

# Entry Airport Selection: Slot Limited Congestion Airport or Secondary Airport

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## Abstract

This paper investigates whether the new carrier enters the slot limited congestion airport or the secondary airport which is located far from the central city, by using very simple model. In addition, this paper analyzes the slot allocation to maximize the social welfare. Then, under the slot allocation maximizing social welfare, we analyze whether the new carrier enters the congested airport or not.

This paper demonstrates following conclusions. When the distance between the secondary airport and the central city is large (small), the new carrier enters the congestion airport (secondary airport). Next, the carrier's cost difference between entering the congested airport and entering the secondary airport is small (large), new carrier has an excessive incentive to enter the secondary (congested) airport. Finally, given that an authority distributes slots to maximize the social welfare, if the marginal cost for slot allocation is large, new carrier may choose to enter the secondary airport which is not socially preferable.

**Keywords:** congested airport, secondary airport, slot allocation.

**JEL:** L93, R41.

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# 1 Introduction

Recently, major airports in each country suffer from congestion due to a slot limitations. In addition, someone argue that the slot limitation brings the entry deterrence of new carriers. For example, Dresner et. al. (2002) pick up three major airports in America, and empirically show that the limitation of airport capacity brings the entry deterrence of new carriers.

As these problems appear, the field of economics mainly handles with these as congestion tax problems which are often analyzed in the field of transportation economics. For example, Brueckner (2002) argues that the traditional Pigouvian congestion charge, which equals to the marginal external cost imposed on all flights, is excessive for the airline with market power. After his argument, Brueckner (2005), Pels and Verhoef (2005), Zhang and Zhang (2006), Morrison and Winston (2007), Brueckner (2009), et al. discuss the airport congestion problems. Recently, Flores-Fillol (2010) treats these problems synthetically, and analyzes some interesting issues, for example, how the number of route or airport capacity influences on congestion.

Now, at the hub airport, the congestion is intensified. Under this situation, in some countries, recent new carriers tend to enter a uncongested secondary airport, instead of entering a congested major airport. On the other hand, in Japan, little carriers use the secondary airport. For example, Ibaragi Airport was opened at 11 March, 2010. This airport has been expected as a alternative airport to congested Haneda Airport or Narita Airport. However, now only Skymark Airlines flies to Kobe Airport in the domestic market<sup>1</sup> and Asiana Airlines flies to Soel in the international market. This state seems to be poor.

When new carriers enter a congested airport, they need a slot allocation to operate its service. However, since the congested airport has little slots to distribute, new carriers hardly operate its service from the congested airport. In addition, because of congestion, too high airport pricing is charged to carriers, which becomes a high operating cost for carriers.

If new carriers enter a secondary airport, they will not suffer from the slot limitation. In addition, the airport pricing will also be cheap. On the other hand, generally, the secondary airport is located away from the central city. Consequently, the access from the secondary airport to the city is a little inferior

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<sup>1</sup>Skymark Airlines announces to pause for operating this route at September 2010.

to that from the congested airport. Considering this trade-off, what condition is required for new carrier to enter a secondary airport?

Recently, the research about entry route of new carriers is progressed. Lin and Kawasaki (2010) adopts the price competition with product differentiation model and discuss whether the new carrier (in particular, regional airline) enters a hub route or a non-hub route. As a result, they demonstrate that new carrier has a strong incentive to enter a non-hub route so as to avoid tough competition. Kawasaki and Lin (2010) introduce the schedule competition model with Cournot type and analyze a similar problem with Lin and Kawasaki (2010). As a result, they argue that when the cost differences between incumbent carriers and low-cost carriers (LCCs) are small (large), LCCs strengthen the incentive to enter a hub (non-hub) route with the increase of incumbent carriers' operating cost.

Here, it is noteworthy that these two papers ignore the slot limitation due to a congestion, which is very important factor for new carriers to decide entry routes. Therefore, they cannot discuss the entry route problem when the congestion originate in a hub airport. In addition, the previous studies about congestion problem handle with the airport pricing and capacity problem, but they do not consider the use of secondary airports. Therefore, this paper assumes that the authority cannot distribute the sufficient slot allocation to the new carriers due to congestion, and analyzes whether the new carriers enter a slot limited congestion airport or a uncongested secondary airport. In addition, we analyze which airport the new carriers should enter from the view of social welfare.

In the following, this paper assumes that the entry to the slot limited congestion airport is socially preferable, and analyzes how to distribute the slot to the new carriers. In particular, it is assumed that the slot allocation by the authority takes some costs. Under the slot distribution by the authority to maximize the social welfare, this paper analyzes whether the new carriers enter the slot limited congestion airport or not<sup>2</sup>.

This paper demonstrates as follows; When the distance between the secondary airport and the central city is large (small), the new carrier enters the slot limited congestion airport (the secondary airport).

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<sup>2</sup>About the slot allocation problem, there are many papers, for example Basso and Zhang (2010), Sieg (2010), Madas and Zografos (2006), Hong and Harker (1992), de Wit and Burghouwt (2008) et al. However, it is noteworthy that every studies do not consider the existence of secondary airport.

The higher the operating cost to enter the slot limited congestion airport is, new carrier strengthens the incentive to enter the secondary airport. In particular, when the slot to new carrier is limited, the incentive is very strong.

When the distance between the secondary airport and the central city is large, if the new carrier enters the secondary airport, the disutility of passengers using new carrier becomes large. Consequently, although they do not enjoy the higher conveniences, they prefer to the incumbent airline entering the congested airport. As a result, the profit of the new carrier entering the secondary airport decreases as comparing the case to enter the congested airport.

Conversely, when the distance is small, even if new carrier enters the secondary airport, it can keep higher conveniences to offset the disutility from the additional travel time. Consequently, passengers strengthen the incentive to use the new carrier entering the secondary airport. These bring the higher profit to the new carrier when it enters a secondary airport than when entering the congestion airport.

Next, when the carrier's cost differences between entering the congestion airport and entering the secondary airport are small (large), new carrier has an excessive incentive to enter the secondary (congestion) airport. When the cost differences are small, even if new carrier enters a congestion airport, it can keep a higher convenience. Consequently, from the view of social welfare, passengers should not incur the additional travel time cost by using a carrier to enter the secondary airport. However, new carrier can provide more convenient service by entering the secondary airport. In addition, the higher convenience becomes a competitive advantage for new carrier. As a result, the new carrier has an excessive incentive to enter the secondary airport.

Conversely, when the cost differences are large, entering the secondary airport gives passengers higher convenience. On the other hand, due to the additional travel time cost, the new carrier weakens the competitive advantage. Therefore, though the higher convenience is sacrificed, it enters the congestion airport in order not to impose passengers additional travel time costs. As a result, it has an excessive incentive to enter the congestion airport.

The analysis of slot allocation problem to maximize the social welfare demonstrates as follows<sup>3</sup>. If

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<sup>3</sup>Note that this analysis assumes that entering the congestion airport is socially preferable to entering the secondary airport.

the marginal cost for slot allocation is small, new carrier enters the socially preferable airport (that is, congestion airport) because it can obtain enough slot allocation. Otherwise, since it cannot obtain enough slot to enter the congestion airport, it may choose to enter the secondary airport, which is not socially preferable.

This paper is organized as follows. In the following section, we set up the model. In section 3, the outcome when new carrier enters the congestion airport is derived. Here, we analyze two cases; one is that the slots to operate new carrier's service are restricted; and the other is that they are not restricted. Section 4 derives the outcome when new carrier enters the secondary airport. Comparing the outcomes of section 3 and 4, section 5 analyzes whether the new carrier enters a congestion airport or a secondary airport. In section 6, deriving the each case's social welfare (that is, the case entering the congestion airport and the case entering the secondary airport) and we compare them. Then, we conclude whether it is socially preferable for new carrier to enter the congestion airport or to enter the secondary airport. In section 8, assuming that it is socially preferable to enter the congestion airport, we analyze the slot allocation problem to maximize the social welfare. Then, under the slot allocation, we examine whether the new carrier enter the congestion airport. Section 8 concludes the outcomes of this analysis.

## 2 The Model

This paper uses two cities model with city  $A$  and  $B$ . Since city  $A$  is a large city, it has two airports; one is located at near the center; and the other is located at a little far from the center.

One airport near the center suffers from congestion because of capacity constraint, that is, limited slots. Therefore, in order to enter the airport, new carrier must receive slots from the authority. Hereafter, we call the slot limited congested airport as "congested airport". The other airport located at a little far from the center does not suffer from the congestion. Therefore, new carrier can freely enter the airport. Hereafter, we refer the uncongested airport as "secondary airport".

City  $B$  is assumed to be a local city. As a reasonable assumption, the city has only one airport which is not congested. Therefore, new carrier can operate its flight freely from (or to) the airport.

Incumbent Airline 1 already operates its flights between congested airport in city  $A$  and city  $B$ 's local

airport. Here, we assume that Airline 1 has enough slots to fly between this city pairs. In this market, entrant Airline 2 plans to enter. Airline 2 has two choices; one is to enter the congested airport, and the other is to enter the secondary airport. When Airline 2 decides to enter the congested airport, the number of flight is limited to  $S$  times because of slot limitation. Here, we assume that if the number of flight frequency between congested airport and local airport by Airline 2 is less than  $S$ , it can operate to the other cities which is not included in this analysis.

When passengers use an airline service entering the congested airport, they can enjoy the high accessibility. On the other hand, When they use an airline service entering the secondary airport, they must move between the secondary airport and the central city. Therefore, they are assumed to incur the additional travel time cost  $T$ , which is disutility for each passenger.

Airline  $i(= 1, 2)$  flies between cities  $A$  and  $B$  by  $f_i$  times per day. When each airline uses the congested airport, they must pay a higher airport charge than when entering the secondary airport. This is for example, each airline is requested to pay a congestion pricing which is decided exogenously. Therefore, we assume that the operational costs of airline entering the congested airport are  $K_H$ ; those of airline to enter the secondary airport are  $K_L$ . Here, it is assumed that  $K_H \geq K_L$ . In the following, the cost per passenger is assumed to be constant and zero. It is noted that this assumption does not lose the important characteristics of economies of density<sup>4</sup>. Hereafter, without loss of generality, we assume that  $K_L = 1$  and  $K_H = K(\geq 1)$ .

Each passenger gains a benefit from using the airline service. Following Brueckner (2004), we assume that the benefit is the sum of travel benefit and a reduction of schedule delay.

The travel benefit derived from the flight service vary among passengers. A passenger's travel benefit is expressed as  $r$ . Here, following Kawasaki and Lin (2010), the benefit  $r$  is assumed to be uniformly distributed over the interval  $[-\infty, R]$  with density one.

The waiting time of passengers using the airline decreases when the airline increases flight frequency. Therefore, each passenger can enjoy greater convenience; this reflects that passenger benefits increase as the flight frequency increases<sup>5</sup>. Hereinafter, following Kawasaki and Lin (2010), we call this the

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<sup>4</sup>About the cost function including the economies of density, see Brueckner (2004).

<sup>5</sup>This assumption has been made by a number of airline studies. See Oum et al. (1995), Brueckner (2004), Brueckner

“scheduling effect” and represent the reduction of schedule delay as  $\sqrt{f}$ .

Finally, when each passenger uses the airline, he/she must pay the airfare. We express it as  $p_i$ .

Summarizing the above discussion, the utility function for each passenger is

$$U_i = \begin{cases} r + \sqrt{f_i} - p_i & \text{if traveling via a congested airport} \\ r + \sqrt{f_i} - T - p_i & \text{if traveling via a secondary airport.} \end{cases} \quad (1)$$

If each passenger does not use the airline service, the utility becomes zero. Consequently, only the passenger to gain negative utility when using the airline services does not use its service.

Here, we discuss the one important restriction. This paper omits the existence of connecting passenger. When we consider the existence of Airline 1’s connecting passenger, the flight frequency of Airline 1 increases. This leads higher competitive power for Airline 1. Then, Airline 2 will select the entry airport to strengthen the scheduling effect. In other words, when the cost  $K$  is small, Airline 2 will strengthen the incentive to enter the congested airport; when  $K$  is high, it will strengthen the incentive to enter the secondary airport. Consequently, even if the existence of connecting passenger is considered, this paper’s main discussion will almost hold.

### 3 The case in which the entrant enters a congested airport

This section analyzes the case that Airline 2 enters the congested airport. Since both airlines enter the congested airport, the each profit function is

$$\pi_1 = \left( R + \sqrt{f_1} - (q_1 + q_2) \right) q_1 - f_1 K \quad (2)$$

$$\pi_2 = \left( R + \sqrt{f_2} - (q_1 + q_2) \right) q_2 - f_2 K. \quad (3)$$

Here, it is noted that the Airline 2 is imposed the restriction of flight number, that is  $f_2 \leq S$ . Considering this restriction, we solve the profit maximization problem. As a result, we obtain following reaction

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and Flores-Fillol (2007) and Kawasaki (2008).

functions.

$$q_1 = -\frac{1}{2}q_2 + \frac{1}{2}(R + \sqrt{f_1}) \quad (4)$$

$$f_1 = \left(\frac{q_1}{2K}\right)^2 \quad (5)$$

$$q_2 = -\frac{1}{2}q_1 + \frac{1}{2}(R + \sqrt{f_2}) \quad (6)$$

$$f_2 = \begin{cases} \left(\frac{q_2}{2K}\right)^2 & \text{if } \left(\frac{q_2}{2K}\right)^2 \leq S \\ S & \text{Otherwise} \end{cases} \quad (7)$$

Solving this system, the following number of flight frequency and demand are derived, respectively.

$$q_1 = \begin{cases} \frac{2K}{6K-1}R & \text{if } K \geq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{K(R-\sqrt{S})}{3K-1} & \text{otherwise} \end{cases} \quad (8)$$

$$q_2 = \begin{cases} \frac{2K}{6K-1}R & \text{if } K \geq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{1}{6K-2}\left((2K-1)R + (4K-1)\sqrt{S}\right) & \text{otherwise} \end{cases} \quad (9)$$

$$f_1 = \begin{cases} \left(\frac{R}{6K-1}\right)^2 & \text{if } K \geq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right) \\ \left(\frac{R-\sqrt{S}}{2(3K-1)}\right)^2 & \text{otherwise} \end{cases} \quad (10)$$

$$f_2 = \begin{cases} \left(\frac{R}{6K-1}\right)^2 & \text{if } K \geq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right) \\ S & \text{otherwise} \end{cases} \quad (11)$$

Substituting these outcomes into respective profit function, the each airline's profit is derived as follows;

$$\pi_1 = \begin{cases} \frac{K(4K-1)R^2}{(6K-1)^2} & \text{if } K \geq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{K(4K-1)(R-\sqrt{S})^2}{4(3K-1)^2} & \text{otherwise} \end{cases} \quad (12)$$

$$\pi_2 = \begin{cases} \frac{K(4K-1)R^2}{(6K-1)^2} & \text{if } K \geq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{((2K-1)^2R^2 + (2K-1)(4K-1)R\sqrt{S} - (36K^3 - 40K^2 + 12K - 1)S)}{4(3K-1)^2} & \text{otherwise} \end{cases} \quad (13)$$

## 4 The case in which the entrant enters a secondary airport

This section analyzes the case that Airline 2 enters the secondary airport. Since Airline 1 enters the congested airport and Airline 2 enters the secondary airport, the each profit function is expressed as follows;

$$\pi_1 = \left( R + \sqrt{f_1} - (q_1 + q_2) \right) q_1 - f_1 K \quad (14)$$

$$\pi_2 = \left( R - T + \sqrt{f_2} - (q_1 + q_2) \right) q_2 - f_2 \quad (15)$$

Solving the profit maximization problem, we obtain the following reaction functions;

$$q_1 = -\frac{1}{2}q_2 + \frac{1}{2} \left( R + \sqrt{f_1} \right) \quad (16)$$

$$f_1 = \left( \frac{q_1}{2K} \right)^2 \quad (17)$$

$$q_2 = -\frac{1}{2}q_1 + \frac{1}{2} \left( R - T + \sqrt{f_1} \right) \quad (18)$$

$$f_2 = \left( \frac{q_2}{2K} \right)^2 \quad (19)$$

From this system, the respective number of flight frequency and demand are derived as follows.

$$q_1 = \frac{2K(R + 2T)}{8K - 3} \quad (20)$$

$$q_2 = \frac{2((2K - 1)R - (4K - 1)T)}{8K - 3} \quad (21)$$

$$f_1 = \left( \frac{R + 2T}{8K - 3} \right)^2 \quad (22)$$

$$f_2 = \left( \frac{(2K - 1)R - (4K - 1)T}{8K - 3} \right)^2 \quad (23)$$

Substituting the above outcomes into each airline's profit function, the profits are

$$\pi_1 = \frac{K(4K - 1)(R + 2T)^2}{(8K - 3)^2}, \text{ and} \quad (24)$$

$$\pi_2 = \frac{3((2K - 1)R - (4K - 1)T)^2}{(8K - 3)^2}. \quad (25)$$

## 5 The selection of entry airport

In this section, we first compare the Airline 1's outcomes when Airline 2 enters the congested airport (congested airport entry case) and those when it enters the secondary airport (secondary airport entry case). In the following, we compare the Airline 2's outcomes of congested airport entry case and those of secondary airport entry case. Finally, using the result of comparison of Airline 2's profit, we discuss whether Airline 2 enters the congested airport or the secondary airport.

### 5.1 The comparison of Airline 1's outcome

Comparing the Airline 1's equilibrium values of the congested airport entry case and those of the secondary airport entry case, we obtain the following proposition.

**Proposition 1** *If and only if  $T \leq T_1^*$ , the relationship that  $f_1^c(q_i^c)$  and  $\pi_1^c \geq f_1^s(q_i^s)$  and  $\pi_1^s$  holds.*

Here, the parameter  $T_1^*$  is defined as follows (See Fig. 1.);

$$T_1^* = \begin{cases} \frac{(2K-1)R - (8K-3)\sqrt{S}}{4(3K-1)} & \text{if } K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{(K-1)R}{6K-1} & \text{otherwise} \end{cases} \quad (26)$$

**Figure 1: The comparison of Airline 1 outcome**

In Fig. 1, the dotted line expresses the value to hold  $f_1^c = f_1^s$  without Airline 2's slot limitation in the range of  $K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right)$ . Consider the case that the distance between the secondary airport and the central city is large. When Airline 2 enters the secondary airport, the passengers using Airline 2 incur the heavy travelling cost. Therefore, they prefer Airline 1 which grounds near the central city. This increases the demand of Airline 1. In addition, since the demand increases, Airline 1 can increase the flight frequency, which increases the profit of Airline 1.

Conversely, consider the case that the distance is small. When Airline 2 enters the secondary airport, although the passengers using Airline 2 incur the additional travel time costs, they enjoy higher convenience because of more Airline 2's flight frequency. Consequently, they prefer Airline 2 to Airline 1, which decreases the demand of Airline 1. In addition, the less passengers bring the Airline 1's flight frequency less, and the profit also decreases.

Here, Fig. 1 shows that the range where the respective outcomes of congested airport entry case is larger than that of the secondary airport entry case becomes large as the operational cost  $K$  increases. In addition, from Fig. 1, we obtain the following lemma.

**Lemma 1** *When the number of Airline 2's flight frequency is limited, the range where the Airline 1's respective outcomes of the congested airport entry case is larger than that of the secondary airport entry case becomes larger.*

When Airline 2 enters the congested airport and is limited on slots, the convenience for passenger using Airline 2 worsens as comparing the case without the limitation. Consequently, the demand of Airline 1 increases. On the other hand, when Airline 2 enters the secondary airport, it can operate its flight without any limitation. Therefore, the convenience of Airline 2 improves and its demand increases. In other words, the demand for Airline 1 decreases. Summerizing the above discussions, the demand of Airline 1 when Airline 2 enters the congested airport with slot limitation is larger than when it enters the secondary airport with no limitation. As a result, Lemma 1 holds.

## 5.2 Comparison of Airline 2's outcomes

This subsection compares the Airline 2's outcomes of the congested airport entry case and those of the secondary airport entry case. In the following, we analyze whether Airline 2 enters the congested airport or the secondary airport. First, the comparison of respective outcomes (flight frequency, demand, and price) of congested airport entry case and that of secondary airport entry case reveals Proposition 2.

**Proposition 2** *When Airline 2 is limited on the number of flights, that is,  $K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right)$ ,*

$$(1) f_2^c \geq f_2^s \iff T \geq \frac{(2K-1)R - (8K-3)\sqrt{S}}{4K-1}$$

$$(2) q_2^c(p_2^c) \geq q_2^s(p_2^s) \iff T \geq \frac{(2K-1)R - (8K-3)\sqrt{S}}{4(3K-1)} .$$

When Airline 2 is not limited on it, that is,  $K > \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right)$ ,

$$(1) f_2^c \geq f_2^s \iff T \geq \frac{4(K-1)(3K-1)}{(4K-1)(6K-1)} R$$

$$(2) q_2^c(p_2^c) \geq q_2^s(p_2^s) \iff T \geq \frac{K-1}{6K-1} R.$$

When Airline 2 enters the secondary airport, it can increase the flight frequency due to lower marginal operational cost, which increases the number of Airline 2's passenger. On the other hand, the entry to the secondary airport brings the disutility  $T$  to the passenger using Airline 2, which decreases Airline 2's demand. Consequently, the entry to the secondary airport bears the trade-off; the merit is to increase the convenience of Airline 2's passenger, and the demerit is to arise the additional travel time cost  $T$ .

Consider the case that  $T$  is large. When Airline 2 enters the secondary airport, passengers prefer Airline 1 to Airline 2 in spite that Airline 2 can operate more flights. As a results, the demand for Airline 2 decreases, as comparing with the congested airport entry case. In addition, this decreases the Airline 2's flight frequency.

Consider the case that  $T$  is small. Although passengers who use Airline 2 entering the secondary airport incur the additional travel time costs, it is attractive for them that Airline 2 operates more flights. Therefore, the passengers prefer Airline 2 to Airline 1. As a result, the demand for Airline 2 of the secondary airport entry case is larger than that of the congested airport entry case, which takes more flight frequencies of Airline 2.

When comparing the Airline 2's profit of the congested airport entry case and that of the secondary airport entry case, we obtain Proposition 3.

**Proposition 3** When  $T \geq T^*$ , Airline 2 enters the congested airport, where

$$T^* = \begin{cases} \left\{ \begin{aligned} &2\sqrt{3}(2K-1)(3K-1)R - (8K-3) \times \\ &((2K-1)^2R^2 + 2(2K-1)(4K-1)R\sqrt{S} - (36K^3 - 40K^2 + 12K - 1)S)^{\frac{1}{2}} \end{aligned} \right\} \\ / (2\sqrt{3}(3K-1)(4K-1)) & \text{if } K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{\sqrt{3}(2K-1)(6K-1) - (8K-3)\sqrt{4K^2-K}}{\sqrt{3}(4K-1)(6K-1)} R & \text{Otherwise.} \end{cases}$$

Figure 2 expresses the result of Proposition 3.

### Figure 2: The selection of entry Airport by Airline 2

In Fig. 2, the dotted line expresses the value to hold  $\pi_2^c = \pi_2^s$  without Airline 2's slot limitation in the range of  $K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right)$ . As is mentioned in Proposition 2, when the additional travel time cost is high, if Airline 2 enters the secondary airport, it loses much passengers. As a result, although the operational cost increases, Airline 2 enters the congested airport in order not to let passengers incur the additional travel time cost, which increases its profit as comparing the secondary airport entry case.

When the additional travel time cost is small, Airline 2 can attract more passenger by entering the secondary airport and operating more flights. Consequently, it is more profitable for Airline 2 to enter the secondary airport.

From Fig. 2, we can also realize that Airline 2 strengthens the incentive to enter the secondary airport as  $K$  increases. This is because the merit to increase the passenger's convenience by entering the secondary airport and increasing the flight frequency becomes large as  $K$  increases. In addition, Fig. 2 gives us the following lemma.

**Lemma 2** Airline 2 strengthens the incentive to enter the secondary airport when it is limited on the slots.

When Airline 2 is limited on the slots, if it enters the congested airport, it loses the opportunity to earn

more profit due to smaller flight frequency. On the other hand, if Airline 2 enters the secondary airport, it does not encounter any limitations, which increases its profits. As a result, Airline 2 strengthens the incentive to enter the secondary airport.

## 6 Social welfare

This section first derives the social welfare of congested airport entry case and that of secondary airport entry case. Then, we compare the social welfare of congested airport entry case with that of secondary airport entry case, and derive the socially preferable entry airport. Finally, we compare the socially preferable entry airport with market equilibrium.

### 6.1 Comparison of Social Welfare

First, we derive the social welfare of the congested airport entry case and that of the secondary airport entry case. The social welfare function is defined as follows;

$$SW = CS + \pi_1 + \pi_2 \quad (27)$$

Here,  $CS$  means the consumer surplus and  $CS = \frac{1}{2}(q_1 + q_2)^2$ .

Substituting each entry case's equilibrium values into the above social welfare function, the social welfare is

$$W^c = \begin{cases} \frac{(32K^2 - 18K + 3)R^2 + 2(16K^2 - 16K + 3)R\sqrt{S} - (72K^3 - 92K^2 + 30K - 3)S}{8(3K - 1)^2} & \text{if } K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right) \\ \frac{2K(8K - 1)R^2}{(6K - 1)^2} & \text{otherwise} \end{cases} \quad (28)$$

$$W^s = \frac{(34K^2 - 25K + 5)R^2 - 2(28K^2 - 26K + 5)RT + (72K^2 - 36K + 5)T^2}{(8K - 3)^2}. \quad (29)$$

Comparison of these social welfare brings the following proposition.

**Proposition 4** *If and only if  $T \geq T^{SW}$ , it is socially preferable for Airline 2 to enter the congested airport. Here, the value of  $T^{SW}$  is as follows.*

$$T^{SW} = \begin{cases} \left[ \begin{aligned} &4(84K^3 - 106K^2 + 41K - 5)R - \sqrt{2}(8K + 3)\{(432K^4 - 840K^3 + 576K^2 - 158K + 15)R^2 \\ &+ 2(1152K^4 - 1728K^3 + 872K^2 - 188K + 15)R\sqrt{S} \\ &- (5184K^5 - 9216K^4 + 5832K^3 - 1756K^2 + 258K - 15)S\} \end{aligned} \right] \\ / (4(3K - 1)(72K^2 - 36K + 5)) \quad \text{if } K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right) \\ \left[ \begin{aligned} &(1008K^4 - 1272K^3 + 520K^2 - 86K + 5) - (48k^2 + 26K - 3)(K(216K^3 - 228K^2 + 66K - 5))^{\frac{1}{2}} \\ &/ ((6K - 1)^2(72K^2 - 36K + 5)) \end{aligned} \right] \quad \text{Otherwise} \end{cases} \quad (30)$$

Figure 3 expresses Proposition 4.

### Figure 3: Socially preferable entry airport

In Fig. 3, the dotted line expresses the value to hold  $SW^c = SW^s$  without Airline 2's slot limitation in the range of  $K \leq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S}}\right)$ . When  $T$  is small, if Airline 2 enters the congested airport, its flight frequency decreases due to higher operational cost as comparing with secondary airport entry case. As a result, the convenience of passenger using Airline 2 worsens. In order to keep the higher convenience of the passenger and let more passengers use the airline services, Airline 2 should enter the secondary airport, which is socially preferable.

When  $T$  is large, if Airline 2 enters the secondary airport, the passenger using Airline 2 incurs the heavily disutility from an additional travel time cost, which decreases the demand of Airline 2. As a result, though it can increase its flight frequency because of lower operational costs, its flight frequency decreases as comparing the congested airport entry case, since most of passenger do not use the Airline 2. This decrease of flight frequency furthermore worsens the Airline 2's convenience. As a result, when  $T$  is large, it is socially preferable for Airline 2 to enter the congested airport.

## 6.2 Comparison of socially preferable entry airport and market equilibrium

This subsection analyzes whether the market equilibrium derived in section 5 is socially preferable or not. Summarizing the figures to express the market equilibrium and to express the socially preferable entry airport into one, we obtain Fig. 4.

### Figure 4: Comparison of market equilibrium and socially preferable entry airport

Figure 4 takes us Proposition 5.

**Proposition 5** *When the operational cost from (to) the congested airport, that is,  $K$  is larger (smaller) than  $K'$ , Airline 2 has an excessive incentive to enter the congested (secondary) airport.*

In addition, Comparison of Fig. 4-a with Fig. 4-b brings us following lemma.

**Lemma 3** *When the slot allocation to Airline 2 is large, Airline 2 has an excessive incentive to enter the secondary airport in the range where it is imposed on the slot limitation. When the slot allocation is small, it has an excessive incentive to enter the congested airport in the range where it is not imposed on the slot limitation.*

Even when  $K$  is small, Airline 2 has an incentive to enter the secondary airport so as to strengthen the competitive power by increasing the flight frequency. However, from the view of social welfare, the social benefit from increase of the flight frequency by entering the secondary airport is small. Rather, the social costs from additional travel time cost which Airline 2's passenger incurs become large. As a result, Airline 2's incentive to enter the secondary airport is socially excessive.

When  $K$  is large, Airline 2 positively plans to enter the secondary airport. However, by entering the secondary airport, passenger using Airline 2 incurs the additional travel time cost  $T$ . When  $T$  is large, passenger does not prefer to use Airline 2 entering the secondary airport, which weakens the Airline 2's competitive power. Consequently, it wants to enter the congested airport. However, from the view of social welfare, even when  $T$  is somewhat large, if Airline 2 enters the secondary airport, the convenience of each passenger improves. As a result, though Airline 2 can increase its flight frequency by entering the

secondary airport, it has an incentive to enter the congested airport in order not to let passengers incur the additional travel time cost, which brings the excessive incentive to enter the congested airport.

## 7 Slot Allocation

Section 6 demonstrated that whether the Airline 2's incentive to enter the congested airport is socially excessive or not depends on both the size of operational cost and the slot allocation (Lemma 3). At this, given that the slots to Airline 2 are limited and that entering the congested airport is socially preferable, this section analyzes whether Airline 2 actually enters the congested airport under the situation that the authority distributes the slots to maximize the social welfare.

### 7.1 How many slots are provided to Airline 2?

The social welfare when Airline 2 enters the congested airport is derived in eq. (28). The authority distributes the slots to maximize the social welfare. Here, it is assumed that allocating one slot to Airline 2 requires the cost  $\tau$ , since the authority must adjust the flight schedule, revise the way of control, et al. As a result, the social welfare function is expressed as follows.

$$SW = \frac{(32K^2 - 18K + 3)R^2 + 2(16K^2 - 16K + 3)R\sqrt{S} - (72K^3 - 92K^2 + 30K - 3)S}{8(3K - 1)^2} - \tau S \quad (31)$$

The authority decides the slot allocation to maximize the above social welfare. As a result, the slot allocation to Airline 2 is

$$S^* = \left( \frac{(16K^2 - 16K + 3)R}{72K^3 - 92K^2 + 30K - 3 + (72K^2 - 48K + 8)\tau} \right)^2. \quad (32)$$

Because we assume that it is socially preferable for Airline 2 to enter the congested airport, the condition that  $T \geq T^{SW}$  must be satisfied.

When analyzing the relationship between slot allocation and  $K$ , we obtain the following lemma.

**Lemma 4** *If and only if  $K \leq \hat{K}$ ,  $\frac{\partial S^*}{\partial K} \geq 0$  holds.*

Because the detail value of  $\hat{K}$  is too complex, we omit to show it. The result of Lemma 4 is expressed in Fig. 5.

**Figure 5: The outcome of comparative static analysis of  $S^*$**

Here, we consider the change of marginal social welfare when the slot to Airline 2 is revised. When  $K$  increases, the flight frequency of Airline 1 decreases, which worsens the convenience of passenger using Airline 1. Given this situation, if the slot to Airline 2 increases, the poor convenience can improve since the passengers change Airline 1 to Airline 2 and enjoy higher convenience. Consequently, as  $K$  becomes large, the marginal consumer surplus by increasing the slot to Airline 2 becomes large. In addition, because Airline 2 increases its flight frequency, Airline 1 decreases the flight frequency<sup>6</sup>, which decreases the operational costs of Airline 1. As a result, the profit of Airline 1 increases.

On the other hand, as the slot allocation to Airline 2 increases, the operational costs of Airline 2 also increase. If  $K$  is small (large), the increase of Airline 2's costs by increasing its slot allocation is small (large). Consequently, comparing the increase of marginal consumer surplus, that of Airline 1's profit, and that of Airline 2's cost, if  $K$  is small and the increase of Airline 2's cost is small, the marginal benefit to increase the slot allocation to Airline 2 becomes large as  $K$  increases. Conversely, if the increase of Airline 2's cost is large, the marginal benefit becomes small as  $K$  increases.

By the above mentioned mechanism, in the range of smaller (larger)  $K$ , when  $K$  increases, the slot allocation to Airline 2 maximizing social welfare decreases.

## 7.2 Does Airline 2 enter the congested airport?

This subsection analyzes whether Airline 2 enters the congested airport or not when the authority distributes the slots to maximize the social welfare.

When Airline 2 enters the congested airport, its profit is

$$\pi_2^c = \frac{(2K-1)^2 R^2 + (2K-1)(4K-1)R\sqrt{S^*} - (36K^3 - 40K^2 + 12K - 1)S^*}{4(3K-1)^2}. \quad (33)$$

---

<sup>6</sup>We note that the relationship of flight frequency between Airline 1 and Airline 2 is strategic substitute.

Here,  $S^*$  means the slot allocation maximizing social welfare. Comparing the Airline 2's profit of congested airport entry case and that of secondary airport entry case, if  $T \geq T^*$ , it enters the congested airport.

Now, we must check whether the  $T$  satisfying the condition that  $T \geq T^*$  exists or not in the range of  $T \geq T^{SW}$  (that is, entering the congested airport is socially preferable). In order to check it, we compare  $T^{SW}$  with  $T^*$ . We must note that the condition that  $K \geq \frac{1}{6} \left(1 + \frac{R}{\sqrt{S^*}}\right)$  holds since Airline 2 is assumed to be imposed on slot limitation. Hereafter, because of complexity of calculation, we use simulation analysis. It is assumed that  $R = 100$  without loss of generality. As a result, we obtain Fig. 6.

**Figure 6: Comparison of  $T^*$  with  $T^{SW}$**

From Fig. 6, the following proposition is obtained.

**Proposition 6** *In the range of  $T^{SW} \geq T^*$ , that is, when  $K$  is large, Airline 2 enters the congested airport. In the range of  $T^{SW} < T^*$ , that is, when  $K$  is small, it has an incentive to enter the secondary airport. In addition, as  $\tau$  increases, the range to realize latter situation becomes large.*

This proposition is consistent with Proposition 5. According to Proposition 5, if the operational cost  $K$  is small, Airline 2 has an excessive incentive to enter the secondary airport. This subsection demonstrates as follows; when Airline 2 selects the entry airport under the situation that the authority distributes the slots to maximize social welfare, the case in which Airline 2 enters the secondary airport exists. In other words, because the Airline 2's incentive entering the secondary airport is stronger than the socially preferable level, the inefficient outcome comes true.

As  $\tau$  becomes large, the slot allocation to Airline 2 decreases. Therefore, Airline 2 strengthens the incentive to enter the secondary airport from (to) which Airline 2 can operate more flights due to non-limitation. In other words, the Airline 2's incentive entering the congested airport becomes small.

These results show us that the authority must distribute the slots by considering the probability for new carrier to enter the secondary airport. If the authority overlooks this probability, the socially inefficiencies happen.

## 8 Concluding Remarks

This paper analyzed which airport the new carrier enters, the congested airport with slot limitation or the secondary airport far from the central city by using very simple framework. This paper demonstrated as follows. If the distance between secondary airport and the central city, that is the additional travel cost, is large (small), new carrier enters the congested (secondary) airport. As the operational costs to enter the congested airport are high, new carrier strengthens the incentive to enter the secondary airport.

Then, when the costs to enter the congested airport are small (high), new carrier has an excessive incentive to enter the secondary (congested) airport. In addition, when the slot allocation to the new carrier is decided to maximize the social welfare, it may not enter the socially preferable congested airport.

This paper analyzes the entry airport by new carrier using two cities model. However, the actual airline network links a lot of cities (and airports). In addition, since many airlines use hub-spoke network, we should not ignore the existence of connecting passenger. Here, if we include this connecting passenger into our model and increase the number of route of incumbent airline, the flight frequency by the incumbent airline increases. Then, the new carrier's competitive power becomes lower. As a result, if the costs of entering the congested airport are large, new carrier will strengthen the incentive to enter the secondary airport in order to increase the flight frequency. Conversely, if the costs are small, it will lower the incentive to enter the congested airport in order to decrease the passengers' additional travel cost. Consequently, even if we relax the assumption of two cities and no connecting passenger, the main result obtained in this paper will almost hold.

We discuss the restriction of this paper. This paper does not handle with the congestion pricing and detailed slot allocation problem. These problems will be very important from the view of policy makers. In the previous studies about airport pricing problem, the existence of secondary airport is not considered. If the authority imposes the congested airport pricing, new carrier (or incumbent airline) may enter the secondary airport, which may increase the passenger's costs. Consequently, we must analyze the congestion pricing problem considering the existence of secondary airport.

Next, this paper assumes that the incumbent airline has enough slots to operate. On the other hand, new carrier suffers from the slot limitation. Is this situation socially preferable? In the future research,

we must analyze how to allocate the slots between incumbent airline and new carrier.

Finally, recently someone argue that the authority constructs too many airport. Here, we need consider the airport near the congested airport as secondary airport. For example, there are New Kitakyushu Airport and Saga Airport near the congested Fukuoka Airport. Do these airports play a role of secondary airport?

These are very important problems to consider in the future research in the view point of airport policy.

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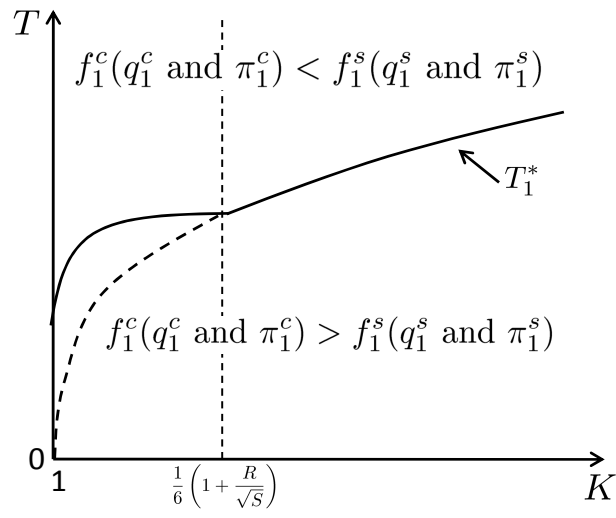


Figure 1: The comparison of Airline 1 outcome

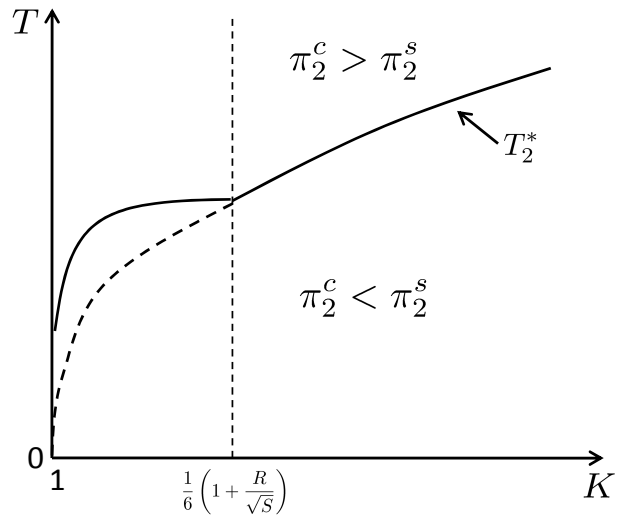


Figure 2: The selection of entry airport by Airline 2

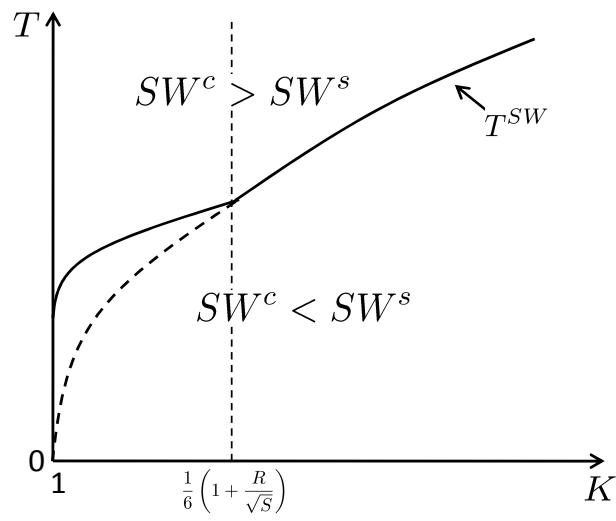


Figure 3: Socially preferable entry airport

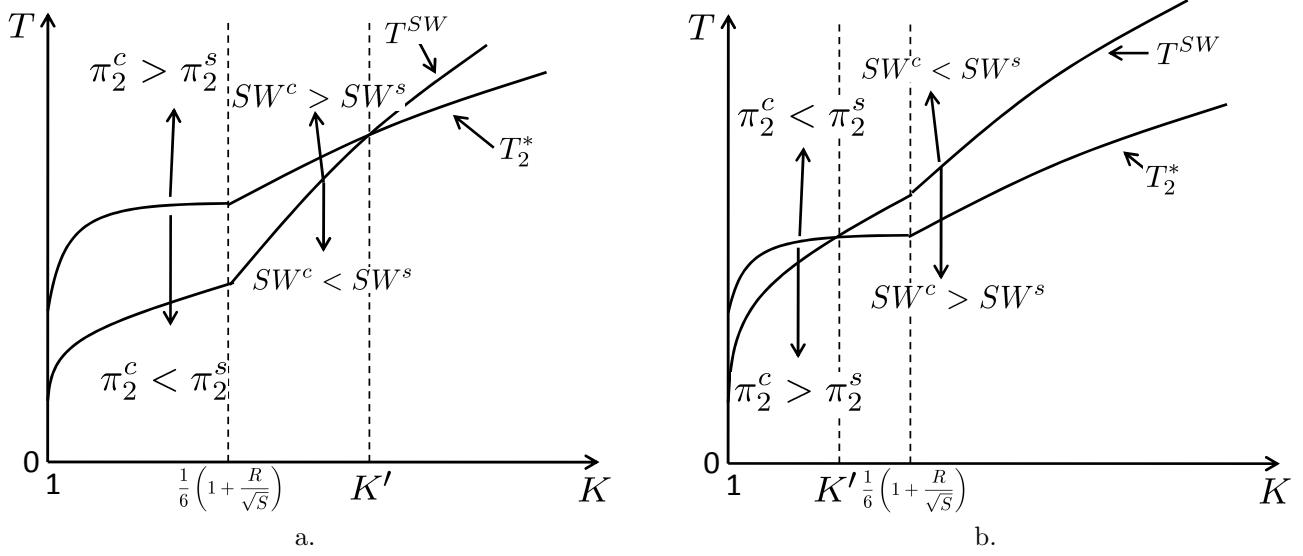


Figure 4: Comparison of profit maximization with the socially preferable hub location

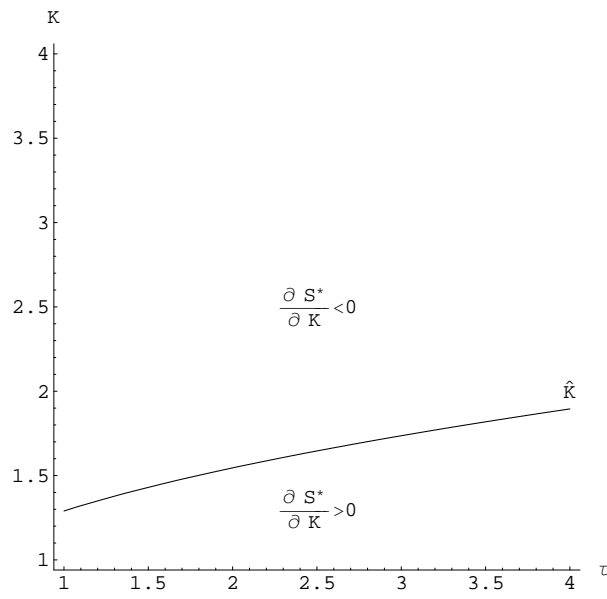


Figure 5: The outcome of comparative static analysis of  $S^*$

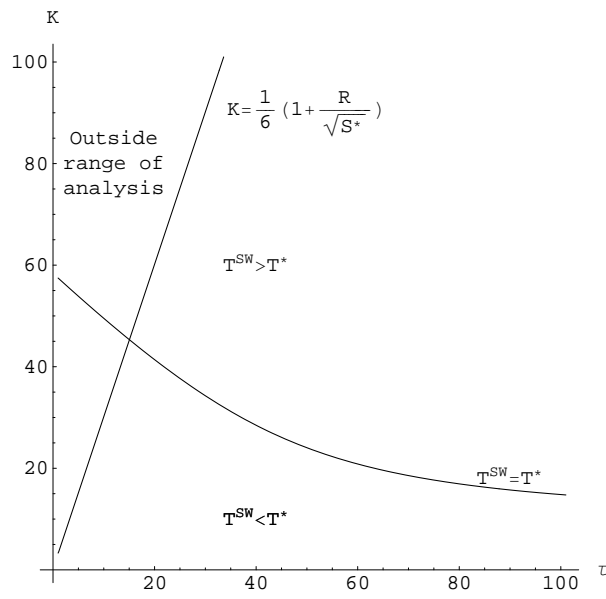


Figure 6: Comparison of  $T^*$  with  $T^{SW}$