



# Airport concession revenue sharing and entry deterrence

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## ABSTRACT

This paper investigates how concession revenue sharing between an airport and an incumbent airline affects the strategic flight frequency choice of that airline for entry deterrence and thus, profits and welfare. Specifically, we construct a model in which the incumbent airline confronts the entry threat of an entrant airline and strategically decides whether to deter or accommodate the entrant airline by choosing its flight frequency. We show that concession revenue sharing between the airport and the incumbent airline may enhance the market power of the incumbent airline, which improves or harms welfare. In addition, concession revenue sharing also diminishes the incentive for the incumbent airline to deter entry, which improves welfare. Our novel results provide important policy implications by determining that the effects of concession revenue sharing depend on the revenue share rate and the airport capacity.

## 1. Introduction

In recent years, airport management has faced several environmental changes. In particular, financial self-sufficiency has grown in importance, and thus airports do not rely on government support. Consequently, the commercialization of airports has accelerated worldwide, and concession (commercial) revenue from non-aeronautical activities has become increasingly important compared to revenue from traditional aeronautical activities, especially for private airports (e.g., [Graham, 2009](#)).

In parallel with the growth of concession revenues, various vertical agreements between airports and airlines are becoming popular in practice (e.g., [Albers et al., 2005](#); [Auerbach and Koch, 2007](#); [Kuchinke and Sickmann, 2005](#)).<sup>1</sup> As noted in [Fu and Zhang \(2010\)](#) and [Zhang et al. \(2010\)](#), concession revenue sharing has been concluded between airports and airlines, such as Tampa International Airport in the US and Ryanair in Europe. In many other cases, revenue sharing occurs when airports allow airlines to hold their shares or manage their facilities. For example, Terminal 2 of Munich Airport was jointly funded by the airport operating company FMG (60%) and the airport's dominant carrier, Lufthansa (40%) ([Kuchinke and Sickmann, 2005](#)). Thus, concession revenue from this terminal is shared between FMG and Lufthansa.

Some previous studies (e.g., [Barbot, 2011](#); [Zhang et al., 2010](#)) have pointed out that concession revenue sharing may have important implications for both competition and welfare, as discussed in detail in Section 2. Specifically, concession revenue sharing allows airlines

and/or airports to internalize the demand complementarity between aeronautical and concession services. Hence, concession revenue sharing increases the outcomes of both types of services and improves their profits and welfare.

However, as shown by [Fu and Zhang \(2010\)](#), revenue sharing with a specific airline may have anti-competitive effects. For example, concession revenue sharing can strengthen the airline's market power and increase only that airline's output, which may harm welfare. Such anti-competitive effects of concession revenue sharing with a specific airline can be applied to a situation in which an incumbent airline with a concession revenue sharing faces the threat of a new airline entering that airport. As shown in previous studies (e.g., [Goolsbee and Syverson, 2008](#); [Bettini et al., 2018](#)), although airlines often face potential entrants and attempt to strategically address them, it is still unclear how concession revenue sharing between an airport and an incumbent airline affects the strategy of that airline, which faces the threat of an entrant airline.

This paper investigates how concession revenue sharing affects an incumbent airline's strategic flight frequency choice for entry deterrence and thus yields profits and welfare. Specifically, we consider a market consisting of an incumbent and a new entrant airline. The incumbent airline agrees to concession revenue sharing with an airport that has limited capacity and receives a part of its concession revenue. Since the incumbent airline chooses its flight frequency before the entrant airline, the incumbent airline strategically decides whether to

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<sup>1</sup> [Fu et al. \(2011\)](#) classifies these vertical agreements into five categories: (1) signatory airlines of airports, (2) airline ownership or control of airport facilities, (3) long-term use contracts, (4) airport issuance of revenue bonds to airlines, and (5) revenue sharing between airports and airlines. Each category has a different impact on competition and welfare.

deter or accommodate the entrant airline in its flight frequency. In other words, the incumbent airline can determine whether to deter the entrant airline by increasing its flight frequency, thereby occupying the limited airport capacity. Therefore, we explore the effects of concession revenue sharing with the airport on the flight frequency choice of the incumbent airline in the market.

Our results show concession revenue sharing has two different effects on the frequency choice. The first is the effect of encouraging the incumbent airline to increase its flight frequency to improve concession revenue, which has been discussed in previous studies. This effect raises the anti-competitive risk that the entrant airline will be blocked by non-strategic decisions pertaining to the flight frequency of the incumbent airline. However, once entry is accommodated, it helps airlines to provide high-quality (high flight frequency) services, resulting in welfare improvement.

Second, the incumbent airline considers the concession revenue from passengers of the entrant airline. This effect reduces the incentive for the incumbent airline to deter the entrant airline strategically. When the incumbent airline decides whether to deter the entrant airline, it faces a trade-off between the revenue from maintaining its monopoly power and the cost of its excessive flight frequency. Concession revenue sharing increases the incumbent's profit when the entry is accommodated. Hence, the incentive for the incumbent airline to maintain its monopoly power decreases relatively. Therefore, we propose that concession revenue sharing has another welfare-improving effect.

The remainder of this paper is structured as follows. Section 2 explains the related literature. In Section 3, we describe the setting of our model. Sections 4 and 5 present the derivation of the equilibrium. Section 6 examines the robustness of our results through some extensions and Section 7 concludes the discussion.

## 2. Related literature

This paper is related to two strands of literature. The first comprises studies of vertical agreements between airports and airlines, most of which have accumulated in recent decades.<sup>2</sup> Barbot (2009) investigates whether competing airline/airport pairs have incentives to collude and shows that collusion can occur when the full-service carrier and major airport pair compete against the low-cost carrier and secondary airport pair. Barbot and D'Alfonso (2014) explore the sustainability of collusive contracts between airlines and airports. Barbot et al. (2013) empirically shows the effects on airline/airport competition of vertical collusion.

Other types of vertical agreements have been examined. Barbot (2011) explores how different types of vertical agreements observed in three regions (Europe, Australia, and the United States) affect welfare. She shows that such vertical agreements could have either or both anti-competitive and welfare-improving effects on air transportation markets. D'Alfonso and Nastasi (2012) investigate whether competing airports have incentives for three types of vertical agreements with their dominant airlines, one of which is concession revenue sharing. They show that the airport and its dominant airline have incentives to cooperate and that there is a misalignment between private and social incentives.

Some studies have focused on concession revenue sharing between airports and airlines. Fu and Zhang (2010) investigate the impact of two types of concession revenue sharing on welfare and show that uniform revenue sharing with all airlines can improve welfare, but revenue sharing with a specific airline may harm welfare. Zhang et al. (2010) find that the degree of concession revenue sharing depends on how airline and concession services relate to each other, i.e., complements, independent, or substitutes. They also show that a sufficiently high degree of substitution could cause payments from airlines to the airport,

<sup>2</sup> See D'Alfonso and Nastasi (2014) and Fu and Yang (2017) for a detailed review.

damaging welfare. Saraswati and Hanaoka (2014) construct a game-theoretic network model to evaluate the effects of concession revenue sharing. They show that this type of revenue sharing favors airline dominance in airports. Consequently, this may harm airline competition. Yang et al. (2015) analyze airport revenue sharing in a bargaining game.

Other studies have focused on airport capacity investment (e.g., Xiao et al., 2016), airport investment for demand improvement (e.g., Sarmiento and Brandao, 2013), and risk sharing between an airport and its airlines (e.g., Hihara, 2012, 2014). Xiao et al. (2016) investigate the effects of vertical agreements on airport capacity choices under demand uncertainty. They suggest that such agreements lead to higher capacity in a private airport but might not increase its profit.

The second strand of literature consists of studies related to strategic entry deterrence and its effects on welfare. Dixit (1980) makes one of the early contributions to literature by connecting overcapacity with entry deterrence. He shows that the incumbent firm may deter a new firm from entering the market by investing excessively in capacity.

Some studies on entry deterrence in the aviation industry have focused on the role of airfare (e.g., Aguirregabiria and Ho, 2010; Chen and Ross, 2000; Gayle and Xie, 2018; Goolsbee and Syverson, 2008; Lin, 2008). Oum et al. (1995) theoretically show that a hub-and-spoke network can be an effective entry deterrence strategy and Aguirregabiria and Ho (2010) empirically demonstrate the above. Chen and Ross (2000) examine possible anti-competitive effects of production capacity sharing between airlines and show that such alliances can reduce welfare even if the incumbent and entrant airlines are not direct competitors. Lin (2008) explores the role of code-sharing alliances between airlines on entry deterrence and suggests that an alliance between incumbent airlines may be a strategy to deter entrants with no significant cost advantage and improve their profits. Gayle and Xie (2018) present a structural econometric model to examine how code-sharing agreements between airlines affect entry deterrence and find evidence of entry deterrence.

However, previous studies that consider flight frequency as a strategic variable for entry deterrence are limited. Some exceptions are the theoretical study of Valido et al. (2020), which consider a strategic flight frequency for entry deterrence, and the empirical study of Bettini et al. (2018), which investigate strategic responses of incumbent airlines facing a potential entry into a secondary airport of a region with multiple airports. Valido et al. (2020) investigate whether a full-service carrier offers its flights with excessive flight frequency to deter the entry of an entrant low-cost carrier. Additionally, they show that if the airport capacity is sufficiently low, the incumbent airline can block or deter the entry of the new low-cost carrier. Bettini et al. (2018) show that the incumbent airlines preemptively fortified their flight frequency on threatened routes from the secondary airport toward the existing primary airports to deter entry. Another exception is the study of Sheng et al. (2019), which explores the effects of grandfather rights of airport capacity on flight frequency choices.

To the best of our knowledge, although a body of research on both vertical agreements and entry deterrence has accumulated, no study has focused on how vertical agreements between airports and airlines affect strategic flight frequency choice for entry deterrence.

## 3. The model

We consider that an airport with limited capacity provides both aeronautical services to airlines and commercial (non-aeronautical) services to passengers and that the airport maximizes its profit. Following Fu and Zhang (2010) and Zhang et al. (2010), the airport derives net concession revenue  $h$  ( $h > 0$ ) from each passenger and each passenger enjoys a benefit  $\eta$  ( $\eta > 0$ ) from the airport concession services. Thus, the consumer surplus derived from concession services is  $CS_c = \eta Q$ , where  $Q$  represents the market output (total number of passengers). In addition, we assume that the airline (aeronautical)

demand is independent of concession services ( $h$  and  $\eta$ ). In other words, a consumer with a negative surplus from her flight will not make a trip just because of a positive surplus from concession services at the airport.

We assume that the airport has an incumbent airline (whose subscript is 1) and a new airline (whose subscript is 2) that intends to enter the market. The airport holds a concession revenue sharing agreement with the incumbent airline to share rate  $r$  of its concession revenue. In addition, the shared incumbent airline has the option of preferentially using the limited capacity of the airport. Specifically, we represent limited airport capacity  $K$  as a cap on the number of flights (flight frequencies) per unit of time that the airlines can operate at the airport (take-offs and landings). The incumbent airline with the first option determines its flight frequency  $f_1$  to maximize its profit within the limited airport capacity. Subsequently, if the airport capacity is still available, the new airline uses (a part of) the remaining airport capacity and enters the airline market with flight frequency  $f_2$ . Meanwhile, if there is no available capacity, the new airline cannot enter the airline market, resulting in a monopoly airline market for the incumbent airline. Therefore, the total market flight frequency  $F(\equiv f_1 + f_2)$  is less than the limited airport capacity  $K$ ,  $F \leq K$ .

Suppose that the representative passenger utility function for air travel is

$$U = \alpha (q_1 + q_2) - \frac{1}{2} (q_1^2 + q_2^2 + 2\beta q_1 q_2), \tag{1}$$

where  $q_i$  ( $i = 1, 2$ ) is the output quantity of airline  $i$ , the parameter  $\alpha$  ( $\alpha > 0$ ) is the willingness to pay of the passenger for air travel, and the parameter  $\beta$  ( $0 \leq \beta \leq 1$ ) is the degree of substitution between airlines. The full price for a passenger who travels with airline  $i$  is given by  $p_i - \gamma f_i$  where  $p_i$  is the price (airfare) of airline  $i$  and the parameter  $\gamma$  ( $\gamma > 0$ ) is the degree of positive spillover from the increased flight frequency on the passenger (e.g., reduction of schedule delays).

Given the prices and flight frequencies, the representative passenger maximizes his consumer surplus obtained from flights,  $CS_a = U - \sum_{i=1}^2 (p_i - \gamma f_i) q_i$ . Solving this maximization problem, we derive the demand functions for the duopoly airline market as

$$q_i = \frac{(1 - \beta)\alpha - (p_i - \gamma f_i) + \beta(p_{-i} - \gamma f_{-i})}{1 - \beta^2}. \tag{2}$$

Note that if the airline market is a monopoly, by substituting  $q_2 = 0$  and solving the maximization problem, we derive the demand function for the monopoly market as

$$q_i = \alpha - (p_i - \gamma f_i). \tag{3}$$

Following Flores-Fillol (2009), the flight operating cost is given by  $\theta f_i + \tau s_i$ . Here,  $f_i$  and  $s_i$  are the flight frequency and aircraft size (i.e., the number of seats), respectively, for airline  $i$ . Additionally, the parameters  $\theta$  and  $\tau$  are the marginal cost per departure (or aircraft operation cost) and the marginal cost per seat, respectively. We assume that all seats are filled so that the load factor equals 100%; i.e.,  $s_i = q_i / f_i$ . This assumption implies that aircraft size can be determined by residually dividing output quantity by flight frequency. In addition, to highlight the impact of airlines' frequency decisions, we assume that the marginal cost per seat is zero (i.e.,  $\tau = 0$ ) without the loss of generality in our analysis. Therefore, airline  $i$ 's total cost is  $\theta f_i^2$ .

The profit functions for the incumbent and entrant airlines can be written as

$$\begin{aligned} \pi_1 &= (p_1 - \omega)q_1 - \theta f_1^2 + rh(q_1 + q_2), \\ \pi_2 &= (p_2 - \omega)q_2 - \theta f_2^2, \end{aligned} \tag{4}$$

respectively, where the parameters  $\omega$  and  $r$  denote the airport charge per passenger and the revenue share rate. The incumbent airline receives the proportion  $r$  of the airport concession revenue from both

airlines' passengers in accordance with the concession revenue sharing agreement with the airport.<sup>3</sup>

If the airline market is a monopoly, the profit function for the incumbent airline is given by

$$\pi_1 = (p_1 - \omega)q_1 - \theta f_1^2 + rhq_1. \tag{5}$$

Note that the airport concession revenue depends only on  $q_1$  because  $q_2 = 0$ .

In addition, the profit function for the airport is given by  $\Pi = \omega Q + (1 - r)hQ$ , the total consumer surplus is given by  $CS = CS_a + CS_c$ , and welfare is given by  $W = CS + \sum_{i=1}^2 \pi_i + \Pi$ .

We construct a three-stage game to investigate how concession revenue sharing between the airport and the incumbent airline affects the airline's entry deterrence strategy against the entrant airline. Specifically, in the first stage, the incumbent airline determines its flight frequency  $f_1$  to maximize its profit. Subsequently, the entrant airline decides whether to enter the market in the second stage. If the entrant airline decides to enter the market, given the incumbent flight frequency  $f_1$ , it determines its flight frequency  $f_2$  to maximize its profit. In the third stage, both airlines set their optimal prices. Specifically, if the entrant airline decides not to enter the market, the incumbent airline sets its optimal price. On the other hand, if the new airline decides to enter, both the incumbent and entrant airlines compete in price in the airline market.

Hence, there are four possible cases concerning the entry strategy and airport capacity constraints. In the first case, Case Duopoly non-binding (hereafter, *Case Dnb*), the entrant airline enters the market so that airlines compete in price, and the airport capacity constraint does not bind. In the second case, Case Duopoly binding (hereafter, *Case Db*), the entrant airline enters the market so that airlines compete in price, and the airport capacity constraint binds. In the third case, Case Monopoly non-binding (hereafter, *Case Mnb*), the entrant airline does not enter the market, the incumbent airline enjoys a monopoly market, and the airport capacity constraint does not bind. In the fourth case, Case Monopoly binding (hereafter, *Case Mb*), the new airline does not enter the market, the incumbent airline has monopoly power, and the airport capacity constraint binds.

Under these market structures and basic assumptions, we derive the outcomes for each case. Subsequently, we use these outcomes to derive the sub-game perfect equilibrium by backward induction.

## 4. Equilibrium outcomes of four cases

### 4.1. Case Duopoly non-binding (Dnb)

The maximization problems faced by airlines in the third stage are given as  $\max_{p_i} \pi_i$  using Eq. (4). Solving these problems yields

$$\begin{aligned} p_1 &= \frac{(2 - \beta - \beta^2)\alpha + (2 - \beta^2)\gamma f_1 - \beta\gamma f_2 + (2 + \beta)\omega - 2(1 - \beta)rh}{4 - \beta^2} \\ p_2 &= \frac{(2 - \beta - \beta^2)\alpha + (2 - \beta^2)\gamma f_2 - \beta\gamma f_1 + (2 + \beta)\omega - (1 - \beta)\beta rh}{4 - \beta^2} \end{aligned} \tag{6}$$

In the second stage, given the airlines' pricing, the entrant airline determines its flight frequency  $f_2$  without airport capacity constraint to maximize its profit, implying

$$f_2 = \frac{(2 - \beta^2)\gamma \{ (2 - \beta - \beta^2)(\alpha - \omega) - \beta\gamma f_1 - (1 - \beta)\beta rh \}}{\theta(1 - \beta^2)(4 - \beta^2)^2 - (2 - \beta^2)\gamma^2}. \tag{7}$$

<sup>3</sup> This study supposes that the airport holds a concession revenue sharing agreement only with the incumbent airline. Therefore, we discuss a case in which the airport holds revenue sharing agreements with all airlines, including the entrant airline, in Section 6.

**Table 1**  
Equilibrium outcomes in Case Dnb.

$f_1^{Dnb}$	$\frac{\gamma \left[ 2(2 - 3\beta^2 + \beta^4) \{ \theta(4 - \beta^2) - \gamma^2 \} \{ \theta(1 - \beta)(2 - \beta)(2 + \beta)^2 - (2 - \beta^2)\gamma^2 \} (\alpha - \omega) + rh \{ \theta^2(1 - \beta)^2(4 - \beta^2)^2(8 + 12\beta - 5\beta^3 + \beta^5) - 2\theta(1 - \beta)^2(2 - \beta^2)(4 - \beta^2)(4 - \beta - 2\beta^2 + \beta^3)\gamma^2 + (2 - \beta^2)^2(2 - 2\beta^2 + \beta^3)\gamma^4 \} \right]}{2 \{ \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 - (1 - \beta^2)(2 - \beta^2)^2\gamma^6 \}}$
$f_2^{Dnb}$	$\frac{(2 - \beta^2)\gamma \left[ 2(1 - \beta) \{ \theta^2(1 - \beta^2)(2 + \beta)(4 - \beta^2)^2 - \theta(2 + \beta)(2 - \beta^2)(4 + \beta - 2\beta^2)\gamma^2 + (1 + \beta)(2 - \beta^2)\gamma^4 \} (\alpha - \omega) - \beta rh \{ 2\theta^2(1 - \beta)(1 - \beta^2)(4 - \beta^2)^2 - \theta(1 - \beta)(8 - 4\beta - 12\beta^2 + \beta^3 + 3\beta^4)\gamma^2 - \beta(2 - \beta^2)\gamma^4 \} \right]}{2 \{ \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 - (1 - \beta^2)(2 - \beta^2)^2\gamma^6 \}}$
$p_1^{Dnb}$	$\omega + \frac{\left[ 2\theta(1 - \beta^2) \{ \theta^2(1 - \beta)(1 - \beta^2)(2 + \beta)(4 - \beta^2)^3 - \theta(1 - \beta)(2 + \beta)(2 - \beta^2)(4 - \beta^2)(4 + \beta - 2\beta^2)\gamma^2 + (2 - \beta^2)^3\gamma^4 \} (\alpha - \omega) - rh(1 - \beta) \{ 4\theta^3(1 - \beta^2)^2(4 - \beta^2)^3 - \theta^2(1 - \beta^2)(2 - \beta^2)(4 - \beta^2)(32 + 4\beta - 14\beta^2 - \beta^3 + \beta^4)\gamma^2 + \theta(2 - \beta^2)(40 + 12\beta - 52\beta^2 - 11\beta^3 + 19\beta^4 + 2\beta^5 - 2\beta^5)\gamma^4 - (1 + \beta)(2 - \beta)(2 - \beta^2)^2\gamma^6 \} \right]}{2 \{ \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 - (1 - \beta^2)(2 - \beta^2)^2\gamma^6 \}}$
$p_2^{Dnb}$	$\omega + \frac{\theta(4 - 5\beta^2 + \beta^4) \left[ 2(1 - \beta) \{ \theta^2(1 - \beta^2)(2 + \beta)(4 - \beta^2)^2 - \theta(2 + \beta)(2 - \beta^2)(4 - \beta - 2\beta^2)\gamma^2 + (1 + \beta)(2 - \beta^2)\gamma^4 \} (\alpha - \omega) - \beta rh \{ 2\theta^2(1 - \beta)(1 - \beta^2)(4 - \beta^2) - \theta(1 - \beta)(8 - 4\beta - 12\beta^2 + \beta^3 + 3\beta^4)\gamma^2 - \beta(2 - \beta^2)\gamma^4 \} \right]}{2 \{ \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 - (1 - \beta^2)(2 - \beta^2)^2\gamma^6 \}}$
$q_1^{Dnb}$	$\frac{\left[ 2\theta \{ \theta^2(1 - \beta)(1 - \beta^2)(2 + \beta)(4 - \beta^2)^3 - \theta(1 - \beta)(2 + \beta)(2 - \beta^2)(4 - \beta^2)(4 + \beta - 2\beta^2)\gamma^2 + (2 - \beta^2)^3\gamma^4 \} (\alpha - \omega) + (2 - \beta^2)rh \{ 2\theta^3(1 - \beta)(1 - \beta^2)(4 - \beta^2)^3 - \theta^2(1 - \beta)(4 - \beta^2)(16 - 4\beta - 22\beta^2 + \beta^3 + 5\beta^4)\gamma^2 + \theta(8 - 20\beta - 8\beta^2 + 19\beta^3 + 2\beta^4 - 4\beta^5)\gamma^4 + \beta(2 - \beta^2)\gamma^6 \} \right]}{2 \{ \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 - (1 - \beta^2)(2 - \beta^2)^2\gamma^6 \}}$
$q_2^{Dnb}$	$\theta(4 - \beta^2) \frac{\left[ 2(1 - \beta) \{ \theta^2(1 - \beta^2)(2 + \beta)(4 - \beta^2)^2 - \theta(2 + \beta)(2 - \beta^2)(4 + \beta - 2\beta^2)\gamma^2 + (1 + \beta)(2 - \beta^2)\gamma^4 \} (\alpha - \omega) - \beta rh \{ 2\theta^2(1 - \beta)(1 - \beta^2)(4 - \beta^2)^2 - \theta(1 - \beta)(8 - 4\beta - 12\beta^2 + \beta^3 + 3\beta^4)\gamma^2 - \beta(2 - \beta^2)\gamma^4 \} \right]}{2 \{ \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 - (1 - \beta^2)(2 - \beta^2)^2\gamma^6 \}}$

In the first stage, given the airlines' pricing and the entrant flight frequency, the incumbent airline determines its flight frequency without airport capacity to maximize its profit, yielding

$$f_1^{Dnb} = \frac{\gamma \{ G_2(\alpha - \omega) + rhG_3 \}}{2G_1}, \tag{8}$$

where

$$G_1 = \theta^3(1 - \beta^2)^2(4 - \beta^2)^4 - 3\theta^2(1 - \beta^2)(8 - 6\beta^2 + \beta^4)\gamma^2 + \theta(2 - \beta^2)^2(12 - 14\beta^2 + 3\beta^4)\gamma^4 + (1 - \beta^2)(2 - \beta^2)^2\gamma^6, \tag{9}$$

$$G_2 = 2(2 - 3\beta^2 + \beta^4) \{ \theta(4 - \beta^2) - \gamma^2 \} \{ \theta(1 - \beta)(2 - \beta)(2 + \beta)^2 - (2 - \beta^2)\gamma^2 \}, \tag{10}$$

$$G_3 = \theta^2(1 - \beta)^2(4 - \beta^2)^2(8 + 12\beta - 5\beta^3 + \beta^5) - 2\theta(1 - \beta^2)(2 - \beta^2)(4 - \beta^2)(4 - \beta - 2\beta^2 + \beta^3)\gamma^2 + (2 - \beta^2)^2 \times (2 - 2\beta^2 + \beta^3)\gamma^4, \tag{11}$$

where superscript Dnb indicates Case Dnb. Other outcomes derived are presented in Table 1. To ensure positive outcomes in equilibrium, we assume the parameter ranges as follows.

$$\theta \geq \underline{\theta}_{Dnb}, \quad h \leq \bar{h}_{Dnb}. \tag{12}$$

where

$$\underline{\theta}_{Dnb} = \frac{1}{2} \left\{ \frac{(8 + 2\beta - 8\beta^2 - \beta^3 + 2\beta^4) + \sqrt{\beta^2(20 + 8\beta - 20\beta^2 - 4\beta^3 + 5\beta^4)\gamma^4}}{(1 - \beta^2)(4 - \beta^2)^2} \right\}, \tag{13}$$

$$\bar{h}_{Dnb} = \frac{2(1 - \beta) \left\{ \theta^2(1 - \beta^2)(2 - \beta^2)(2 + \beta)^3 - \theta(2 + \beta)(2 - \beta^2)(4 + \beta - 2\beta^2)\gamma^2 + (1 + \beta)(2 - \beta^2)\gamma^4 \right\} (\alpha - \omega)}{s\beta \{ 2\theta^2(1 + \beta)(4 - 4\beta - \beta^2 + \beta^3)^2 - \theta(8 - 12\beta - 8\beta^2 + 13\beta^3 + 2\beta^4 - 5\beta^5) - \beta(2 - \beta^2)\gamma^4 \}}. \tag{14}$$

#### 4.2. Case Duopoly binding (Db)

The maximization problems faced by airlines in the third stage are given as  $\max_{p_i} \pi_i$  using Eq. (4). Solving these problems yields Eq. (6).

In the second stage, given the airlines' pricing and the airport capacity constraint  $f_2 \leq K - f_1$ , the entrant airline determines its flight frequency to maximize its profit. Evidently, the optimal flight frequency for the entrant airline is  $K - f_1$ , which indicates that the entrant airline should fly to the maximum remaining airport capacity.

In the first stage, given the airlines' pricing and the entrant flight frequency, the incumbent airline determines its flight frequency to maximize its profit, yielding

$$f_1^{Db} = \frac{\gamma \{ 2(2 - \beta - \beta^2)(\alpha - \omega) - 2\beta\gamma K - \beta^2(1 - \beta)rh \}}{2(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}, \tag{15}$$

where superscript Db indicates Case Db. Other outcomes derived are presented in Table 2. To ensure positive outcomes in equilibrium, we assume the parameter ranges as follows.

$$\theta \geq \underline{\theta}_{Db}, \quad h \leq \bar{h}_{Db}, \quad K \leq \bar{K}_{Db}. \tag{16}$$

where

$$\underline{\theta}_{Db} = \frac{\gamma(2 - \beta - \beta^2)(\alpha - \omega) + (2 - \beta^2)\gamma K}{(2 + \beta)^2(2 - 3\beta + \beta^2)K}, \tag{17}$$

$$\bar{h}_{Db} = \frac{2 \{ (2 - \beta - \beta^2)(\alpha - \omega) - \beta\gamma K \}}{s(1 - \beta)\beta^2}, \tag{18}$$

$$\bar{K}_{Db} = \frac{(2 - \beta - \beta^2)(\alpha - \omega)}{\beta\gamma}. \tag{19}$$

#### 4.3. Case Monopoly non-binding (Mnb)

The maximization problem faced by the incumbent airline in the third stage is given as  $\max_{p_1} \pi_1$  using Eq. (5). Solving the problem yields

$$p_1 = \frac{\alpha + \gamma f_1 + \omega - rh}{2} \tag{20}$$

In Case Mnb, since the entrant airline does not enter the market, the second stage is skipped. In the first stage, given the pricing in the third

**Table 2**  
Equilibrium outcomes in Case Db.

$f_1^{Db}$	$\frac{\gamma \{2(2 - \beta - \beta^2)(\alpha - \omega) - 2\beta\gamma K - \beta^2(1 - \beta)rh\}}{2(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}$
$f_2^{Db}$	$K - \frac{\gamma \{2(2 - \beta - \beta^2)(\alpha - \omega) - 2\beta\gamma K - \beta^2(1 - \beta)rh\}}{2(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}$
$p_1^{Db}$	$\omega + \frac{2\theta(2 - \beta - \beta^2)(\alpha - \omega) - 2\theta\beta(2 - \beta - \beta^2)\gamma K - rh(1 - \beta) \{4\theta(2 - \beta - \beta^2) - (2 + \beta - \beta^2)\gamma^2\}}{2(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}$
$p_2^{Db}$	$\omega + \frac{2(1 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - 2(1 + \beta)\gamma^2 \} (\alpha - \omega) + 2(1 - \beta) \{ \theta(4 + 2\beta - 2\beta - \beta^3) - (1 + \beta)\gamma^2 \} \gamma K - \beta rh \{2\theta(2 - 3\beta + \beta^3) - (1 - \beta^2)\gamma^2\}}{2(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}$
$q_1^{Db}$	$\frac{2\theta(1 - \beta)(2 + \beta)^2(\alpha - \omega) - 2\theta\beta(2 + \beta)\gamma K + rh \{2\theta(1 - \beta)(2 + \beta)(2 - \beta^2) - (1 + \beta)(2 - \beta)\gamma^2\}}{2(1 + \beta)(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}$
$q_2^{Db}$	$\frac{2 \{ \theta(1 - \beta)(2 + \beta)^2 - 2(1 + \beta)\gamma^2 \} (\alpha - \omega) + 2 \{ \theta(4 + 2\beta - 2\beta^2 - \beta^3) - (1 + \beta)\gamma^2 \} \gamma K - \beta rh \{2\theta(2 - \beta - \beta^2) - (1 + \beta)\gamma^2\}}{2(1 + \beta)(2 - \beta) \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \}}$

**Table 3**  
Equilibrium outcomes in Case Mnb and Mb.

	Case Mnb	Case Mb
$f_1$	$\frac{\gamma(\alpha - \omega + rh)}{4\theta - \gamma^2}$	$K$
$p_1$	$\omega + \frac{2\theta(\alpha - \omega) - rh(2\theta - \gamma^2)}{4\theta - \gamma^2}$	$\omega + \frac{\alpha - \omega + \gamma K - rh}{2}$
$q_1$	$\frac{2\theta(\alpha - \omega + rh)}{4\theta - \gamma^2}$	$\frac{\alpha - \omega + \gamma K + rh}{2}$

stage, the incumbent airline determines its flight frequency to maximize its profit, yielding

$$f_1^{Mnb} = \frac{\gamma(\alpha - \omega + rh)}{4\theta - \gamma^2}, \tag{21}$$

where superscript *Mnb* indicates Case *Mnb*. Other outcomes derived are presented in Table 3.

4.4. Case Monopoly binding (Mb)

The maximization problem faced by the incumbent airline in the third stage is given as  $\max_{p_i} \pi_i$  using Eq. (5). Solving these problems yield Eq. (20).

In Case *Mb*, since the entrant airline does not enter the market, the second stage is skipped. In the first stage, since the airport capacity constraint works on the frequency choice of the incumbent airline, it is obvious that the optimal flight frequency for the incumbent airline is

$$f_1^{Mb} = K, \tag{22}$$

where superscript *Mb* indicates Case *Mb*. Other outcomes derived are presented in Table 3.

5. Analysis

In this section, we derive the sub-game perfect equilibrium using the outcomes of the four cases calculated in the previous section. Specifically, we investigate the optimal flight frequency decision by the incumbent airline under a given airport capacity constraint. The incumbent airline has three possible strategies to deal with the threat of the entrant airline. The first strategy is *blocked entry*, which means that even if the incumbent airline determines its flight frequency to maximize its profit as a monopolist, the new airline cannot enter the market. The second strategy is *accommodated entry*, which means that the incumbent airline accommodates the entrant airline and the airlines compete in a duopoly market. The last strategy is *entry deterrence*, which means that the incumbent airline strategically sets its flight frequency high enough to deter the entrant airline from entering the market.

5.1. Blocked entry

We first find the following lemma and proposition regarding the *blocked entry* strategy.

**Lemma 1.** *There always exists a critical airport capacity  $K_B$ , where*  

$$K_B \equiv \frac{\gamma(\alpha - \omega + rh)}{4\theta - \gamma^2} (= f_1^{Mnb}), \tag{23}$$

*such that if  $K \leq K_B$  the entry is blocked. Contrarily, if  $K > K_B$  the entry cannot be blocked, and thus it must be either deterred or accommodated.*

**Proposition 1.** *The critical airport capacity for blocking entry;  $K_B$  increases as the revenue share rate  $r$  increases; i.e.,  $\frac{\partial K_B}{\partial r} \geq 0$ , as shown in Fig. 1.*

Lemma 1 shows that if the airport capacity  $K$  is sufficiently small, (i.e., smaller than the optimal flight frequency for the incumbent airline in Case *Mnb*;  $f_1^{Mnb}$ ), then the new airline is blocked from entry regardless of the strategic frequency choice of the incumbent airline, which is quite intuitive.

Proposition 1 points out that a deeper vertical agreement between the incumbent airline and the airport encourages the blocking of the new airline from entering the market. The incumbent airline has the incentive to increase passenger demand and thereby concession revenue due to the revenue sharing agreement with the airport. Thus, the incumbent airline should offer a lower price and more flight frequencies as a result of a deeper revenue sharing agreement. Therefore, the range of airport capacity at which the new airline is blocked from entering the market expands.

5.2. Entry deterrence

Further, we investigate the flight frequency decision of the incumbent airline when the airport capacity is sufficiently large so that the new airline cannot be blocked from entry, i.e.,  $K > K_B$ .

If airport capacity remains after the incumbent airline decides on its flight frequency, it is optimal for the new airline to enter the market with that airport capacity since there is no entry cost. Hence, it is clear that the incumbent airline can deter the entry of the new airline by occupying the airport capacity. We propose the following lemmas regarding the *entry deterrence* strategy.

**Lemma 2.** *Solving  $\pi_1^{Mb} = \pi_1^{Dnb}$  and  $\pi_1^{Mb} = \pi_1^{Db}$  for  $K$ , we can obtain the critical airport capacities  $K_{Dnb}$  and  $K_{Db}$ , respectively,<sup>4</sup> as shown in Table 4.*

<sup>4</sup> The incumbent has a choice of either deterring entry and thereby earning the monopoly profit (i.e.,  $\pi_1^{Mb}$ ), or accommodating entry and thereby earning the duopoly profit (i.e.,  $\pi_1^{Dnb}$  or  $\pi_1^{Db}$ ). The incumbent airline can keep its

**Table 4**  
Airport capacity for entry deterrence strategy.

$K_{Dnb}$	$\frac{1}{4\theta - \gamma^2} \left\{ \gamma(\alpha - \omega + rh) + \sqrt{\frac{4\theta^2 \beta H_1(\alpha - \omega)^2 - 4\theta rh H_2(\alpha - \omega) + \beta r^2 h^2 H_3}{G_1}} \right\}$
$K_{Db}$	$\frac{H_4(\gamma\alpha - \omega) + \beta\gamma rh(1 - \beta)H_5 + \sqrt{H_6 \{4\theta\beta H_7(\alpha - \omega)^2 - 4rh H_8(\alpha - \omega) + 4\beta r^2 h^2 H_9\}}}{(2 - \beta)^2 \left\{ 4\theta^2(1 - \beta^2)(2 + \beta)^2 + (1 + \beta)^2\gamma^4 - \frac{\theta(32+16\beta-40\beta^2-8\beta^3+13\beta^4-\beta^6)\gamma^2}{(2-\beta)^2} \right\}}$

where

$$\begin{aligned}
 h_1 &= \theta^2(1 - \beta)^2(4 - \beta^2)^2(4 + \beta - 2\beta^2 + \beta^3) - \theta(1 - \beta^2)(2 + \beta)(4 - \beta^2)(16 - 14\beta - 3\beta^2 + 6\beta^3 - 2\beta^4) \\
 &\quad + (2 - \beta^2)(8 - 10\beta^2 + 2\beta^3 + 2\beta^4 - \beta^5)\gamma^4 \\
 h_2 &= 2\theta^3(1 - \beta)(1 - \beta^2)(2 + \beta)(4 - \beta^2)^2(8 - 4\beta + 3\beta^3 - \beta^4) - \theta^2(1 - \beta^2)(4 - \beta^2)(96 - 64\beta - 56\beta^2 + 60\beta^3 - 6\beta^4 - 17\beta^5 + 4\beta^6 + \beta^7)\gamma^2 \\
 &\quad + \theta(2 - \beta)(2 - \beta^2)(24 + 4\beta - 30\beta^2 + 3\beta^3 + 8\beta^4 - 5\beta^5 - 2\beta^6)\gamma^4 - (2 - \beta^2)(4 - 5\beta^2 + 2\beta^3 + \beta^5 - \beta^5)\gamma^6 \\
 h_3 &= 4\theta^4(1 - \beta)(1 - \beta^2)(4 - \beta^2)^2(16 + 8\beta - 4\beta^2 - 3\beta^3 + \beta^4) - 4\theta^3(1 - \beta^2)(2 - \beta)(4 - \beta^3)(16 + 14\beta - 13\beta^2 - 11\beta^3 + 2\beta^4 + \beta^5)\gamma^2 \\
 &\quad + \theta^2(2 - \beta)(32 + 120\beta - 60\beta^2 - 186\beta^3 + 23\beta^4 + 84\beta^5 + 2\beta^6 - 10\beta^7 - \beta^8)\gamma^4 - 2\theta(2 - \beta)(2 - \beta^2)(6 + \beta - 4\beta^3 - \beta^3)\gamma^6 + \beta(2 - \beta^2)^2\gamma^8 \\
 h_4 &= \theta(16 + 8\beta - 28\beta^2 - 4\beta^3 + 9\beta^4 - \beta^6) - (2 + \beta - \beta^2)^2\gamma^2 \\
 h_5 &= \theta(8 - 4\beta - 8\beta^2 + \beta^3 + \beta^4) - (2 + \beta - \beta^2)\gamma^2 \\
 h_6 &= (1 + \beta)(2 - \beta)^2 \{ \theta(1 - \beta)(2 + \beta)^2 - (1 + \beta)\gamma^2 \} \\
 h_7 &= \theta(1 - \beta)(2 + \beta)^2(4 - 3\beta + \beta^2) - (4 + \beta - 2\beta^2)\gamma^2 \\
 h_8 &= 2\theta^2(1 - \beta)(2 + \beta)(8 - 4\beta + 3\beta^3 - \beta^4) - \theta(16 - 4\beta - 10\beta^2 + 5\beta^3 - \beta^5)\gamma^2 - (2 + \beta - \beta^2)\gamma^4 \\
 h_9 &= 4\theta^2(1 - \beta)(16 + 8\beta - 4\beta^2 - 3\beta^3 + \beta^4) - 4\theta(8 - \beta - 3\beta^2 - 2\beta^3 + \beta^4)\gamma^2 + (4 + \beta - \beta^3)\gamma^4
 \end{aligned}$$

**Lemma 3.** There exists a critical airport capacity  $K_D$ , where

$$K_D \equiv \begin{cases} K_{Dnb} & \text{if } 0 \leq r \leq \underline{r} \\ K_{Db} & \text{if } \underline{r} \leq r \leq \bar{r} \end{cases}, \tag{24}$$

such that if  $K_B < K \leq K_D$  the entry deterrence strategy is optimal for the incumbent airline. Here,  $\underline{r}$  denotes the threshold of revenue share rate such that  $K_{Dnb} = K_A$  (or  $K_{Db} = K_A$ ),<sup>5</sup> where

$$K_A \equiv f_1^{Dnb} + f_2^{Dnb}, \tag{25}$$

and  $\bar{r}$  denotes the threshold of revenue share rate such that  $K_{Db} = K_B$ .

**Lemma 2** presents the thresholds of airport capacity at which the incumbent airline deters the entry of the new airline. If the airport capacity is slightly larger than  $K_B$  (the optimal flight frequency for the incumbent airline as a monopolist), then the incumbent airline can deter the new airline from entering the market and retain its monopoly power by taking up airport capacity. However, occupying additional airport capacity by increasing the flight frequencies increases the costs of the incumbent airline. Hence, there is an upper limit of airport capacity that the incumbent airline has the incentive to occupy. If the incumbent airline does not use all the airport capacity, the new airline can enter the market, and thus, a duopoly competition arises. Therefore, we can derive the threshold of airport capacity by comparing its profit in the two duopoly cases (*Case Dnb* and *Db*) and the monopoly case with capacity constraint (*Case Mb*).

**Lemma 3** shows that if the airport capacity is at a moderate level (i.e.,  $K_B < K \leq K_D$ ), the incumbent airline has the incentive to occupy all airport capacity to deter the new airline from entering the market. As a result, a monopoly market is realized and the incumbent airline preserves its market power.

Moreover, we investigate the impact of concession revenue sharing on the entry deterrence strategy. However, since this calculation is too complex to analyze analytically, we use numerical examples to explore this issue. We suggest the following proposition by using a numerical example.

monopoly (i.e., deter entry) by occupying the airport capacity. Hence, we can characterize the critical airport capacities by comparing the monopoly and duopoly profits of the incumbent airline.

<sup>5</sup> Strictly speaking, the critical value  $\underline{r}^{Dnb}$  obtained by solving  $K_{Dnb} = K_A$  is not equal to the value  $\underline{r}^{Db}$  obtained by solving  $K_{Db} = K_A$ . However, the difference is extremely small, and thus the two values are acceptable as equal for this paper. More details upon request.

**Proposition 2.** The critical airport capacities for deterring entry;  $K_{Dnb}$  and  $K_{Db}$  decrease as the revenue share rate  $r$  increases as shown in Fig. 1.

**Proposition 2** indicates that a deeper concession revenue sharing agreement between the airport and the incumbent airline can diminish an incentive for the incumbent airline to deter entry. This result is opposite to **Proposition 1**. The incumbent airline, when deciding whether or not to deter entry, compares the profit obtained by exclusive possession of airport capacity and holding a monopoly power with the profit obtained by accommodating the entrant airline to enter the market. The incumbent airline can earn a part of concession revenue that comes from its own passengers in the monopoly market, whereas it can earn a part of concession revenue that comes from passengers carried by both itself and the entrant airline in the duopoly market. Hence, the marginal profit from the revenue share rate  $r$  is more significant in the duopoly market than in the monopoly market. Therefore, the incentive for incumbent airline to deter entry declines as the revenue sharing agreement deepens. In addition, as shown in Fig. 1, entry deterrence can only occur in the lower ranges of revenue share rate  $r$ . It is consistent with **Proposition 1** that a high revenue share rate increases the incumbent's incentive to block entry and **Proposition 2** that it decreases its incentive to deter entry.

5.3. Accommodated entry

If the airport capacity is sufficiently large, the incumbent airline cannot block or deter the new airline from entering the market and accommodates the new airline. Thus, airlines compete in a duopoly market. We present the following lemma and proposition regarding the *accommodated entry* strategy.

**Lemma 4.** If airport capacity is sufficiently large that the incumbent airline cannot help but accommodate the entry of a new airline, the following two equilibria are realized.

1. If the airport capacity is larger than  $K_{Db}$ , but is smaller than  $K_A$ , then, *Case Db* (represented as “Accommodate (b)” in Fig. 1) is realized, resulting in the total flight frequency of  $K(= f_1^{Db} + f_2^{Db})$ .
2. If the airport capacity is larger than both  $K_{Dnb}$  and  $K_A$ , then *Case Dnb* (represented as “Accommodate (nb)” in Fig. 1) are realized, resulting in the total flight frequency of  $K_A(= f_1^{Dnb} + f_2^{Dnb})$ .

**Proposition 3.** The critical airport capacity for accommodating entry;  $K_A$  increases with the revenue share rate  $r$ , as shown in Fig. 1.

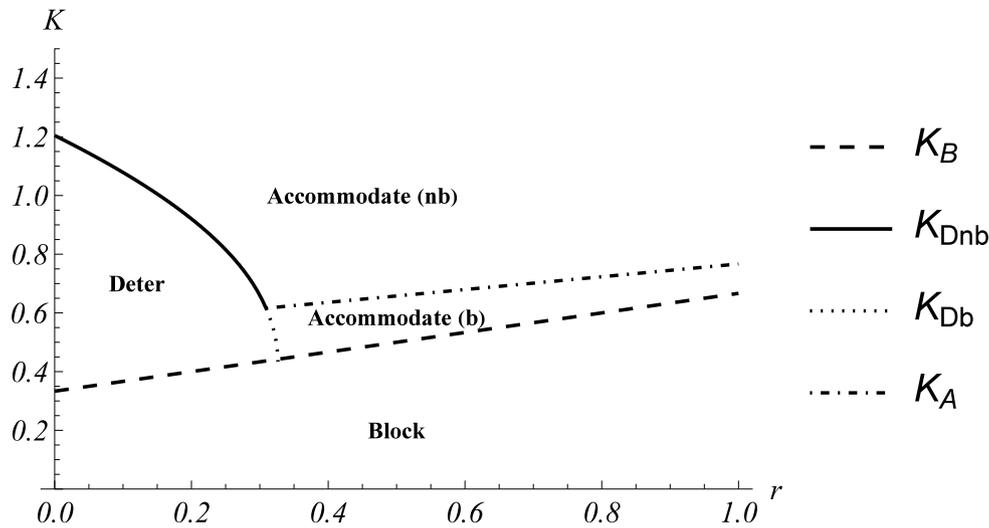


Fig. 1. Incumbent optimal strategies: block, deter, or accommodate. Note: The vertical and horizontal axes of this plot represent the airport capacity  $K$  and revenue share rate  $r$ , respectively. The following parameter set where all outputs are positive is used for this numerical example:  $\alpha = 10$ ,  $\beta = 0.5$ ,  $\omega = 5$ ,  $h = 5$ ,  $\gamma = 1$ , and  $\theta = 4$ .

Lemma 4 shows that when the incumbent airline accommodates (i.e., cannot block or deter) the entry of the new airline, two types of equilibria are realized. When the airport capacity is large enough not to deter entry but is bound (i.e.,  $K_{Db} < K \leq K_A$ ), the entire airport capacity is used by the incumbent and entrant airlines. Contrarily, if the airport capacity is quite large (i.e.,  $K > K_{Dnb}$  and  $K > K_A$ ), then a part of the airport capacity is not used, and the total flight frequency in the market is potentially lower than if entry deterrence occurs. In other words, although the airport capacity must be sufficiently large to avoid entry deterrence by the incumbent airline, not all of it may be used by airlines, even if entry is accommodated.

Proposition 3 also shows that when the entrant airline is accommodated and a duopoly market occurs, the total flight frequency in the market increases as the revenue share rate  $r$  increases. Specifically, an increase in the revenue share rate causes the incumbent airline to increase its flight frequency while the entrant airline decreases its frequency. The former impact is greater than the latter impact, thus increasing the total flight frequency in the market. The mechanism by which the incumbent airline increases its flight frequency is consistent with that explained in Proposition 1.

5.4. Effects of parameters on optimal strategies

In this subsection, we investigate how the optimal strategies of the incumbent airline shown in Fig. 1 depend on some parameters and provide the following observations (as shown in Fig. 2).

Observation 1.

- (i) As the differentiation between the incumbent and entrant airlines expands, the incumbent airline has less incentive to deter entry. Meanwhile, as airline services become more homogeneous, the incumbent airline has a greater incentive to deter entry.
- (ii) As the concession revenue per passenger decreases (increases), the incumbent airline has a greater (less) incentive to deter entry.

These results can be explained as follows. First, if airline services are well differentiated, an entry of the entrant airline would not reduce the demand of the incumbent airline much. Hence, the incumbent airline has little incentive to deter entry. Conversely, if airline services are homogeneous, an entry would significantly take away demand from the incumbent airline. Hence, the incumbent airline has a strong incentive to deter entry. Second, if the concession revenue per passenger is

small, the incumbent airline prefers to deter entry because of the small concession revenue that would be obtained if it accommodates entry. However, if the concession revenue per passenger is large, the incumbent airline prefers to accommodate entry because of the large concession revenue from new passengers. In addition, these results guarantee the results of this paper are realized in various situations.

5.5. Effects on profits, consumer surplus, and welfare

Summarizing our analysis above, we explore the effects of the entry deterrence strategy on profits, consumer surplus, and welfare, and make the following observations (as shown in Fig. 3).

Observation 2.

- (i) The incumbent airline with concession revenue sharing can earn a higher profit than the incumbent airline.
- (ii) Blocking or deterring entry leads to a monopoly market, which harms the airport profit, consumer surplus, and welfare while accommodating entry (and thus airline competition) dramatically improves them.
- (iii) Even in the absence of a concession revenue sharing agreement (i.e.,  $r = 0$ ), an entry deterrence strategy could be the optimal strategy for the incumbent airline if it determines its flight frequency before the entrant airline.
- (iv) A concession revenue sharing agreement between the airport and the incumbent airline with a high share rate  $r$  may improve the airport's profit, consumer surplus, and welfare by preventing the incumbent airline from adopting an entry deterrence strategy.

These results provide policy implications for concession revenue sharing between airports and airlines. First, a concession revenue sharing agreement between an airport with a small capacity and a particular incumbent airline may encourage the airline to block a new airline without strategic decision-making, which results in a monopoly airline market and welfare losses. Second, a non-intimate concession revenue sharing agreement between an airport with medium capacity and a particular incumbent airline may help the airline strategically deter an entrant airline. Thus, this generates welfare loss. Finally, a concession revenue sharing agreement between an airport with a large capacity and a particular incumbent airline can encourage the airlines to offer lower prices and higher flight frequencies, thereby improving the airport's profit and welfare.

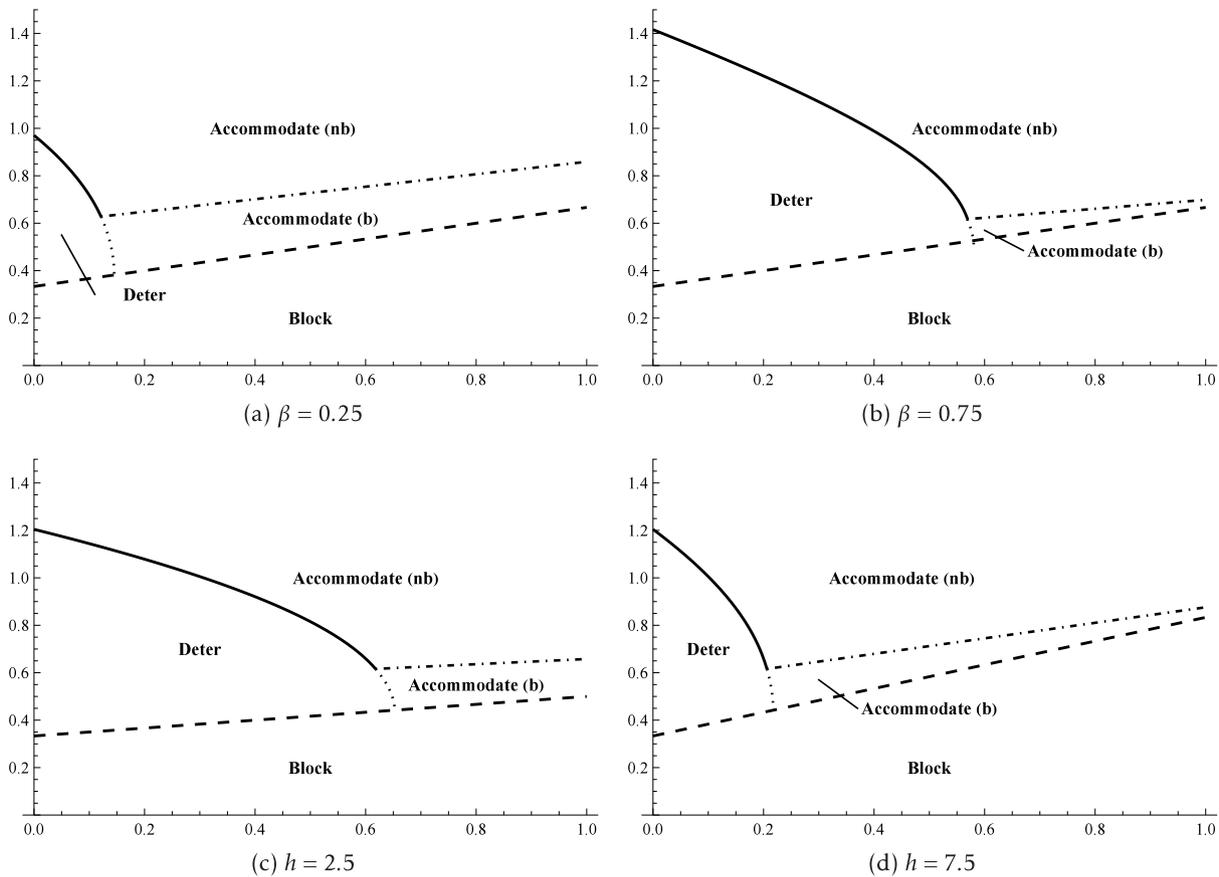


Fig. 2. Effects of parameters on optimal strategies ( $\beta$  and  $h$ ). Note: The vertical and horizontal axes of this plot represent the airport capacity  $K$  and revenue share rate  $r$ , respectively. The following parameter set where all outputs are positive is used for this numerical example:  $\alpha = 10$ ,  $\beta = 0.5$ ,  $\omega = 5$ ,  $h = 5$ ,  $\gamma = 1$ , and  $\theta = 4$ .  $\beta$  represents the degree of substitution, and  $h$  represents the concession revenue per passenger. The legends for these plots are the same as in Fig. 1.

6. Extension

In this section, we extend our model in two ways and provide additional insightful results. The first extension examines a situation in which an airport has a concession revenue sharing agreement not only with an incumbent airline but also with an entrant airline. Such a situation has often been discussed in the related studies that have analyzed vertical relationships between airports and airlines (e.g., Fu and Zhang, 2010). The second extension examines a situation in which two or more incumbent airlines in an oligopolistic market are faced with a potential entrant airline. A number of previous studies (e.g., Brander and Zhang, 1993) empirically point out that airline markets are oligopolistic, and thus introducing the oligopolistic market into our model is worthwhile. We show that our results about the entry deterrence strategy are acceptable in the context of these related studies.

6.1. Concession revenue sharing to both incumbent and entrant airlines

In this subsection, we discuss the entry deterrence strategy for the incumbent airline in a situation where the airport has concession revenue sharing agreements with the entrant airline as well as the incumbent airline. Specifically, the profit function for the incumbent airline remains the same as in the basic model, that is, Eq. (4), while the profit function for the entrant airline is revised as

$$\pi_2 = (p_2 - \omega)q_2 - \theta f_2^2 + rh(q_1 + q_2), \tag{26}$$

As in the basic model, we derive equilibria for the four cases (Case  $Dnb$ ,  $Db$ ,  $Mnb$ , and  $Mb$ ), and compare the results to find the thresholds of

the airport capacity that define the optimal strategies of the incumbent airline, i.e.,  $K_B$ ,  $K_{Dnb}$ ,  $K_{Db}$ , and  $K_A$ .

We present the following proposition regarding this extended model.<sup>6</sup>

**Proposition 4.** *The airport's concession revenue sharing with both incumbent and entrant airlines has little impact on the entry deterrence strategy of the incumbent airline, as shown in Fig. 4.*

Proposition 4 points out that the concession revenue sharing agreement between the airport and the entrant airline does not enhance or mitigate the incumbent's incentive to deter entry. This result can be explained as follows. In a monopoly market, since revenue sharing with the entrant airline does not affect increasing the incumbent's profit, the profit that the incumbent airline can earn by holding its monopoly power does not change. In a duopoly market, revenue sharing with the entrant airline has both positive and negative effects on the incumbent airline. The positive effect is that the entrant airline lowers its price and increases its flight frequency, which in turn increases concession revenue. The negative effect is that the advantage of the incumbent airline diminishes because the entrant airline earns concession revenue as well as the incumbent airline, which results in a decrease in the incumbent's passengers. These two effects above offset each other and have little effect on the incentive for the incumbent airline to deter entry.

<sup>6</sup> The results in equilibrium for this extended model are more complicated than the basic model and are available upon request.

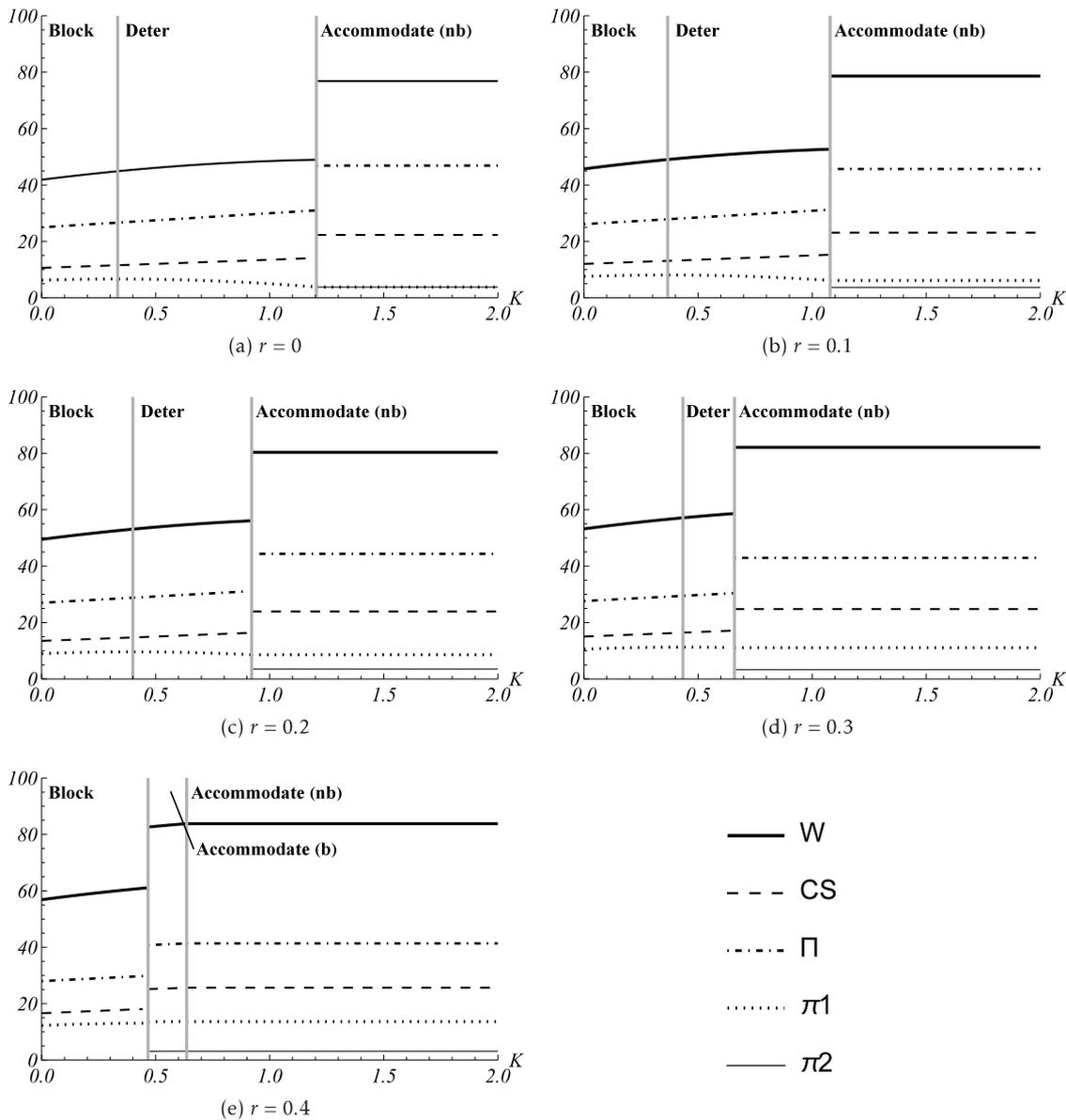


Fig. 3. Effects on profits, consumer surplus, and welfare. Note: The vertical and horizontal axes of this plot represent the values of each output and the airport capacity  $K$ , respectively. The following parameter set where all outputs are positive is used for this numerical example:  $\alpha = 10$ ,  $\beta = 0.5$ ,  $\omega = 5$ ,  $h = 5$ ,  $\gamma = 1$ , and  $\theta = 4$ .

### 6.2. Competition between incumbent airlines

In this subsection, we discuss the entry deterrence strategy for incumbent airlines in an oligopolistic market. For simplicity, we investigate the entry deterrence strategy in a situation where two symmetric incumbent airlines (whose subscripts are 1 and 2) face potential entry (whose subscript is 3).<sup>7</sup> In addition, this extended model assumes that airlines determine the quantity and flight frequency instead of the price and flight frequency.<sup>8</sup> Namely, the timeline of the game is revised as follows. In the first stage, the incumbent airlines determine their flight frequencies  $f_1$  and  $f_2$  to maximize their profit, respectively. Subsequently, the entrant airline decides whether to enter the market

and, if so, its flight frequency  $f_3$  in the second stage. In the third stage, airlines in the market set their quantities.

Suppose that the representative passenger utility function for air travel is

$$U = \alpha (q_1 + q_2 + q_3) - \frac{1}{2} \{q_1^2 + q_2^2 + q_3^2 + 2\beta (q_1 q_2 + q_1 q_3 + q_2 q_3)\}, \quad (27)$$

and solving the maximization problem,  $\max_{q_i} U - \sum_{i=1}^3 (p_i - \gamma f_i) q_i$  ( $i = 1, 2, 3$ ), the inverse demand functions are derived as follows:

$$p_i = \alpha + \gamma f_i - q_i - \beta Q_{-i}, \quad (28)$$

where  $Q_{-i}$  is the sum of quantities other than airline  $i$ .

As in the basic model, we derive equilibria for the four cases. The first case is parallel to *Case Dnb*, where the entrant airline enters the market so that two incumbent and entrant airlines compete in quantity, and the airport capacity constraint does not bind. The second case is parallel to *Case Db*, where two incumbent and entrant airlines compete in quantity, and the airport capacity constraint binds. The third case is parallel to *Case Mnb*, where the entrant airline does not enter so that two incumbent airlines compete in quantity, and the airport capacity

<sup>7</sup> Similar results can be obtained for three or more incumbent airlines. Details are available upon request.

<sup>8</sup> The change from price to quantity as a decision variable is a simplifying way for this extended analysis, but it keeps the continuity between this analysis and the main one. Therefore, the results from this analysis and the main one are comparable, and the basic results remain.

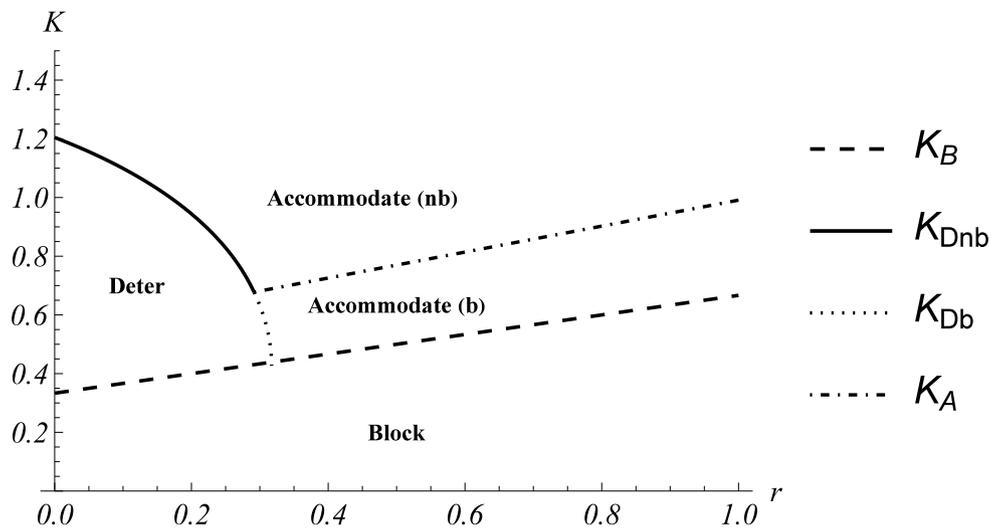


Fig. 4. Share to both airlines. Note: The vertical and horizontal axes of this plot represent the airport capacity  $K$  and revenue share rate  $r$ , respectively. The following parameter set where all outputs are positive is used for this numerical example:  $\alpha = 10$ ,  $\beta = 0.5$ ,  $\omega = 5$ ,  $h = 5$ ,  $\gamma = 1$ , and  $\theta = 4$ .

constraint does not bind. The last case is parallel to *Case Mb*, where two incumbent airlines compete in quantity and the airport capacity constraint binds.<sup>9</sup> We compare the results to find the thresholds of the airport capacity that define the optimal strategies of the incumbent airline, i.e.,  $K_B$ ,  $K_{Dnb}$ ,  $K_{Db}$ , and  $K_A$ .

We present the following proposition regarding this extended model.<sup>10</sup>

**Proposition 5.** *Even in the presence of competition between incumbent airlines, they have incentives to deter entry. However, the competition between incumbent airlines may diminish those incentives, as shown in Fig. 5.*

Proposition 5 indicates that competition between incumbent airlines may reduce incentives for the incumbent airlines to deter entry, but that entry deterrence can be the optimal strategy for the incumbent airlines. In addition, the incentives to deter entry are diminished by competition between incumbents, which is caused because the competition decreases the incumbents' profits that can be earned by deterring entry. These results are intuitive.

### 7. Conclusion

This study investigates how concession revenue sharing between an airport and an incumbent airline affects the strategic flight frequency choice of that airline for entry deterrence and thus, profits and welfare. We show that concession revenue sharing encourages the incumbent airline to increase its flight frequency to boost concession revenue, as previous studies stated. While this effect of increasing the flight frequency, if entry is realized, could improve welfare by enhancing passengers' service, it could harm the airport's profit and welfare by encouraging the incumbent airline to block the entry of the new airline. In addition, we show that such concession revenue

<sup>9</sup> We focus only on a case where two symmetric incumbents occupy half of the airport capacity, for the sake of simplicity. This is a strict assumption that may imply collusion between the incumbent airlines. It may provide a richer discussion to analyze the incentive for one of the incumbent airlines to block or deter entry by monopolizing all of the airport capacity in a competitive market. However, this issue is more complicated and we will work on it in future research.

<sup>10</sup> The results in equilibrium for this extended model are more complicated than the basic model and are available upon request.

sharing has the different effect of diminishing the incumbent airline to strategically deter entry. This effect is caused by the incumbent airline accommodating the entrant airline to enter the market, thereby earning concession revenues not only from incumbent passengers but also from entrant passengers. As a result, concession revenue sharing between airports and airlines can have various effects on the incumbent strategies, profits, and welfare, depending on the revenue share rate and the airport capacity.

We conclude by describing some limitations of the proposed model and discussing potential avenues for future research. First, we did address airport charges and capacity decisions (e.g., Xiao et al., 2016). These decisions may affect the airline's entry deterrence strategy. For example, expanding airport capacity at an airport with a low capacity cost may prevent an entry deterrence strategy by airlines, while it may produce additional welfare losses at an airport with a high capacity cost. An analysis involving these airport decisions could provide additional airport policy and managerial insights.

Second, we assume that the revenue share rate is an exogenous parameter. In practice, the revenue share rate is determined by the airport (e.g., Fu and Zhang, 2010) or by the interaction between airports and airlines (e.g., Yang et al., 2015). This analysis might provide additional insights into the share rate of the airport-airline agreements and suggest effective methods to regulate revenue sharing.

Third, we assume that airlines offer flights between an airport and one destination. In practice, however, airlines form their flight networks to provide flights to different destinations (e.g., Saraswati and Hanaoka, 2014). If an incumbent airline offers flights to more than one destination, its entry deterrence strategy becomes more complex. For example, an incumbent airline with a network might be able to deter an entrant airline easily by reducing its flight frequency in the market without the threat of an entrant airline and increasing its flight frequency in the market with a threat.

Finally, we do not focus on the problem of airport congestion to simplify the model. However, airport congestion has been widely discussed both academically and practically in airport management, and a body of research has accumulated (e.g., Basso and Zhang, 2007; Czerny, 2010). Airport congestion would affect both the entry deterrence strategies of airlines and the airport capacity choices of airports. Thus, it is an important and complex issue. As a brief discussion to analyze the problem of airport congestion, we address a case where the spillover from flight frequency  $\gamma$ , assumed to be positive in our model, has a negative value (or zero). In this case, the airline cannot increase passengers' utility by increasing their flight frequencies, so they offer

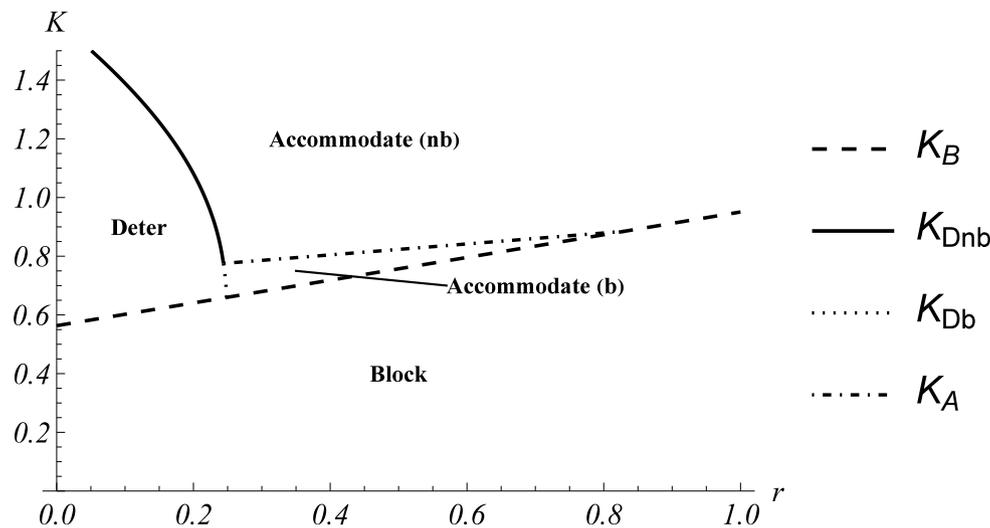


Fig. 5. Competition between incumbent airlines. Note: The vertical and horizontal axes of this plot represent the airport capacity  $K$  and revenue share rate  $r$ , respectively. The following parameter set where all outputs are positive is used for this numerical example:  $\alpha = 10$ ,  $\beta = 0.5$ ,  $\omega = 5$ ,  $h = 5$ ,  $\gamma = 1$ , and  $\theta = 4$ .

the minimum flight frequency  $f = q/s$  to carry  $q$  passengers with an aircraft size  $s$ . Therefore, the critical airport capacities presented in our paper may move downward.

#### CRedit authorship contribution statement

**Yushi Tsunoda:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing.

#### Data availability

Data will be made available on request.

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