Entry Airport Selection: Slot-constrained Congested Airport versus Secondary Airport [1]

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Abstract

This paper investigates whether a new carrier decides to enter a slot-constrained congested airport or a secondary airport located far from the city center using a very simple model. In addition, this paper analyzes the slot allocation to maximize social welfare. Then, under the slot allocation that maximizes social welfare, we analyze whether or not the new carrier enters the congested airport.

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

Keywords: congested airport, secondary airport, slot allocation.
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1 Introduction

In recent years, major airports across the globe have begun experiencing congestion issues due to the limited availability of slots. In addition, some argue that slot constraints deter new carriers. For example, Dresner et. al. (2002) study three major airports in America, and empirically show that the limitation in airport capacity deters new carriers.

The field of economics mainly handles such problems as congestion tax problems often analyzed in the field of transportation economics. For example, Brueckner (2002) argues that the traditional Pigouvian congestion charge, which equals the marginal external cost imposed on all flights, is excessive for an airline with market power. Following his work, Brueckner (2005), Pels and Verhoef (2004), Zhang and Zhang (2006), Morrison and Winston (2007), Brueckner (2009), etc., discuss airport congestion problems. Recently, Flores-Fillol (2010) synthetically treats these problems, and analyzes some interesting issues, for example, how the number of routes or airport capacity influence congestion.

At hub airports, congestion is even more intensified. Given this situation, in some countries, new carriers have recently started entering uncongested secondary airports, instead of congested major airports. However, in Japan, the situation is somewhat different from the other countries. For example, Ibaragi Airport was opened on March 11, 2010. This airport is expected as an alternative airport to the congested Haneda Airport and Narita Airport. However, at present, from the Ibaragi Airport, only Skymark Airlines flies to Kobe Airport in the domestic market[3] and only Asiana Airlines flies to Seoul in the international market[4]. As such, the airport seems to be in dire straits.

When new carriers enter a congested airport, they need an allocated slot to commence operations. However, since the congested airport has a limited number of slots for distribution, new carriers rarely operate from congested airports. In addition, because of congestion, airport prices are very high, and this leads to increased operating cost.

If new carriers enter secondary airports, they will not suffer from slot constraints. In addition, airport prices too are lower in secondary airports. However, at the same time, secondary airports are generally located away from the city center. Consequently, access from secondary airports to the city is usually lacking as compared to that from congested airports. Considering this trade-off, what is the required condition for a new carrier to enter a secondary airport?

Recent years have seen progress in the research on the entry routes of new carriers. Lin and Kawasaki (2010) use a product differentiation model with price competition to discuss whether the new carrier (in particular, a regional airline) enters a hub route or a non-hub route. They demonstrate that the new carrier has a strong incentive to enter a non-hub route to avoid tough competition. Kawasaki and Lin (2010)

[3] In addition, Skymark Airlines plans to fly to Sapporo and Central Japan int. Airport.
[4] In addition, Asiana Airlines plans to fly to Busan.

introduce a Cournot-type schedule competition model and analyze a problem similar to that in Lin and Kawasaki (2010). They argue that when the cost difference between incumbent carriers and low-cost carriers (LCCs) is small (large), the incentive for the LCCs to enter a hub (non-hub) route strengthens with the incumbent carriers' operating cost.

Here, it should be noted that these two papers ignore slot constraints due to congestion, which is a very important factor for new carriers when they are deciding entry routes. Therefore, they cannot discuss the entry route problem when a hub airport is congested. In addition, the previous studies on the congestion problem deal with the problems of airport prices and capacity, but do not consider the use of secondary airports. As such, this paper assumes that the authority is unable to distribute enough slots to the new carriers because of congestion, and analyzes whether the new carriers enter a slot-constrained congested airport or an uncongested secondary airport. In addition, we analyze which airport is better for the new carriers in terms of social welfare.

In what follows, this paper assumes that entry to the slot-constrained congested airport is socially preferable, and analyzes the distribution of slots to new carriers. In particular, it is assumed that slot allocation by the authority does have a certain cost. Under the slot distribution by the authority to maximize social welfare, this paper analyzes whether or not the new carrier enters the slot-constrained congested airport[5].

This paper demonstrates the following. When the distance between the secondary airport and the city center is large (small), the new carrier enters the slot-constrained congested airport (secondary airport). The higher the operating cost to enter the slot-constrained congested airport, the stronger the incentive of the new carrier to enter the secondary airport. In particular, when the available slots for new carriers are limited, this incentive is very strong.

When the distance between the secondary airport and the city center is large, if the new carrier enters the secondary airport, the disutility of the passengers using the new carrier becomes large. Consequently, as the passengers do not enjoy better convenience, they prefer the incumbent airline entering the congested airport. As a result, the profit of the new carrier entering the secondary airport decreases.

Conversely, when the distance is small, even if the new carrier enters the secondary airport, it is able to provide better convenience to offset the disutility from the increase in the travel time cost. Consequently, the passengers prefer the new carrier entering the secondary airport, which increases the new carrier's profit.

Further, when the cost difference between entering the congested airport and entering the secondary

[5]There are many papers on the slot allocation problem, such as Basso and Zhang (2010), Sieg (2010), Madas and Zografos (2006), Hong and Harker (1992), and de Wit and Burghouwt (2008). However, it is noteworthy that not all studies consider the existence of a secondary airport.

airport is small (large), the new carrier has an excessive incentive to enter the secondary (congested) airport. When the cost difference is small, even if the new carrier enters the congested airport, it can provide better convenience. Consequently, from the viewpoint of social welfare, passengers' travel time cost should not increase when the carrier enters the secondary airport. However, the new carrier can provide better convenience by entering the secondary airport. In addition, better convenience becomes a competitive advantage for the new carrier. As a result, the new carrier has an excessive incentive to enter the secondary airport.

Conversely, when the cost difference is large, entering the secondary airport is more convenient for the passengers. On the other hand, due to the increase in travel time cost, the new carrier's competitive advantage weakens. Therefore, though convenience is sacrificed, the new carrier enters the congested airport to save passengers' travel time cost. As a result, the carrier has an excessive incentive to enter the congested airport.

The analysis of the slot allocation problem to maximize social welfare demonstrates the following[6]. If the marginal cost for slot allocation is small, the new carrier enters the socially preferable airport (that is, the congested airport) because it can obtain enough slots. Otherwise, since it is unable to obtain enough slots, 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 the new carrier enters the congested airport is derived. Here, we analyze two cases: one where slots are restricted and the other where slots are available. Section 4 derives the outcome when the new carrier enters the secondary airport. Comparing the outcomes of sections 3 and 4, section 5 analyzes whether the new carrier enters the congested airport or the secondary airport. In section 6, we derive the social welfare when the carrier enters the congested airport and when it enters the secondary airport, and compare the two. Then, we conclude whether it is socially preferable for the new carrier to enter the congested airport or to enter the secondary airport. In section 7, assuming that it is socially preferable to enter the congested airport, we analyze the slot allocation problem to maximize social welfare. Following this, under the slot allocation to maximize social welfare, we examine whether or not the new carrier enters the congested airport. Section 8 concludes.

2 Model

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

The airport near the city center suffers from congestion because of capacity constraints-limited slots.

[6]Note that this analysis assumes that entering the congested airport is socially preferable to entering the secondary airport.

Therefore, in order to enter this congested airport, the new carrier must receive slots from the authority. The airport located away from the city center does not suffer from congestion. Therefore, the new carrier can freely enter this secondary airport.

City B is assumed to be a local city. As a reasonable assumption, the city has only one airport that is not congested. Therefore, the new carrier can operate freely from this airport.

The incumbent, Airline 1, already operates its flights between the congested airport in city A and the airport in city B. Here, we assume that Airline 1 has enough slots for its operations between the two cities. The entrant, Airline 2, plans to enter this market. 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 flights is limited to S because of the limited availability of slots. Here, we assume that if the frequency of Airline 2 flights between the congested airport and the local is less than S, the company can serve other cities that are not included in this analysis.

When passengers use an airline entering the congested airport, they can enjoy better accessibility. On the other hand, when they use an airline entering the secondary airport, they have to travel between the secondary airport and the city center. In such a case, they are assumed to incur an additional travel time cost T, which is a disutility for each passenger.

Airline i (= 1, 2) flies between cities A and B f_i times a day. When each airline uses the congested airport, it must pay a higher airport charge than when entering the secondary airport; in other words, each airline is expected to pay a congestion charge that is decided exogenously. Therefore, we assume that the operational cost of an airline entering the congested airport is K_H, and that of an airline entering the secondary airport is K_L. Here, it is assumed that $K_H \geq K_L$. In what follows, the cost per passenger is assumed to be constant and zero. It is noted that this assumption does not result in a loss of the important characteristics of the economies of density[7]. Hereafter, without loss of generally, we assume that $K_L = 1$ and $K_H = K$ (≥ 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 the reduction in schedule delay.

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

The waiting time for the passengers using an airline decreases when the airline increases its flight frequency so that each passenger can enjoy better convenience; this gives that the passengers' benefits increase as the flight frequency increases[8]. Hereinafter, following Kawasaki and Lin (2010), we call this

[7]For the cost function including the economies of density, see Brueckner (2004).

[8]This assumption has been made by a number of airline studies. See Oum et. al. (1995), Brueckner (2004), Brueckner and Flores-Fillol (2007), and Kawasaki (2008).

the “scheduling effect” and represent the reduction in 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 given as

$$Ui = \begin{cases} r+\sqrt{fi}-p_i & \text{if traveling via the congested airport} \\ r+\sqrt{fi}-T-p_i & \text{if traveling via the secondary airport:} \end{cases} \tag{1}$$

If a passenger does not use the airline service, his/her utility becomes zero. Consequently, only the passenger who gains a negative utility when using the airline service, does not use it.

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

3 Case of the Entrant Entering the Congested Airport

This section analyzes the case of Airline 2 entering the congested airport. Since both airlines enter the congested airport, their profit functions are given as

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

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

Here, it should be noted that Airline 2 suffers from a restriction on the number of flights, that is, $f_2 \leq S$. Considering this restriction, we solve the profit maximization problem. As a result, we obtain the following reaction functions:

$$q_1 = -\frac{1}{2}q_2 + \frac{1}{2}\left(R+\sqrt{f_1}\right), \tag{4}$$

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

$$q_2 = -\frac{1}{2}q_1 + \frac{1}{2}\left(R+\sqrt{f_2}\right), \tag{6}$$

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

Solving this system, we determine the number of flights and demand, respectively, as follows:

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

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

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

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

Substituting these outcomes into the airlines' respective profit functions, we obtain their profits as follows:

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

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

4 Case of the Entrant Entering the Secondary Airport

This section analyzes the case of Airline 2 entering the secondary airport. Since Airline 1 enters the congested airport and Airline 2 enters the secondary airport, their profit functions are given as

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

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

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

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

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

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

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

Solving this system, we determine the number of flights and demand, respectively, as follows:

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

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

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

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

Substituting these outcomes into the airlines' respective profit functions, we obtain their profits as follows:

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

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

5 Selection of the Entry Airport

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

5.1 Comparison of Airline 1's outcomes

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

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

Here, the parameter T_1^* is defined as follows (see Fig. 1):

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

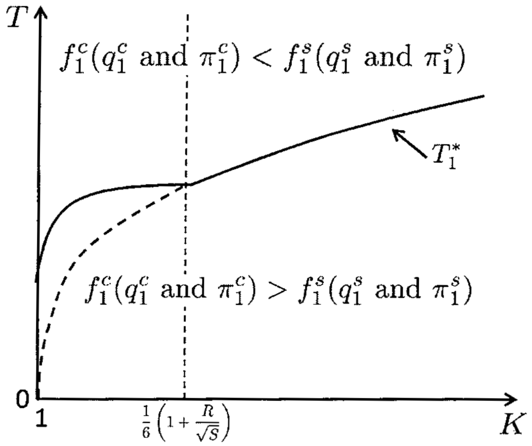

Figure 1: Comparison of Airline 1's outcomes

In Fig. 1, the dotted line expresses the values for which $f_1^C = f_1^S$ holds when Airline 2 does not face any slot restrictions in the range $K \leq \frac{1}{6}\left(1+\frac{R}{\sqrt{S}}\right)$. Consider the case where the distance between the secondary airport and the city center is large. When Airline 2 enters the secondary airport, the passengers using Airline 2 incur a heavy traveling cost. Therefore, they prefer Airline 1 that grounds near the city center. This increases Airline 1's demand, allowing it to increase its flight frequency, and consequently, its profit.

Conversely, consider the case where the distance is small. When Airline 2 enters the secondary airport, although the passengers using Airline 2 incur an additional travel time cost, they enjoy better convenience because of the high frequency of Airline 2's flights. Consequently, they prefer Airline 2 to Airline 1, which decreases Airline 1's demand. Further, the reduction in passengers leads to a decrease in Airline 1's flight frequency and profit.

Here, Fig. 1 shows that the range wherein Airline 1's outcomes in the congested airport entry case are larger than those in the secondary airport entry case increases with the operational cost K. In addition, from Fig. 1, we obtain the following lemma.

Lemma 1 *When the Airline 2's fight frequency is limited, the range wherein Airline 1's outcomes in the congested airport entry case are larger than those in the secondary airport entry case increases.*

When Airline 2 enters the congested airport, the passengers' convenience from using Airline 2 worsens as compared to when Airline 2 enters the secondary airport. Consequently, Airline 1's demand increases. On the other hand, when Airline 2 enters the secondary airport, it can operate without any limitations. Therefore, the passengers' convenience from using Airline 2 improves, and Airline 2's demand increases. In other words, Airline 1's demand decreases. Summarizing the above discussions, we can say that when Airline 2 enters the congested airport, Airline 1's demand is larger than when it enters the secondary airport. As a result, Lemma 1 holds.

5.2 Comparison of Airline 2's outcomes

This subsection compares Airline 2's outcomes in the congested airport entry case and in the secondary airport entry case. In what follows, we analyze whether Airline 2 enters the congested airport or the secondary airport. First, the comparison of Airline 2's outcomes in the congested airport entry case and in the secondary airport entry case reveals Proposition 2.

Proposition 2 *When Airline 2 is constrained with regard to the number of fights, 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 constrained with regard to the number of fights, 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 its flight frequency owing to the lower marginal operational cost, and thus increase the number of passengers using its services. On the other hand, entering the secondary airport results in the disutility T for the passengers of Airline 2, which decreases Airline 2's demand. Consequently, entering the secondary airport represents a trade-off; the merit lies in increasing the convenience of Airline 2's passenger, and the demerit lies in the resultant increase in the additional travel time cost T.

Consider the case where T is large. When Airline 2 enters the secondary airport, passengers prefer Airline 1 to Airline 2 even though Airline 2 can operate more flights. As a result, the demand for Airline 2 decreases, as compared to in the congested airport entry case. In addition, this decreases Airline 2's flight frequency.

Consider the case where T is small. Although Airline 2's passengers incur an additional travel time cost when Airline 2 enters the secondary airport, Airline 2 is more attractive for them because it operates more flights. Therefore, passengers prefer Airline 2 to Airline 1. As a result, the demand for Airline 2 in the secondary airport entry case is larger than that in the congested airport entry case. In addition, this increases Airline 2's flight frequency.

When comparing Airline 2's profits in the congested airport entry case and in the secondary airport entry case, we obtain Proposition 3.

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

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

Fig. 2 expresses the result of Proposition 3.

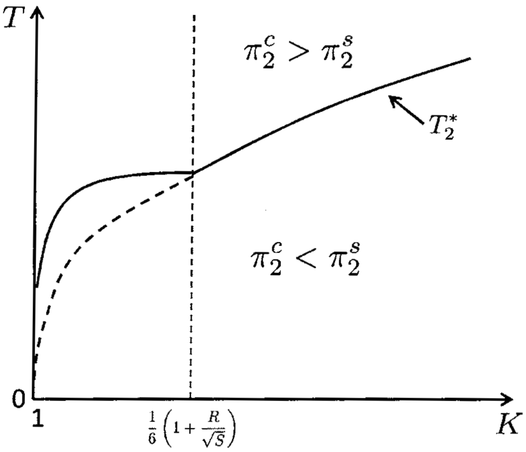

Figure 2: Airline 2's choice of the entry airport

In Fig. 2, the dotted line expresses the values for which $\pi_2^C = \pi_2^S$ holds when Airline 2 is slot constrained in the range $K \leq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right)$. As mentioned in Proposition 2, when the additional travel time cost is high, if Airline 2 enters the secondary airport, it loses many passengers. As a result, although its operational cost increases, Airline 2 enters the congested airport to ensure that the passengers do not incur an additional travel time cost. This increases Airline 2's profit as compared to in the secondary airport entry case.

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

From Fig. 2, we can also realize that Airline 2's incentive to enter the secondary airport strengthens as K increases. This is because an increase in K improves the convenience of the passengers of Airline 2 when it enters the secondary airport, which in turn increases Airline 2's flight frequency. In addition, Fig. 2 gives us the following lemma.

Lemma 2 *Airline 2's incentive to enter the secondary airport strengthens when it is slot constrained.*

When Airline 2 is slot constrained and enters the congested airport, it loses the opportunity to earn more profit due to its lower flight frequency. On the other hand, if Airline 2 enters the secondary airport, it can operate freely and increase its profits. As a result, Airline 2's incentive to enter the secondary airport strengthens.

6 Social Welfare

This section first derives the social welfare in the congested airport entry case and in the secondary airport entry case, and then compares the two to 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 in the congested airport entry case and in the secondary airport entry case. The social welfare function is defined as follows:

$$SW = CS + \pi_1 + \pi_2. \tag{27}$$

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

Substituting the equilibrium values in the congested airport entry case and in the secondary airport entry case into the above social welfare function, we get the social welfare as

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

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

A comparison of the social welfare in the congested airport entry case and in the secondary airport entry case yields 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:*

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

Fig. 3 expresses Proposition 4.

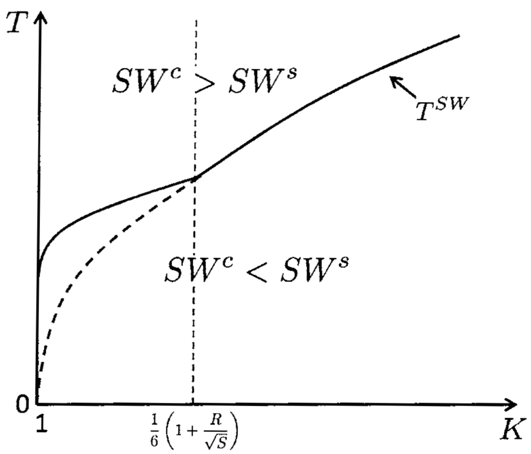

Figure 3: Socially preferable entry airport

In Fig. 3, the dotted line expresses the values for which $SW^c = SW^s$ holds when Airline 2 is slot constrained in the range $K \leq \frac{1}{6}\left(1 + \frac{R}{\sqrt{S}}\right)$. When T is small and Airline 2 enters the congested airport, its flight frequency decreases due to the higher operational cost. As a result, the convenience of Airline 2's passengers worsens. In order to ensure that the convenience of Airline 2's passengers remains high and to attract more passengers, Airline 2 should enter the secondary airport, which is socially preferable.

When T is large and Airline 2 enters the secondary airport, the passenger using Airline 2 incurs a large disutility from the additional travel time cost, which decreases the demand for Airline 2. As a result, though flight frequency can increase because of lower operational costs, flight frequency actually decreases as compared to the congested airport entry case, since most passengers move to Airline 1. This decrease in flight frequency worsens the convenience of Airline 2's passengers. 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 or not the market equilibrium derived in section 5 is socially preferable. Summarizing the figures to express the market equilibrium and to express the socially preferable entry airport into one, we obtain Fig. 4.

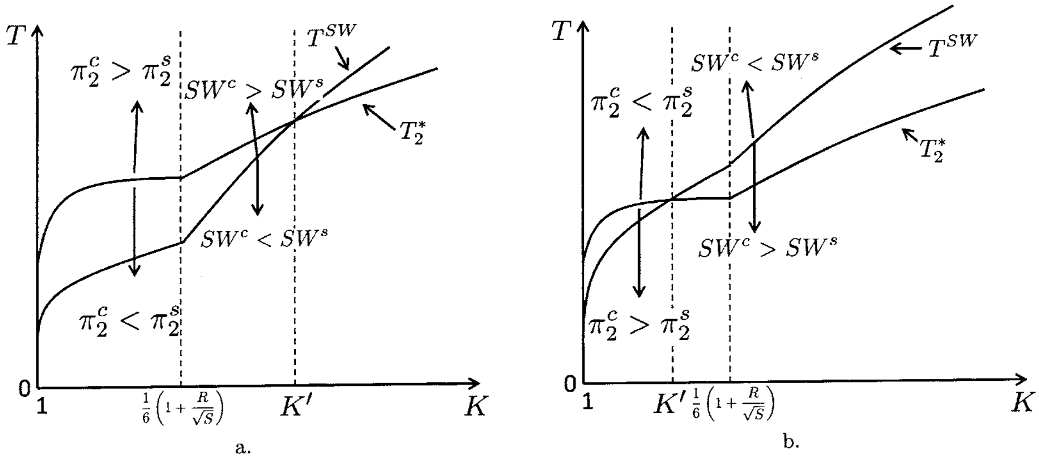

Figure 4: Comparison of market equilibrium and socially preferable entry airport

Fig. 4 gives us Proposition 5.

Proposition 5 *When the operational cost of flying 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 yields the following lemma.

Lemma 3 *When many slots are allocated to Airline 2, Airline 2 has an excessive incentive to enter the secondary airport in the range where it is imposed on the slot constraint. 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 constraint.*

Even when K is small, Airline 2 has an incentive to enter the secondary airport to strengthen its competitive power by increasing its flight frequency. However, from the viewpoint of social welfare, the social benefit from the increase in flight frequency by entering the secondary airport is small. In fact, the social cost from the additional travel time cost incurred by Airline 2's passengers is large. As a result, Airline 2's incentive to enter the secondary airport is socially excessive.

When K is large, Airline 2 plans to enter the secondary airport. However, doing so would result in the additional travel time cost T for its passengers. When T is large and Airline 2 enters the secondary airport, passengers begin preferring Airline 1, which weakens Airline 2's competitive power. Consequently, Airline 2 wants to enter the congested airport. However, from the viewpoint of social welfare, even when T is somewhat large, if Airline 2 enters the secondary airport, the convenience of its passengers 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 so that its passengers do not have to incur an additional travel time cost. This results in the excessive incentive to enter the congested airport.

7 Slot Allocation

Section 6 demonstrated that whether or not Airline 2's incentive to enter the congested airport is socially excessive depends on both the operational cost and the slot allocation (Lemma 3). Given that the slots allocated 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 wherein the authority distributes the slots to maximize social welfare.

7.1 Number of slots allocated to Airline 2

Social welfare when Airline 2 enters the congested airport is derived in eq. (28). The authority distributes the slots to maximize social welfare. Here, it is assumed that allocating one slot to Airline 2 incurs a cost τ, since the authority must adjust the flight schedule, revise the way of control, etc. 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 social welfare. As a result, the number of slots allocated 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 $T \geq T^{SW}$ 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.

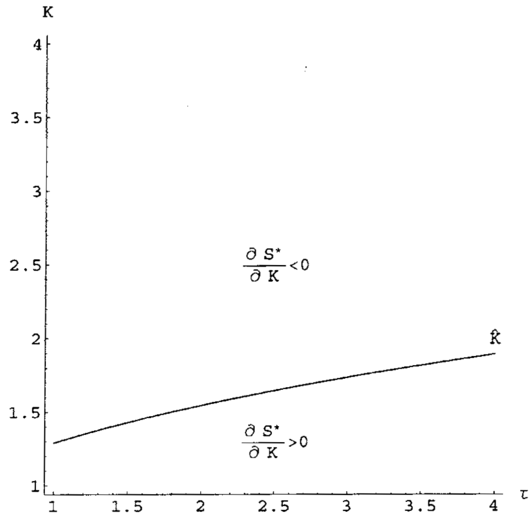

Figure 5: Comparative static analysis of S^*

Here, we consider the change in marginal social welfare when the number of slots allocated to Airline 2 is revised. When K increases, the flight frequency of Airline 1 decreases, which worsens the convenience of Airline 1's passengers. Given this situation, if the number of slots allocated to Airline 2 increases, overall passenger convenience may improve since passengers will shift from Airline 1 to Airline 2 for better convenience. Consequently, as K becomes large, the marginal consumer surplus derived from the increase in the number of slots allocated to Airline 2 becomes large. In addition, because Airline 2 increases its flight frequency, Airline 1's flight frequency decreases[9], which decreases the operational cost of Airline 1. As a result, Airline 1's profit increases.

On the other hand, as the number of slots allocated to Airline 2 increases, the operational cost of Airline 2 also increases. If K is small (large), the rise in Airline 2's operational cost because of the increase in the number of slots allocated to it is small (large). Consequently, comparing the increases in marginal consumer surplus derived from Airline 1's profit and from Airline 2's operational cost, we get that if K is small and the increase in Airline 2's operational cost is small, the marginal benefit from the increase in the number of slots allocated to Airline 2 becomes large as K increases. Conversely, if the increase in Airline 2's operational cost is large, the marginal benefit becomes small as K increases.

[9]We note that the relationship between the flight frequencies of Airline 1 and Airline 2 is that of strategic substitution.

By the above-mentioned mechanism, for any range of K, when K increases, the number of slots allocated to Airline 2 to maximize social welfare decreases.

7.2 Airline 2's entry into the congested airport

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

When Airline 2 enters the congested airport, its profit is

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

Here, S^* denotes the slot allocation that maximizes social welfare. Comparing Airline 2's profits in the congested airport entry case and in the secondary airport entry case, we get that if $T \geq T^*$, Airline 2 enters the congested airport.

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

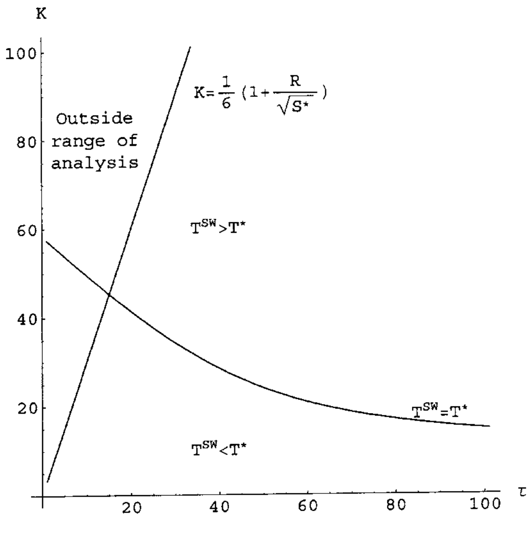

Figure 6: Comparison of T* and T^{SW}

Proposition 6 *In the range $T^{SW} \geq T^*$, that is, when K is large, Airline 2 enters the congested airport. In the range $T^{SW} < T^*$, that is, when K is small, it has an incentive to enter the secondary airport. In addition,* *as increases, the latter range 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. Under the situation wherein the authority distributes the slots to maximize social welfare, there exists the possibility of Airline 2 entering the secondary airport. In other words, because Airline 2's incentive to enter the secondary airport is stronger than the socially preferable level, an inefficient outcome is realized.

As τ becomes large, the number of slots allocated to Airline 2 decreases. Therefore, Airline 2's incentive to enter the secondary airport where it can operate more flights strengthens. In other words, Airline 2's incentive to enter the congested airport becomes small.

These results show that the authority must distribute the slots considering the probability of a new carrier entering the secondary airport. If the authority overlooks this probability, social inefficiencies occur.

8　Concluding Remarks

This paper analyzed the new carrier's choice of an entry airport – the slot-constrained congested airport or the secondary airport located away from the city center–using a very simple framework. This paper demonstrated the following. If the distance between the secondary airport and the city center, that is, the additional travel cost, is large (small), the new carrier enters the congested (secondary) airport. Further, as the operational cost to enter the congested airport is high, the new carrier's incentive to enter the secondary airport strengthens.

Then, when the cost to enter the congested airport is small (high), the new carrier has an excessive incentive to enter the secondary (congested) airport. In addition, when the number of slots allocated to the new carrier is decided to maximize social welfare, the new carrier may not enter the socially preferable congested airport.

This paper analyzes the entry airport chosen by the new carrier using a two-cities model. However, an actual airline network links multiple cities (and airports). In addition, since many airlines use hub–spoke networks, we should not ignore the existence of connecting passengers. If we include connecting passengers in our model and increase the number of routes serviced by the incumbent carrier, the flight frequency of the incumbent carrier increases. Then, the new carrier's competitive power decreases. As a result, if the cost of entering the congested airport is large, the new carrier's incentive to enter the secondary airport strengthens for it seeks to increase its flight frequency. Conversely, if the cost is small, the new carrier's incentive to enter the congested airport weakens for it wants to decrease its passengers' additional travel cost. Consequently, even if we relax the assumption of two cities and no connecting passengers, the main results obtained in this paper almost hold.

We now discuss the limitations of this paper. This paper does not consider congestion pricing in a detailed slot allocation problem. These problems will be very important for policy makers. In the previous studies on the airport pricing problem, the existence of a secondary airport is not considered. If the authority imposes congestion pricing, the new carrier (incumbent carrier) may enter the secondary airport, which may increase the passengers' additional travel cost. Consequently, we must analyze the congestion pricing problem considering the existence of a secondary airport.

Next, this paper assumes that the incumbent carrier has enough slots for full-fledged operations. On the other hand, the new carrier suffers from slot constraints. Is this situation socially preferable? In the future, we must analyze the allocation of slots between the incumbent carrier and the new carrier.

Finally, recently, it was argued that authorities have constructed too many airports. Here, we need to consider the airport near a congested airport as a secondary airport. For example, do the New Kitakyushu Airport and Saga Airport that are located near the congested Fukuoka Airport play the role of a secondary airport?

These are very important problems that need to be considered in the future research from the viewpoint of airport policy.

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