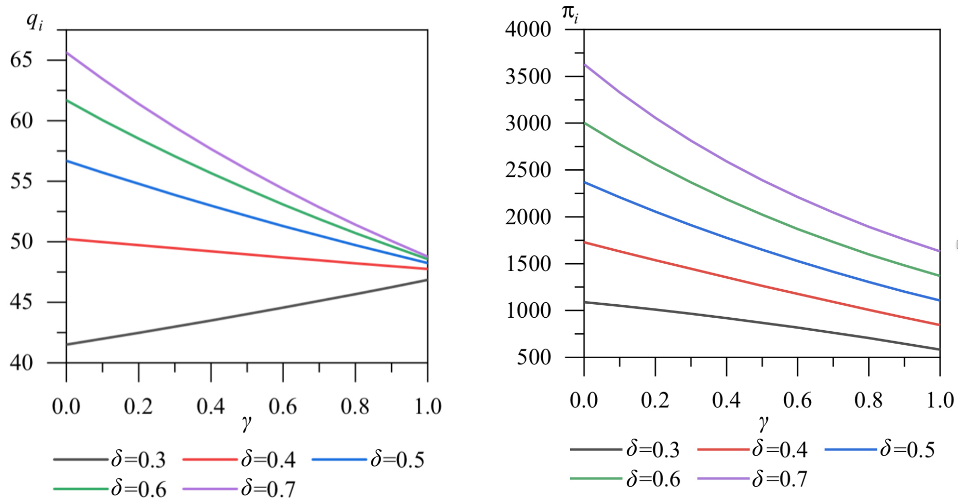
$$\lambda = \delta c + (1-\delta)\cdot\frac{(\alpha-q_i-\gamma q_{-i})q_i+(\alpha-q_{-i}-\gamma q_i)q_{-i}}{q_i+q_{-i}} \tag{29}$$

The corresponding profit of the market airline is as follows:

$$\pi_i = [\alpha - q_i - \gamma q_{-i}(1+k)\delta c]q_i - \frac{(1+k)(1-\delta)[(\alpha-q_i-\gamma q_{-i})q_i+(\alpha-q_{-i}-\gamma q_i)q_{-i}]q_i}{(q_i+q_{-i})} \tag{30}$$

Next, the two marketing airlines obtain the equilibrium demand quantity by solving the equation $q_i=\text{argmax}\pi_i$. A numerical experiment is presented to observe the variation trend of demand quantity for the marketing airlines. The parameter values are as follows: market size α=200, operating cost per seat c=50, separate bargaining power for the two marketing airlines θ_{io}=0.3 and θ_{io}=0.2, bargaining power for the agent $\delta\in\{0.3,0.4,0.5,0.6,0.7\}$, substitution factor between the two marketing airlines $\gamma\in[0,1]$ and commission proportion charged by the agent k=5%.

Figure 5a illustrates the trend of each marketing airline's demand quantity for the substitution factor. The X-axis represents the substitution factor γ, while the Y-axis represents the demand quantity of the marketing airline under different bargaining powers of the agent. From *Figure 5a*, when the bargaining power σ is less than or equal to the separate bargaining power θ_{io} (0.3 in this case), the equilibrium demand quantity increases with the substitution factor. However, when the bargaining power of the agent exceeds the separate bargaining power of the marketing airline, the equilibrium demand quantity of the marketing airline decreases with the substitution factor. Additionally, as the substitution factor increases, the slope of the curves decreases, indicating that the rate of decrease in demand quantity becomes faster. *Figure 5b* illustrates the profit of the marketing airline under different bargaining powers of the agent. From *Figure 5b*, we observe that when the bargaining power of the agent is unchanged, the profit of the marketing airline decreases as the substitution factor increases. However, as the bargaining power of the agent increases, the profit of the marketing airline increases under the same substitution factor. Additionally, the slope of the curves decreases as the bargaining power of the agent increases, indicating that the rate of increase in profit becomes slower with higher bargaining power of the agent.



a) *b)*

Figure 5 – Trend of each marketing airline's demand quantity and profit under different agent's bargaining power

Based on the numerical experiment conducted, it is evident that the bargaining power of the agent has a significant impact on the profit of the marketing airlines. Specifically, when the agent has a higher bargaining power, the marketing airlines tend to benefit more in terms of profit. This highlights the crucial role played by the agent in negotiating favourable terms and conditions with the operating airline, leading to increased profitability for the marketing airlines.

5. COMPARATIVE ANALYSIS

In this section, we first compare representative-based cooperation models with and without internal negotiation. Then, we contrast these with agent-based cooperative bargaining strategies. We aim to provide decision-making guidance for participants engaged in bargaining, analysing from the perspectives of market competition and airline revenue optimisation.

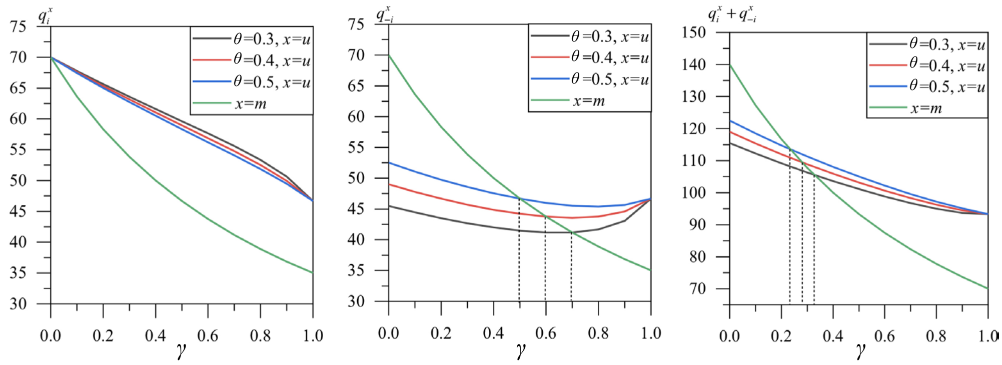
5.1 RC without internal negotiation and RC with internal negotiation

Performance comparison results based on non-cooperative bargaining in Section 3 were conducted. The analysis reveals that in representative-based cooperation scenarios, demand and profit vary depending on whether internal negotiation occurs. Without internal negotiation, demand increases for the representative marketing airline but decreases for the follower. With internal negotiation, demand decreases for both. Profit-wise, the representative airline always benefits more from cooperative strategies than in non-cooperative scenarios, and both marketing airlines generally earn more in cooperative settings. However, the follower airline's profit and the total profit may not always surpass non-cooperative cases, especially when the follower's bargaining power is below a certain threshold. The operating airline can also potentially earn more in cooperative scenarios under specific conditions. Additionally, total profit for all airlines is generally higher in internal negotiation scenarios, with some exceptions based on the substitution factor. Based on the comparisons between the two sub-strategies in representative-based cooperative bargaining and the non-cooperative case, it is evident that marketing airlines tend to prefer the strategy of representative-based cooperative bargaining with internal negotiation as it consistently leads to higher benefits for the marketing airlines.

In the following, we directly compare the performance of the two different sub-strategies under representative-based bargaining by numerical experiments, where the parameters are set as follows: market size α=150, operating cost per seat c=10 and substitution factor $\gamma \in [0,1]$. It is assumed that the bargaining power of the representative marketing airline is greater than that of the follower marketing airline $\theta_{io} > \theta_{-io}$. We assume the bargaining power of the representative marketing airline remains the same in the non-cooperation case, $\theta_i = \theta_{io}$.

First, the demand quantities under representative-based cooperative bargaining without and with internal negotiation are analysed. In the case of representative-based cooperation without internal negotiation, the demand quantity is influenced by the bargaining power, while in the case of internal negotiation, the demand quantity is independent of the bargaining power. *Figure 7* illustrates the demand quantity under the two sub-strategies of representative cooperation. The X-axis represents the substitution factor γ ranging from 0 to 1, and the Y-axis represents the quantity of demand. The black, red and blue curves represent the demand quantity under the RC without internal negotiation case with different bargaining power values (θ_{io}=0.3,0.4,0.5), while the green curve represents the demand quantity under the RC with internal negotiation case.

Figure 6a shows the trend of the demand quantity of the representative marketing airline. As the substitution factor increases, the demand quantity of the representative marketing airline decreases in both cases, with or without internal negotiation. In the scenario of the RC without internal negotiation cooperation, the demand quantity of the representative marketing airline decreases as the bargaining power θ_{io} increases. In contrast, under the RC with internal negotiation cooperation, the demand quantity of the representative marketing airline is lower than that under the RC without internal negotiation case, regardless of the bargaining power.



a) b) c)

Figure 6 – Profit for marketing airline(s) of RC without and with internal negotiation

Figure 6b shows the demand trends for the follower airline in a representative-based cooperative strategy, both with and without internal negotiation. In scenarios without internal negotiation, the follower airline's demand increases with the substitution factor. However, when internal negotiation is included, the demand curve intersects at specific points, depending on the substitution factor. Specifically, when the substitution factor is comparatively low, the demand is higher with internal negotiation than without. Conversely, when the substitution factor is comparatively high, the demand is lower with internal negotiation compared to without it. This indicates the impact of the substitution factor on demand under different cooperative negotiation settings.

Figure 6c illustrates how the total demand quantity for both marketing airlines changes under different strategies. With RC without internal negotiation, the demand quantity rises with bargaining power but falls when the substitution factor increases. When RC internal negotiation is introduced, the trend intersects with the non-negotiation case at various points, contingent on bargaining power levels. Below a substitution factor of 0.23, internal negotiation yields higher total demand than without it. Above a substitution factor of 0.33, the outcome reverses, showing lower total demand with internal negotiation compared to the case without it.

Then the analysis assesses the profit trends of marketing airlines under two sub-strategies of representative-based cooperative bargaining. Parameters include a market size of α=150 and an operating cost per seat of c=10, with the substitution factor γ ranging from 0 to 1 in increments of 0.05. The bargaining power ratio between the representative and the follower marketing airlines is $\theta_{-io}=0.6\theta_{io}$, with $\theta_{io}\in[0,1]$ in increments of 0.1. For negotiations with internal strategy, the bargaining power is set at σ=0.7.

Figures 7a–7c depict the profit comparison for marketing airlines using internal negotiation and without it within a representative-based cooperative bargaining context. The graphs utilise the substitution factor on the X-axis, the representative marketing airline's bargaining power on the Y-axis and the Z-axis shows the profit rate variation when internal negotiation is applied versus when it is not.

Figure 7a illustrates that the profit of the representative marketing airline improves when internal negotiation is utilised as compared to when it is not. This increase is depicted by a positive variation rate. Additionally, the graph shows that the profit growth rate declines as the substitution factor rises. Conversely, if the substitution factor is held steady, the profit growth rate augments with an increase in bargaining power.

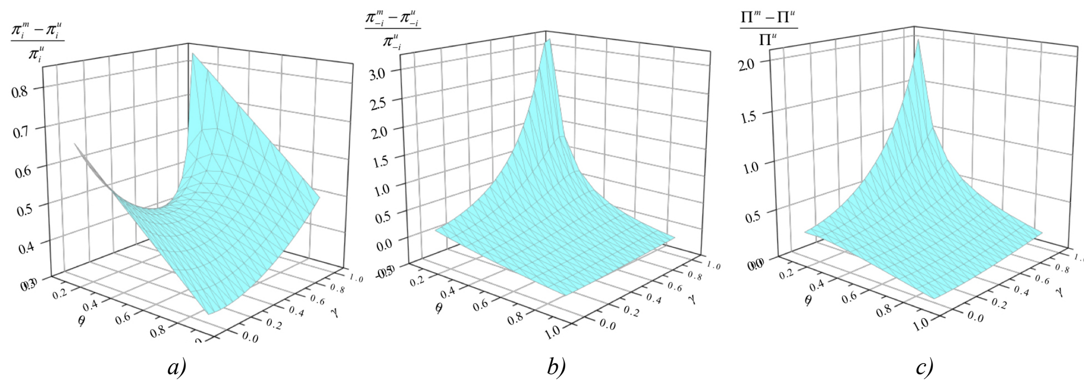


Figure 7 – Comparison of the marketing airline's profit under representative-based cooperation with and without internal bargaining

Figure 7b shows the variation in the follower marketing airline's profit when comparing representative-based cooperation with and without internal negotiation. It is observed that the profit variation depends on both the bargaining power and the substitution factor. Lower bargaining power results in higher profit under internal negotiation. However, as the representative's bargaining power increases, the follower's profit under internal negotiation becomes less than without negotiation. This trend reverses at a certain point, showing the complexity of the relationship between bargaining power, strategy choice and profit outcomes.

Figure 7c shows the variation rate of the total profit of both marketing airlines with internal negotiation cooperation compared to the case of cooperation without internal negotiation. The total profit of both marketing airlines under the RC with internal negotiation cooperation strategy is higher than that under the RC without internal negotiation strategy. When the substitution factor is constant, the variation rate of the total market airlines decreases with the increasing bargaining power. When the bargaining power is constant, the variation rate of the total marketing airline profit increases with the increasing substitution factor.

To conclude, from the perspective of marketing airlines, adopting cooperation with internal negotiation can enhance the profit of the representative marketing airline and the marketing airline alliance. However, the follower's profit may be negatively affected when the bargaining power of the marketing airline is comparatively high under cooperation with internal negotiation. Therefore, cooperation with internal negotiation could enhance the total profit of the alliance compared to the case without internal negotiation. In this scenario, the motivation for cooperation is stronger for the representative marketing airline than for the follower.

5.2 RC and AC

In this section, we conduct a comparative analysis of the performance between representative-based cooperation and agent-based cooperation strategies by numerical experiment. The numerical analysis is employed with the following parameter settings: market size α=200, the marginal cost per seat c=50, separate bargaining power for the two marketing airlines θ_{io}=0.3 and θ_{-io}=0.2, agent's bargaining power $\delta\in\{0.3,0.4,0.5,0.6,0.7\}$, substitution factor $\gamma\in[0,1]$, the commission proportion charged by the agent k=5% and bargaining power between the two marketing airlines in the two-stage cooperative bargain σ=0.65.

Figure 8 presents the results of the comparative analysis, where the x-axis represents the substitution factor and the y-axis represents the growth rate of the profit of the marketing airline alliance compared to the non-cooperative case. The superscript x denotes the strategy, with values of $x=s,u,m,a$ representing non-cooperative, representative-based cooperation without internal negotiation, representative-based cooperation with internal negotiation and agent-based cooperation, respectively. The two bold black curves represent the outcomes of the two representative-based cooperation strategies. It is important to note that the variation rate of the total profit of the marketing airline alliance under these strategies is independent of the agent's bargaining power. The thin lines in the figure represent the variation rates of the total profit of the marketing airline alliance under agent-based cooperation for different levels of the agent's bargaining power. These curves are compared against the non-cooperative case, allowing for a direct comparison of the outcomes across different strategies.

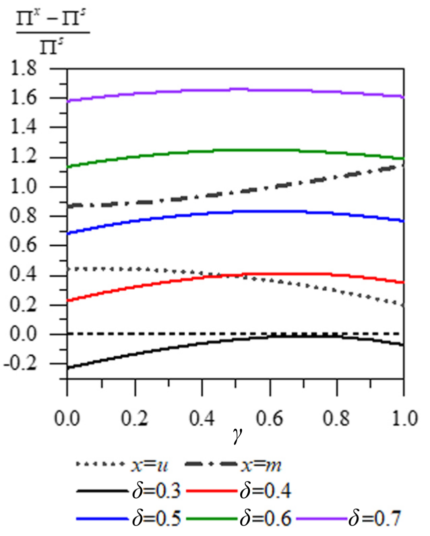


Figure 8 – Comparison of total market profit of different strategies

From *Figure 8*, we can observe the impact of the agent's bargaining power on the total profit of the marketing airline alliance. The curves represent different values of the agent's bargaining power δ compared to the separate bargaining power of the representative marketing airline θ_{io}. When δ=0.3, the total profit of the marketing airline alliance is lower than the non-cooperative case, suggesting that if the agent's bargaining power is not higher than the separate bargaining power of the representative marketing airline, it may not be suitable to hire an external agent for bargaining. However, when $\delta>\theta_{io}$ (when δ=0.4, 0.5, 0.6, 0.7), adopting agent-based cooperative bargaining can be more beneficial for the marketing airline alliance compared to the non-cooperative case. The curves intersect with the one-stage representative marketing airline-based cooperative bargaining curve, indicating that there are certain ranges of substitution factor γ where adopting either representative-based or agent-based cooperative bargaining can be advantageous.

Specifically, when δ=0.4, the curve intersects with the one-stage representative-based cooperative bargaining curve. For γ<0.5, adopting representative-based cooperative bargaining with internal negotiation yields the highest total profit for the marketing airline alliance. When γ>0.5, the total profit is highest under representative-based cooperation with internal negotiation, and the agent-based cooperation is higher than that under representative-based cooperation without internal negotiation. Similarly, when δ=0.5, adopting representative-based cooperative bargaining with internal negotiation leads to higher total profit compared to the non-cooperative case. For higher values of the agent's bargaining power, adopting agent-based cooperative bargaining becomes more advantageous in terms of total profit.

The analysis of *Figure 8* suggests that the choice between representative-based and agent-based cooperative bargaining depends on the relative bargaining powers and the substitution factor. When the agent's bargaining power is higher than the bargaining power of the representative marketing airline, adopting agent-based cooperative bargaining can yield higher total profit for the marketing airline alliance.

The strategic choice for marketing airline alliances depends on the relative bargaining power between the agent and the representative airline, and the substitution factor of their service products. If the agent's bargaining power is lower, it is not advantageous to use an agent for bargaining. The decision between representative-based or agent-based cooperative bargaining depends on the substitution factor when the agent's power is higher. If brand differentiation is high (low substitution factor), representative-based bargaining is beneficial. However, if brands are less differentiated (high substitution factor), agent-based bargaining is preferable. The optimal strategy varies with bargaining power and product differentiation levels.

6. CONCLUSIONS

The main objective of this paper is to investigate the foundations for cooperative bargaining among multiple marketing airlines in their negotiations with the operating airline, particularly in the context of implementing code share contracts. To simplify the problem, we focus on a marketing airline alliance comprising two marketing airlines that jointly negotiate with a single operating airline. The alliance has the option to appoint a representative from within the alliance or hire an external agent to engage in bargaining with the operating airline.

As a baseline model, a non-cooperative bargaining case is considered. We then compare the performance of the two cooperative bargaining strategies with this non-cooperative case. Through our multi-dimensional comparisons, we draw several conclusions regarding the optimal approach to negotiating transfer prices. Firstly, compared to the separate bargaining of the two marketing airlines, representative-based cooperation without internal negotiation increases the degree of competition between the marketing airlines, while cooperation with internal negotiation reduces this competition. The decision for each marketing airline to participate in cooperative bargaining depends on whether it yields greater benefits than the non-cooperative case. The profit of the alliance and both individual members is consistently higher under the cooperative bargaining with internal negotiation than under the non-cooperative case. The profit of the representative marketing airline always surpasses that of the non-cooperative case. However, whether the follower marketing airline and the overall alliance benefit more depends on the bargaining power of the follower marketing airline. When the follower's bargaining power is comparatively low, both the follower and the alliance benefit more from cooperative bargaining than from separate bargaining with the operating airline. Furthermore, we compare the performance of the alliance with and without internal negotiation when the cooperative bargaining power of the representative marketing airline is the same as that in the separate bargaining case using numerical analysis. The total profit of the alliance under representative-based cooperation with internal negotiation is consistently higher than that under cooperation without internal negotiation. However, the follower marketing airline benefits more from adopting internal negotiation only when the bargaining power of the representative marketing airline is below a threshold and the substitution factor exceeds another threshold.

By comparing the total profit of the alliance under the three strategies – representative-based cooperation without internal negotiation, representative-based cooperation with internal negotiation and agent-based cooperation – we conclude that agent-based cooperative bargaining is beneficial for the marketing airline alliance when the agent's bargaining power significantly surpasses that of the marketing airline. Additionally, the choice between representative-based cooperation with internal negotiation and agent-based cooperation depends on the substitution factor between the two marketing airlines, with both strategies proving advantageous under different conditions.

It is important to acknowledge some limitations in our model assumptions, which were made to simplify the modelling and solution processes. Future research could consider incorporating dynamic ticket pricing and exploring operating airline alliances as well. Furthermore, in agent-based cooperative bargaining, it would be more realistic to account for the commission proportion of the agent as dependent on their bargaining power. These extensions would enhance the applicability of the cooperative codeshare decision-making problem in real-world scenarios.

ACKNOWLEDGEMENTS

The authors are grateful to the editor and reviewers for their helpful comments. This work was supported by the Research Foundation for Youth Scholars of Beijing Technology and Business University.

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滕岚，汤敏聪

航空公司代码共享协议合作策略的比较分析

摘要

航空联盟种多家不同的市场航空公司通过代码共享协议从实际承运航空公司订购座位，并在市场中相互竞争。本文对两种议价定价过程进行了建模和讨论：基于代表的合作议价和基于代理的合作议价。同时考虑了基于代表的合作议价策略中市场营销航空联盟内部的谈判机制。运用博弈论中合作议价的方法，分析了市场营销航空公司在与运营航空公司的代码共享协议中不同合作方式的效果，对比了不同策略下航空公司的收益。研究发现有内部谈判的合作议价对市场营销航空公司和运营航空公司都有益，而没有内部谈判的基于代表的议价可能导致总利润的损失。运营管理

过程中具体采取何种合作定价策略取决于参与者的议价能力以及不同航空公司品牌之间的可替代程度。此研究为航空联盟代码共享的内部定价策略的制定提供依据和支持。

关键词
航空联盟；代码共享协议；转移价格；合作议价；讨价还价