



# Research on the Optimization Strategy of Airline Capacity Sharing under Complex Market Environments

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**Abstract.** As a solid bridge spanning the globe, air transport serves as an indispensable key component in the development of modern society. However, behind the growing ease of transportation, airlines are facing the dual pressures of imbalanced capacity supply and demand and fierce price competition. This paper constructs a Stackelberg game model consisting of a leading airline with a larger market size and a following airline with a smaller market size. It investigates capacity-sharing strategies under price and ancillary service competition, considering scenarios of capacity supply-demand imbalance between the two airlines. The results indicate that when the leading airline enhances its ancillary service level, both its own demand and pricing increase, but this tends to inhibit its capacity expansion. Conversely, the following airline can leverage its fuel efficiency advantages to capture market share by expanding capacity under mandatory blending ratio policies. Additionally, increases in cross-service sensitivity and service cost coefficients diminish the leading airline's willingness to invest in services. This paper provides a theoretical basis and decision-making support for airlines to formulate capacity-sharing strategies in the context of ancillary service competition.

**Keywords:** Airline capacity sharing; Ancillary services; Stackelberg game.

## 1 Introduction

In recent years, with the rapid recovery of passenger volumes on domestic and international routes, the number of domestic and international flights has gradually increased, and the passenger volume of global airlines has continued to soar, demonstrating the vibrant vitality of the air transport industry. However, according to existing operational data from airline companies, their operating performance has improved, but the operating conditions of several major airlines have not yet turned profitable. To actively respond to the fierce global aviation competition environment, airlines need to continuously open up new routes, increase flight frequencies on existing routes, expand their route networks, and improve seat occupancy rates. However, different countries have regulations regarding market access for their domestic aviation markets, imposing

restrictions on opening new routes. Additionally, the varying advantages of different airlines at different times and on different routes lead to an imbalance in capacity supply and demand among airlines. Therefore, airlines choose to cooperate and share capacity to quickly enter new markets, improve existing route networks, address capacity supply and demand imbalances, and thereby expand market share.

While actively expanding external cooperation, airlines are also exploring new operational models internally to enhance their core competitiveness. Several major domestic airlines have launched various promotional activities, attempting to win over travelers through price reduction strategies. However, relying solely on price competition as a strategic approach is difficult to guarantee the quality of airline services and cannot stabilize their revenue sources. Apart from price wars, airlines are also fiercely competing in service innovation, offering personalized service options such as luxurious experiences in first and business class, as well as introducing convenient online check-in and self-service boarding services. Airlines continuously innovate their service models to meet the diverse needs of travelers. However, these innovative services often require substantial capital investments and technological support, posing a significant challenge for some small airlines. Therefore, relevant policies and airlines have begun exploring differentiated service reforms, with ancillary service strategies emerging as a new strategic choice for airlines facing price competition.

Motivated by this, our paper aims at exploring the following research questions:

(1) Under the competition of prices and ancillary services, how can airlines formulate capacity-sharing strategies in the face of the practical issues of capacity constraints and imbalances in capacity supply and demand.

(2) Faced with the pressure brought by vicious price competition, how should airlines decide on their ancillary service levels, and what impact will the implementation of ancillary service strategies have on capacity-sharing cooperation among airlines.

## 2 Literature Review

As early as the last century, numerous scholars have conducted extensive research on various aspects of airlines, including ticket sales, pricing strategies, and airline alliances. Faced with shrinking survival spaces, many airlines have begun to explore collaborative paths in competitive environments to optimize resource allocation and enhance competitiveness. Capacity sharing, as a model addressing imbalances in capacity resources and inefficient scheduling, facilitates the effective exchange of capacity resources and improves resource utilization efficiency. With the rise of alliances such as Star Alliance, SkyTeam, and the International Airlines Group, code-sharing agreements have become one of the most common practices in capacity-sharing collaborations. Kimms et al. (2013) designed a game-theoretic model based on airline alliance relationships to address the issue of allocating available capacity within a two-airline alliance<sup>[1]</sup>. Zhou et al. (2021) investigated strategic alliance issues under a bilateral monopoly structure, identifying both vertical and horizontal alliance effects<sup>[2]</sup>. Research by Yimng et al. (2016), Lu et al. (2022), Wang et al. (2023), and other scholars has revealed differences in airfare prices and operational efficiency resulting from various

alliance structures. There is a general consensus that alliances often lead to lower airfares and improved performance, influencing supply-demand dynamics and the overall profitability of the industry<sup>[3-5]</sup>.

While airlines engage in capacity-sharing collaborations externally to enhance competitiveness, they also seek ways to differentiate themselves in a highly homogeneous market by exploring differentiated competitive strategies. Over the years, it has been proven that ancillary service strategies are key to maintaining a differentiated advantage. Through a review of existing literature, academic research on the classification of ancillary services has been conducted from multiple dimensions. Kilipiris (2021) proposed a function-oriented classification framework based on the specific functional value provided by ancillary services<sup>[6]</sup>. Yarde and Zhang (2022) noted in an industry analysis report that leading airlines are deeply integrating ancillary services with cabin classes and customer segmentation markets to form a tiered system<sup>[7]</sup>. Colin et al. (2022) conducted a random questionnaire survey of over 400 passengers from Lao Airlines, with research results showing that passengers' purchase intentions are significantly positively influenced by the quality of ancillary services and customer satisfaction<sup>[8]</sup>.

From the aforementioned literature review, it is evident that there has been extensive research in the fields of airline capacity sharing, ancillary services, as well as price and ancillary service competition. However, few scholars have considered airline capacity-sharing strategies under conditions of capacity supply-demand imbalance while simultaneously accounting for both price and ancillary service competition. To fill this gap, this paper establishes a competitive model with two airlines as the supply chain entities and conducts game-theoretic analysis under different scenarios. Unlike previous studies, this paper incorporates not only price competition but also airline ancillary services into the decision-making scope to explore capacity-sharing strategies under different scenarios of price and ancillary service competition.

### 3 Problem Description and Model Construction

Consider a passenger air route market dominated by duopolistic airlines  $i$  ( $i = 1, 2$ ), where airline 1 with larger market size and stronger market power acts as the leader, in contrast airline 2 is the market follower. Two airlines provide passengers transport services at the price  $p_i$  with transport capacity  $q_i$ . The transportation cost of the airline is denoted as  $c_i$ . In addition to the primary service items, the airlines offer ancillary services to passengers who have purchased the primary item. The ancillary services of airline  $i$  is offered with level  $s_i$  at a cost  $\eta_i s_i^2 / 2$ , where  $\eta_i$  represents the cost coefficient of ancillary services. Considering the impacts of each other's ticket price and ancillary service, the market demand functions of airlines are characterized as a structure widely used in the literature. (e.g., Tsay and Agrawal 2000, Jena and Meena 2019, Lai et al. 2022).

$$D_i(p_i, p_j, s_i, s_j) = a_i - p_i + p_j + b_s s_i - \theta_s s_j, \quad i, j = 1, 2, \quad i \neq j$$

where  $a_i$  is the potential market size of airline  $i$ ,  $b_s$  is demand sensitivity on ancillary services, and  $\theta_s$  is cross demand sensitivity on ancillary services. Generally, the effect

of ancillary services on the market demand of the services providing airline is more significant than the other airline, so we assume that  $b_s > \theta_s > 0$ .

Depending on the combination of capacity sharing and ancillary service offering, there are two distinct cases arise for capacity sharing, i.e., (1) Airline 1 as the leader-airline offers ancillary services and has surplus capacity (O); (2) Airline 1 as the leader-airline provides ancillary services and Airline 2 as the follower-airline has surplus capacity (P).

## 4 Model Solving and Analysis

### 4.1 The Leader-Airline has Capacity Surplus

In this section, we assume that Airline 2 which has a shortage of capacity can purchase capacity from Airline 1 which has capacity surplus. As outlined earlier, Airline 1 can provide ancillary services to consumers to increase their demand. The set of equations that characterize these profits functions are given by:

$$\pi_1(p_1, p_2, s_1) = (p_1 - c_1)D_1 + (w - c_1) \min\{q_1 - D_1, D_2 - q_2\} - \frac{1}{2} \eta_1 s_1^2 \quad (1)$$

$$\pi_2(p_1, p_2, s_1) = (p_2 - c_2)q_2 + (p_2 - w) \min\{q_1 - D_1, D_2 - q_2\} \quad (2)$$

By solving the problem, we discuss two patterns of part-in capacity sharing ( $q_1 - D_1 \geq D_2 - q_2$ ), and all-in capacity sharing ( $q_1 - D_1 < D_2 - q_2$ ) respectively. The backward induction is used to solve the game equilibrium decision of two airlines.

**Theorem 1:** Under the patterns of part-in capacity sharing, when  $q_2 < \frac{b_s \theta_s (5w + 2a_1 - a_2 - 5c_1) - \theta_s^2 (3w + a_1 - 3c_1)}{2b_s^2 (-w + a_2 + c_1) - \eta_1 (2a_1 + 3a_2) + 4\eta_1 + (-2b_s + \theta_s)^2}$ , the equilibrium pricing of the leading airline is  $p_1^{O1*} = \frac{-2\eta_1 [2(w + a_1) + a_2] + (2b_s - \theta_s) [2b_s c_1 + \theta_s (w - 2c_1)]}{-2\eta_1 + (-2b_s + \theta_s)^2}$ ; and the equilibrium ancillary service level is  $s_1^{O1*} = \frac{-2b_s (2w + 2a_1 + a_2 - 2c_1) + \theta_s (4w + 2a_1 + a_2 - 4c_1)}{-4\eta_1 + (-2b_s + \theta_s)^2}$ ; the equilibrium pricing of the following airline is  $p_2^{O1*} = \frac{2b_s^2 (w + a_2 + c_1) - \eta_1 (4w + 2a_1 + 3a_2) + b_s \theta_s (w + 2a_1 - a_2 - 5c_1) - \theta_s^2 (2w + a_1 - 3c_1)}{-4\eta_1 + (-2b_s + \theta_s)^2}$ .

**Corollary 1:** Under the patterns of part-in capacity sharing, the impacts of ancillary service-related parameters on the optimal ancillary service levels, sales prices, market demands, and capacity-sharing volumes of the two airlines are as follows:

- a)  $\frac{\partial s_1^{O1*}}{\partial b_s} > 0, \frac{\partial p_1^{O1*}}{\partial b_s} > 0, \frac{\partial D_1^{O1*}}{\partial b_s} > 0; \frac{\partial s_1^{O1*}}{\partial \theta_s} < 0, \frac{\partial p_1^{O1*}}{\partial \theta_s} < 0, \frac{\partial D_1^{O1*}}{\partial \theta_s} < 0; \frac{\partial s_1^{O1*}}{\partial \eta_1} < 0, \frac{\partial p_1^{O1*}}{\partial \eta_1} < 0, \frac{\partial D_1^{O1*}}{\partial \eta_1} < 0;$   
 $0, \frac{\partial p_1^{O1*}}{\partial \theta_s} < 0, \frac{\partial D_1^{O1*}}{\partial \theta_s} < 0.$
- b) When  $0 < \theta_s \leq \frac{2b_s}{3}$ ,  $\frac{\partial p_2^{O1*}}{\partial b_s} > 0, \frac{\partial D_2^{O1*}}{\partial b_s} > 0; \frac{\partial p_2^{O1*}}{\partial \theta_s} < 0, \frac{\partial D_2^{O1*}}{\partial \theta_s} < 0; \frac{\partial p_2^{O1*}}{\partial \eta_1} < 0, \frac{\partial D_2^{O1*}}{\partial \eta_1} < 0.$
- c) When  $0 < \theta_s \leq \frac{2b_s}{3}$ ,  $\frac{\partial \Delta_2^{O1*}}{\partial b_s} > 0, \frac{\partial \Delta_2^{O1*}}{\partial \eta_1} < 0, \frac{\partial \Delta_2^{O1*}}{\partial \theta_s} < 0.$

**Theorem 2:** Under the patterns of all-in capacity sharing, when  $q_2 < \frac{-b_s^2 q_1 - a_1 \eta_1 + 3q_1 \eta_1}{\eta_1}$ , the equilibrium pricing of the leading airline is  $p_1^{02*} = \frac{wb_s^2 - 2(2w + a_1 + q_1 + q_2)\eta_1}{b_s^2 - 4\eta_1}$ ; and the equilibrium ancillary service level is  $s_1^{02*} = \frac{-a_1 b_s - b_s q_1 - b_s q_2}{b_s^2 - 4\eta_1}$ ; the equilibrium pricing of the following airline is  $p_2^{02*} = \frac{b_s^2(w + q_1 + q_2) + (-4w + a_1 - 3q_1 - 3q_2)\eta_1}{b_s^2 - 4\eta_1}$ .

**Corollary 2:** Under the patterns of all-in capacity sharing, the impacts of ancillary service-related parameters on the optimal ancillary service levels, sales prices, market demands, and capacity-sharing volumes of the two airlines are as follows:

- a)  $\frac{\partial s_1^{02*}}{\partial b_s} > 0, \frac{\partial p_1^{02*}}{\partial b_s} > 0, \frac{\partial D_1^{02*}}{\partial b_s} > 0; \frac{\partial s_1^{02*}}{\partial \eta_1} < 0, \frac{\partial p_1^{02*}}{\partial \eta_1} < 0, \frac{\partial D_1^{02*}}{\partial \eta_1} < 0.$
- b)  $\frac{\partial p_2^{02*}}{\partial b_s} < 0, \frac{\partial p_2^{02*}}{\partial \eta_1} > 0.$
- c)  $\frac{\partial \Delta_1^{02*}}{\partial b_s} < 0, \frac{\partial \Delta_1^{02*}}{\partial \eta_1} > 0.$

### 4.2 The Follower-Airline has Capacity Surplus

In this section, we assume that Airline 1 which has a shortage of capacity can purchase capacity from Airline 2 which has capacity surplus. As outlined earlier, Airline 1 can provide ancillary services to consumers to increase their demand. The set of equations that characterize these profits functions are given by:

$$\pi_1(p_1, p_2, s_1) = (p_1 - c_1)q_1 + (p_1 - w) \min\{D_1 - q_1, q_2 - D_2\} - \frac{1}{2}\eta_1 s_1^2 \quad (3)$$

$$\pi_2(p_1, p_2, s_1) = (p_2 - c_2)D_2 + (w - c_2) \min\{D_1 - q_1, q_2 - D_2\} \quad (4)$$

By solving the problem, we discuss two patterns of part-in capacity sharing ( $q_2 - D_2 \geq D_1 - q_1$ ), and all-in capacity sharing ( $q_2 - D_2 < D_1 - q_1$ ) respectively. The backward induction is used to solve the game equilibrium decision of two airlines.

**Theorem 3:** Under the patterns of part-in capacity sharing, when  $q_1 < \frac{2a_1 \eta_1 + a_2 \eta_1}{4\eta_1 - (-2b_s + \theta_s)^2}$ , the equilibrium pricing of the leading airline is  $p_1^{P1*} = w - \frac{2(2a_1 + a_2)\eta_1}{-4\eta_1 + (-2b_s + \theta_s)^2}$ ; and the equilibrium ancillary service level is  $s_1^{P1*} = \frac{(2a_1 + a_2)(2b_s - \theta_s)}{-4\eta_1 + (-2b_s + \theta_s)^2}$ ; the equilibrium pricing of the following airline is  $p_2^{P1*} = \frac{-2b_s^2(2w + a_2) + \eta_1(4w + 2a_1 + 3a_2) + b_s \theta_s(4w - 2a_1 + a_2) + \theta_s^2(a_1 - w)}{4\eta_1 - (-2b_s + \theta_s)^2}$ .

**Corollary 3:** Under the patterns of part-in capacity sharing, the impacts of ancillary service-related parameters on the optimal ancillary service levels, sales prices, market demands, and capacity-sharing volumes of the two airlines are as follows:

- a)  $\frac{\partial s_1^{P1*}}{\partial b_s} > 0, \frac{\partial p_1^{P1*}}{\partial b_s} > 0, \frac{\partial D_1^{P1*}}{\partial b_s} > 0; \frac{\partial s_1^{P1*}}{\partial \theta_s} < 0, \frac{\partial p_1^{P1*}}{\partial \theta_s} < 0, \frac{\partial D_1^{P1*}}{\partial \theta_s} < 0; \frac{\partial s_1^{P1*}}{\partial \eta_1} < 0, \frac{\partial p_1^{P1*}}{\partial \eta_1} < 0, \frac{\partial D_1^{P1*}}{\partial \eta_1} < 0.$

b) When  $0 < \theta_s \leq \frac{2b_s}{3}$ ,  $\frac{\partial p_2^{P1*}}{\partial b_s} > 0$ ,  $\frac{\partial D_2^{P1*}}{\partial b_s} > 0$ ;  $\frac{\partial p_2^{P1*}}{\partial \theta_s} < 0$ ,  $\frac{\partial D_2^{P1*}}{\partial \theta_s} < 0$ ;  $\frac{\partial p_2^{P1*}}{\partial \eta_1} < 0$ ,  $\frac{\partial D_2^{P1*}}{\partial \eta_1} > 0$ .

c)  $\frac{\partial \Delta_1^{P1*}}{\partial b_s} > 0$ ,  $\frac{\partial \Delta_1^{P1*}}{\partial \theta_s} < 0$ ,  $\frac{\partial \Delta_1^{P1*}}{\partial \eta_1} < 0$ .

**Theorem 4:** Under the patterns of all-in capacity sharing, when  $q_2 > \frac{a_2\eta_1 + 2q_1\eta_1 - q_1\theta_s^2}{2\eta_1}$ , the equilibrium pricing of the leading airline is  $p_1^{P2*} = w + \frac{2\eta_1[a_2 - 2(q_1 + q_2)]}{-4\eta_1 + \theta_s^2}$ , and the equilibrium ancillary service level is  $s_1^{P2*} = \frac{a_2\theta_s - 2q_1\theta_s - 2q_2\theta_s}{-4\eta_1 + \theta_s^2}$ , the equilibrium pricing of the following airline is  $p_2^{P2*} = w + q_1 + q_2 + \frac{\eta_1[a_2 - 2(q_1 + q_2)]}{4\eta_1 - \theta_s^2}$ .

**Corollary 4:** Under the patterns of all-in capacity sharing, the impacts of ancillary service-related parameters on the optimal ancillary service levels, sales prices, market demands, and capacity-sharing volumes of the two airlines are as follows:

a)  $\frac{\partial s_1^{P2*}}{\partial \theta_s} > 0$ ,  $\frac{\partial p_1^{P2*}}{\partial \theta_s} > 0$ ,  $\frac{\partial D_1^{P2*}}{\partial \theta_s} > 0$ ;  $\frac{\partial s_1^{P2*}}{\partial \eta_1} < 0$ ,  $\frac{\partial p_1^{P2*}}{\partial \eta_1} < 0$ ,  $\frac{\partial D_1^{P2*}}{\partial \eta_1} < 0$ .

b)  $\frac{\partial p_2^{P2*}}{\partial \theta_s} < 0$ ,  $\frac{\partial D_2^{P2*}}{\partial \theta_s} < 0$ ;  $\frac{\partial D_2^{P2*}}{\partial \eta_1} > 0$ ,  $\frac{\partial p_2^{P2*}}{\partial \eta_1} > 0$ .

c)  $\frac{\partial \Delta_2^{P2*}}{\partial \theta_s} > 0$ ,  $\frac{\partial \Delta_2^{P2*}}{\partial \eta_1} < 0$ .

### 5 Numerical Analysis

In this section, to visually demonstrate the impacts of different factors on airlines' capacity-sharing decisions, numerical simulation analyses are conducted for two distinct capacity-sharing scenarios under the one-way capacity-sharing cooperation model. Using MATLAB for numerical simulations, this study examines how changes in the demand-service sensitivity coefficient, cross-service sensitivity coefficient, and service cost factor related to ancillary services affect Airline 1's ancillary service level, the optimal pricing of both airlines, and the volume of capacity sharing. This analysis further explores capacity-sharing strategies. Based on actual market conditions, let  $a_1 = 1000$ ,  $a_1 = 500$ ,  $c_1 = 200$ .

The relationships between Airline 1's ancillary service level, the optimal pricing of both airlines, the volume of capacity sharing, and its own service sensitivity coefficient  $b_s$  are illustrated in Figure 1. According to actual market conditions, let  $w = 500$ ,  $\eta_1 = 1.3$ ,  $\theta_s = 0.2$ .

The relationships between Airline 1's ancillary service level, the optimal pricing of both airlines, the volume of capacity sharing, and its own service sensitivity coefficient  $\theta_s$  are illustrated in Figure 2. According to actual market conditions, let  $w = 500$ ,  $\eta_1 = 1.3$ ,  $\theta_s = 0.8$ .

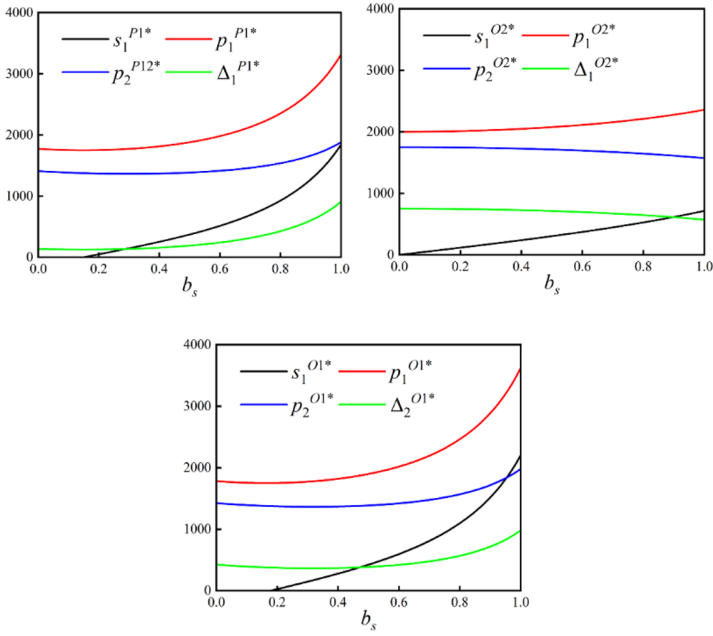


Fig. 1. Relationship between balanced decision-making and  $b_s$

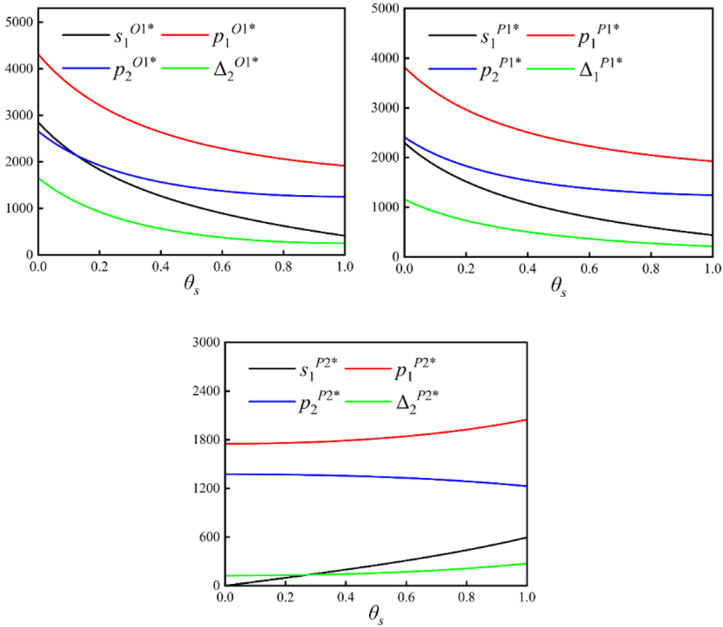


Fig. 2. Relationship between balanced decision-making and  $\theta_s$

The relationships between Airline 1's ancillary service level, the optimal pricing of both airlines, the volume of capacity sharing, and its own service sensitivity coefficient  $\eta_1$  are illustrated in Figure 3. According to actual market conditions, let  $w = 500, b_s = 0.9, \theta_s = 0.87$ .

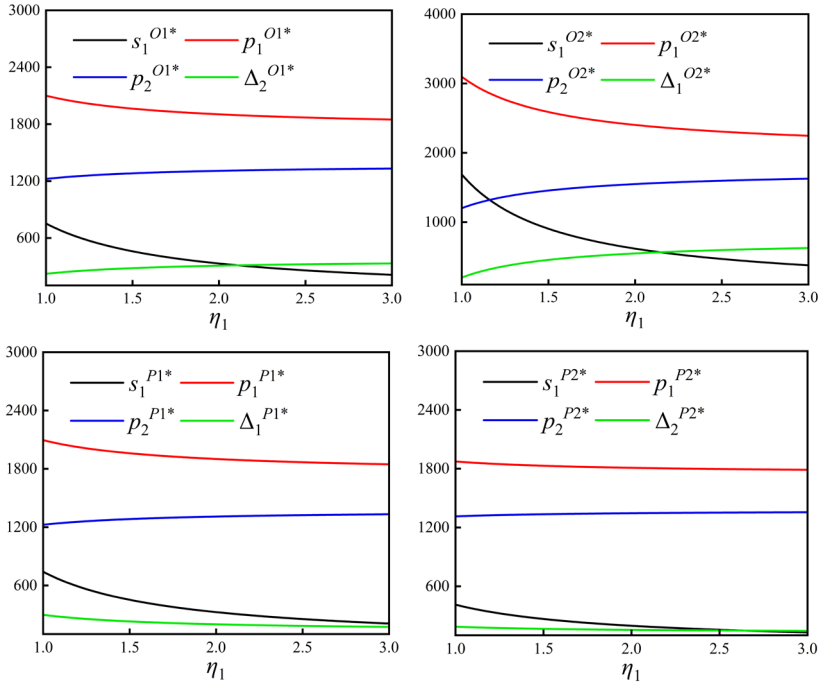


Fig. 3. Relationship between balanced decision-making and  $\eta_1$

## 6 Conclusion

This study addresses the practical challenge of economic opportunity costs arising from capacity supply-demand imbalances in the air transport market by focusing on the research problem of airline capacity sharing under price and ancillary service competition. Starting from the market demands of two airlines, a Stackelberg game model involving two entities is constructed to systematically analyze the optimal pricing and ancillary service level decisions of a leading airline with a larger market size and a following airline with a smaller market size under different capacity supply-demand relationships. This analysis further yields the market demands, maximum profits, and capacity-sharing volumes of both airlines. Building on this foundation, the study explores the impacts of ancillary service-related parameters.

The main research conclusions are as follows: (1) Equilibrium strategy issues under different capacity-sharing cooperation models. The relative supply-demand relationship between an airline's capacity and market demand directly determines its pricing, ancillary service levels, and ultimately the volume of capacity shared. (2) Ancillary

services are a key factor influencing airline capacity sharing. As passengers' sensitivity to their own services increases, Airline 1 tends to enhance its ancillary service levels and raise ticket prices to capture a service quality premium. However, when cross-service sensitivity or service cost factors increase, Airline 1 reduces its investment in ancillary services and lowers its pricing. (3) The pricing advantage of airlines with larger market sizes is prevalent. For some smaller airlines, engaging in price wars is a more direct and effective means of competing with rivals for market share.

Future research could construct an airline network model to extend the research problem to competition among multiple airlines, or shift the focus to capacity sharing and collaborative optimization across multiple routes and nodes. This would bring the research closer to the actual complexities of airline operations.

## Disclosure of Interests

I declare that I am not involved in competing interests in relation to the content of this article.

## References

1. Graf, M. and Kimms, A., (2013), Transfer Price Optimization for Option-Based Airline Alliance Revenue Management, *International Journal of Production Economics*, 145 (1), pp. 281–293.
2. Zhuo X, Wang F, Niu B. Brand-owners' vertical and horizontal alliance strategies facing dominant retailers: Effect of demand substitutability and complementarity. *Omega*. 2021; 103: 102449. DOI: 10.1016/j.omega.2021.102449.
3. Yinga JO. Airline code-sharing and its effects on on-time performance. *Journal of Air Transport Management*. 2017; 58: 76–90. DOI: 10.1016/j.jairtraman.2016.10.001.
4. Lu JL, Yang CW. Good or bad? Passenger feelings regarding code-share alliances among airlines. *Journal of Air Transport Management*. 2022; 103: 102252. DOI: 10.1016/j.jairtraman.2022.102252.
5. Wang X, Fung RYK. An option-based capacity control mechanism for code-sharing alliances. *Transport Economics and Management*, 2023;1:1–12. DOI: 10.1016/j.team.2023.04.001.
6. Kilipiris E. Impact of Ancillary Revenues in the Airline Industry: Preparing for the New Normality[J]. *JOURNAL OF TOURISM RESEARCH* V. 26 June 2021, 2021: 234.
7. Yarde K, Zhang C. Airline Business Models and the Strategic Planning and Implementation of Air Services[M]. *Strategies for Sustainable Air Services Development*. Routledge, 2024: 84–110.
8. Colin C H, Law, Yahua Zhanga, Jeff Gow. service quality, customer satisfaction, and repurchase Intention: Laotian air passengers'perspective [J]. *Case Studies on Transport Policy*, 2022.

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