Who should own component airports?*

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Abstract

This paper investigates who should own airports; national government or local government. This paper assumes that there are two types of component airports. These airports charge an airport price to carriers to maximize (1) national social welfare when the airport is owned by the national government, or (2) local social welfare when it is owned by the local government. In addition, it is assumed that when the airport is owned by the national government, the cost of managing the airport is higher than when it is owned by the local government.

Using a simple model, this paper demonstrates the following. When the cost difference between the national-ownership and local-ownership airports is small, it is socially preferable that one airport is owned by the central government and the other is owned by the local government. When the costs difference is large, it is socially preferable that each airport is owned by its respective local government.

Keywords: national ownership airport, local ownership airport, airport pricing.

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1 Introduction

In recent years, studies on airport pricing have been aggressively pursued. This is because major airports suffer from congestion. Under this situation, some prescriptions to airport congestion have been proposed by many papers. One way is congestion tax. Congestion is an external diseconomy. Therefore, we believe that the Pigouvian tax will improve social welfare under congestion. The other way is slot trading. We also think that it is socially preferable that the carriers exchange slots for money. That is, a carrier for whom the value of an airport slot is low sells the slot to another carrier for whom the value of the slot is high. With regard to slot trading, Brueckner (2009) and Verhoef (2010) are the recent representative papers.

Slot auctions are another way of dealing with the congestion problem. We realize that an efficient resource allocation can be realized by using an auction. This can also hold in airline slot markets. Brueckner (2009) and Basso and Zhang (2010) analyze the slot auction problem[1].

The representative paper on airport congestion pricing is Brueckner (2002)[2]. Brueckner (2002) argues that the traditional Pigouvian congestion pricing is excessive for an airline with market power. This is because an airline can partially internalize congestion. Brueckner (2002) was followed by multiple papers on airport pricing. For example, Brueckner (2005) introduces the factor of network structure and analyzes the airport congestion pricing. As a result, he demonstrates that the airport charge must be equal the congestion from an extra flights times one minus the carrier's airport flight share. Here, we note that this conclusion argues that an airline can internalize some of the congestion effects. Brueckner and Van Dender (2008) also demonstrate that because airlines can internalize some congestion, congestion pricing should be lower than the traditional congestion pricing. In addition, Flores-Fillol (2010) considers some factors affecting congestion and shows some interesting results.

We particularly focus on one of the preceding works: Pels and Verhoef (2004). They take note of the fact that Brueckner (2002) do not consider airline scheduling. Therefore, Brueckner's (2002) congestion pricing does not contain the market power effect. Pels and Verhoef (2004) criticize this point, and show

[1] With regard to the slot allocation, there exist some papers. Madas and Zografos (2006) and Sieg (2010) are among the examples.

[2] Zhang and Zhang (2006) is also one popular paper about the airport congestion pricing.

that if the market power effect is ignored, the introduction of congestion airport pricing worsens social welfare under certain conditions.

In addition, Pels and Verhoef (2004) are concerned with the manner of regulation, that is, cooperation to maximize joint welfare (policy coordination) and form of tax competition (policy competition). They show that both policies yield similar results.

Further, in the previous studies on airport pricing including the ones mentioned, the factor of the complement of airports has been ignored. That is, carriers must use two complementary airports when supplying their airline services[3]. Then, if both airports used by the carriers are congested, each carrier will have to pay the airport charge when it takes-off from a congested airport and lands in another congested airport and vice versa[4]. Considering the above probability, it is natural to consider that both airports' pricing influences the airline's strategy. However, in the previous studies, only one airport's pricing is considered.

In addition, when the ownership of the airport is different, the objective function to decide the airport charge is also different. For example, in Japan, there are three type of airports: national-ownership airports (owned by the national government), local-ownership airports (owned by local governments), and private airports. In Japan, almost all airports are national-ownership or local-ownership airports. More importantly, in national-ownership airports, the national government decides the airport pricing; in local-ownership airports, the corresponding local governments decide the airport pricing.

In the previous studies, the airport charge was decided to maximize total welfare. As such, this paper considers two ownership patterns: national ownership and local ownership. In a national-ownership airport, the national government decides the airport charge to maximize total social welfare. In a local-ownership airport, the corresponding local government decides the airport charge to maximize local social welfare. Considering the complementary of airports, the difference in airport ownership may yield unexpected inefficiencies. Moreover, we do not consider private airports. With regard to airport privatization, see Vasigh and Mehdi (1996), Zhang and Zhang (2003), Fu, et al. (2006), Basso (2008), Matsumura and Matsushima (2010), etc.

[3]Matsumura and Matsushima (2010) introduce this factor and analyze the airport privatization problem.

[4]For example, Fukuoka and Haneda Airports are a pair of congested airports in Japan.

In this paper, the airport pricing problem is analyzed using a two-region model where two carriers compete in flight frequency and quantity. It is assumed that when the national government owns and manages the airport, the managing cost is higher than that when the local government owns and manages it. Then, we consider three cases: both airports (namely, airport 1 and airport 2) are owned by the national government (NN), one airport (namely, airport 1) is owned by the national government and the other (namely, airport 2) is owned by the local government (NL), and the final case is that each local government owns respective airports (LL). Given these situations, this paper derives the airport charge, the airport profits, the airline profits, the social welfare, and the regional welfare in respective case. Then, we compare each outcome with each case. Then, comparing the social welfare, we conclude which case is socially preferable. Finally, comparing the welfare of each region in each case, we present the influence of the airport ownership pattern on regional welfare.

This paper demonstrates the following. With regard to airport 1's pricing, when the managing cost under national ownership is small, the airport charge for LL is the highest and that for NL is the lowest. When the managing cost becomes slightly larger, the airport charge for NN is higher than that for LL. When the managing cost increases even further, the airport charge for NL is higher than that for LL. When the managing cost is very large, the airport charge for NL is the highest and that for LL is the lowest. With regard to airport 2's pricing, the following conclusions are obtained. When the managing cost is small, the airport charge for NN is the lowest and that for NL is the highest. When the managing cost increases, the airport charge for NN is higher than that for LL. Then, when the managing cost increases even further, the airport charge for NN is higher than that for NL. When the managing cost is very large, the airport charge for NN is the highest and that for NL is the lowest.

Next, we analyze the airports' profits. At airport 1, when the managing cost under national ownership is small, the profit for NN is the highest and that for NL is the lowest. When the managing cost is moderate, the profit for LL is the lowest. When the managing cost is high, the profit for NN is the lowest. At airport 2, when the managing cost is small, the profit for NL is the highest and that for LL is the lowest. When the managing cost is moderate, the profit for NN is the lowest. When the managing cost is large, the profit for LL is the highest. When the managing cost increases further, the profit for

NL becomes the lowest.

Finally, we compare the social welfare for the three cases. When the managing cost is small, NL is socially preferable; when it is large, LL is socially preferable. In addition, in the range where NL is socially preferable, region 1's welfare is the lowest and region 2's welfare is the highest. In the range where LL is socially preferable, region 1's welfare is the highest among three cases. In region 2, if the managing cost is moderate, LL is not preferable, and if it is high, LL is preferable.

This paper makes the following contributions to the existing literature. First, introducing the component relationship of an airport, we obtain that the airport charge is strategic substitute. From this relationship, we can conclude that the airport charge obtained in the previous studies is excessive. Second, this paper considers some patterns of airport ownership, which are not analyzed in the previous studies. As a result, we are aware that when the national government's management of an airport is somewhat inefficient (that is, incurring a somewhat higher managing cost), the local government should manage at least one airport. This is because, only when there exists one national-ownership airport, can the inefficiency from the local-ownership airports can be internalized. However, if the management cost incurred by the national government is very large, all airports should be managed by local government. Finally, analyzing social welfare, we can prove that the socially preferable airport ownership pattern sometimes worsens welfare in one region. Consequently, the national government must attend to the concerns between regions when the pattern of airport ownership changes.

This paper is organized as follows. The following section presents a model for airport pricing. In section 3, the strategies of a competitive airline are derived. Given these results, section 4 derives the airport pricing in each case. In section 5, the outcomes (airport charge, airline profit, and airports' profit) in each case are compared. In section 6, we compare the social welfare for each case and conclude which ownership is socially preferable. Section 7 analyzes the social welfare of each region, and discusses whether the national government's decision is preferable for each region. Section 8 presents the conclusions and directions for future research.

2 Model

There are two regions in one country. We refer to them as region 1 and region 2. In each region, there is one congested airport; we refer to region j's airport as airport j $(j = 1, 2)$. There are two airlines: Airline A and Airline B. Each airline flies from region 1 to region 2 and back f_i $(i = A, B)$ times per day.

Each airline must pay an airport charge when using the airport facilities. The airport charge is expressed as k_j. Because each airline uses the airport facilities f_i times, the total payment is $(k_1 + k_2)f_i$. In other words, each airport gains the airport charge $(f_A + f_B)k_j$.

Following Pels and Verhoef (2004) and Flores-Fillol (2010), this paper assumes that each airline incurs a congestion cost at each airport when it takes off from or lands at an airport. That is, when using airport j, each airline incurs the marginal congestion cost $2(f_A + f_B)$. Because each airline must use both airports 1 and 2, the total congestion cost is $4(f_A + f_B)f_i$ $(i = A, B)$. As each airline must pay the airport charge, its costs becomes $(k_1 + k_2 + 4(f_A + f_B))f_i$.

The following is with regard to the cost of managing an airport (airport management cost). When airlines use an airport, each airport incurs various costs. Here, we assume that these costs are different for national-ownership airports and local-ownership airports. Hereafter, we assume that the management cost when the national government owns an airport are higher than that when the local government owns it. Therefore, the airport management cost is expressed as follows:

$$C(f_A, f_B) = \begin{cases} c(f_A + f_B)^2 & \text{if the national government owns the airport,} \\ (f_A + f_B)^2 & \text{if the local government owns the airport.} \end{cases} \tag{1}$$

Here, $c \geq 1$ is presumed.

In each region, there exist many potential airline passengers. Each passenger gains a benefit from using the airline service. Following Brueckner (2004) and Kawasaki and Lin (2011), we assume that this benefit is the sum of the travel benefit and the reduction in the schedule delay cost.

We assume that the travel benefit derived from the flight service varies among passengers. Here, a passenger's travel benefit is expressed as r. The benefit r is assumed to be uniformly distributed over the interval $[-\infty, R]$ with density one.

The waiting time of passengers using an airline decreases when the airline increases its flight frequency. This provides a passenger with greater convenience; this implies that a passenger's benefits increase when the flight frequency increases[5]. Hereinafter, following Kawasaki (2007) and Flores-Fillol (2009), the reduction in the schedule delay is represented as αf_i. Further, in order to guarantee a positive demand (and price), we assume that $2 < \alpha < 5$.

On the other hand, when airline schedules are delayed due to congestion, a passenger incurs a disutility[6]. Therefore, this paper assumes that when airlines increase the flight frequency, a passenger's utility decreases because of the delay in schedule owing to congestion, which we refer to as congestion damage in Flores-Fillol (2010). In this paper, this congestion damage is expressed as $-(f_1 + f_2)$.

The airfare is expressed as p_i. As a result, the utility function of each region is

$$U_i = r + \alpha f_i - (f_1 + f_2) - p_i. \tag{2}$$

We assume that when a passenger does not use the airline, the utility becomes zero. Consequently, the passenger who gains a utility larger than zero uses the airline service.

Here, it is noteworthy that the passenger in each region has the same utility function. Consequently, we need not differentiate the utility function between regions. In addition, since both regions' passengers use an airline service, both airlines gain revenues from both regions' passengers.

This paper considers the following two-stage game. In stage 1, each airport decides its charge. In stage 2, given the airport charges, each airline simultaneously decides its flight frequency and quantity. Solving this game by backward induction, we derive the Subgame Perfect Nash Equilibrium.

[5]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).

[6]This assumption is in the line of Flores-Fillol (2010) and Brueckner and Van Dender (2008).

3 Airline's strategy

This section analyzes the strategies of each airline, that is, flight frequency and quantity. First, we derive the demand function. It is noteworthy that the demand function of regions 1 and 2 is the same. Therefore, without loss of generality, we derive region 1's demand function.

As mentioned in the model, only the passenger who gains a non-negative utility uses the airline service. In addition, for both carriers to be used by a passenger, $U_1 = U_2$ must hold. Here, it is noteworthy that the term $-(f_1 + f_2)$ is the same for each utility function. Therefore, defining $p_i - \alpha f_i \equiv \phi$, only the passenger for whom $r \geq (f_1 + f_2) + \phi$ uses the airline. Consequently, the demand function is

$$p_i = R + (\alpha - 1)f_i - f_j - (q_A + q_B)(i \neq j). \tag{3}$$

Therefore, the profit function of Airline i is

$$\pi_i = 2(R + (\alpha - 1)f_i - f_j - (q_A + q_B))q_i - (k_1 + k_2 + 4(f_A + f_B))f_i. \tag{4}$$

Solving the profit maximization problem by q_i and f_i, the Nash equilibrium is as follows:

$$f_i = \frac{3(k_1 + k_2) - 2(\alpha - 1)R}{2\alpha^2 - 6\alpha - 32}, \quad q_i = \frac{(\alpha - 2)(k_1 + k_2) - 12R}{2(\alpha^2 - 3\alpha - 16)}. \tag{5}$$

Substituting these outcomes into each profit function, we get the profit as

$$\pi_i = \frac{(k_1 + k_2)^2(-2\alpha^2 + 5\alpha + 16) + (\alpha^3 - 4\alpha^2 - \alpha + 16)(2k_2 + 1)R - 16(\alpha^2 - 2\alpha - 8)R^2}{2(\alpha^2 - 3\alpha - 16)^2}. \tag{6}$$

From the airline profit, we obtain following lemma:

Lemma 1 *When* $k_1 + k_2 \geq (<) \frac{\alpha^3 - 4\alpha^2 - \alpha + 16}{2\alpha^2 - 5\alpha - 16}$, *the profit of each airline decreases (increases) with the airport charge.*

In the following, we present the above intuitive interpretations. When the airport charge increases, the flight frequency decreases. As a result, the revenue decreases through the scheduling effect[7]. However, because of the reduction in congestion damage, an effect that increases the profit also exists. On the other hand, from the viewpoint of the airline's cost, as flight frequency decreases, the congestion cost also decreases. In addition, the total airport charge payment may also decrease. Consequently, the cost reduction effect exists.

Comparing these effects, when the total airport charge is low (high), if the airport charge increases, the decrease in profit through the scheduling effect is smaller (larger) than the increase in profit through the reduction in the cost and congestion damage from the higher (lower) flight frequency. As a result, the airline profit increases (decreases).

4 Airport charge

First, we must define welfare. Here, without loss of generality, it is assumed that each airline profit is equally divided into each region. Therefore, the welfare from the viewpoint of the national government is defined as follows:

$$W_n = \sum_{j=A}^{B} CS_j + \sum_{i=1}^{2} \pi_i + \sum_{j=A}^{B} \Pi_j. \tag{7}$$

Here, CS_j refers to the consumer surplus in region j and Π_j is airport j's profit. In the following, the welfare from the viewpoint of local government j is defined as

$$W_j = CS_j + \frac{\sum_{i=1}^{2} \pi_i}{2} + \Pi_j. \tag{8}$$

We analyze the following three cases:

(1) both airports are owned by the national government (NN);

(2) one airport is owned by the national government and the other is owned by the local government (NL);

(3) each airport is owned by its respective local government (LL).

[7] This term implies that a passenger's benefit increases with flight frequency. See Kawasaki and Lin (2010).

4.1 NN

In this case, the objective function for the national government is

$$W_n = (q_A + q_B)^2 + \pi_A + \pi_B + (k_1 + k_2)(f_A + f_B) - 2c(f_A + f_B)^2. \tag{9}$$

Here, it is noteworthy that the outcomes of f_i and q_i are as derived in section 3. In addition, since airports 1 and 2 are symmetric, we can assume that $k_1 = k_2 = k$ without loss of generality. Using this assumption and solving the above welfare maximization problem, the airport charge is

$$k_1^{NN} = k_2^{NN} = \frac{3((\alpha - 1)c + 2)}{-\alpha^2 + 4\alpha + 14 + 9c} R. \tag{10}$$

Consequently, we derive the flight frequency, demand, profit of each airline, profit of each airport, and social welfare. These are listed in table 1.

Table 1: Solutions for NN

Flight frequency	$f_A^{NN} = f_B^{NN} = \frac{\alpha-2}{-\alpha^2+4\alpha+9c+14} R$
Demand	$q_A^{NN} = q_B^{NN} = \frac{3(c+2)}{-\alpha^2+4\alpha+9c+14} R$
Airline profit	$\pi_A^{NN} = \pi_B^{NN} = \frac{2(-(3c+4)\alpha^2+(9c+10)\alpha+9c^2+30c+32)}{(-\alpha^2+4\alpha+9c+14)^2} R^2$
Airport profit	$\Pi_1^{NN} = \Pi_2^{NN} = \frac{2(\alpha-2)(c\alpha+c+6)}{(-\alpha^2+4\alpha+9c+14)^2} R^2$
Regional welfare	$SW_1^{NN} = SW_2^{NN} = \frac{4(c+2)}{-\alpha^2+4\alpha+9c+14} R^2$
Social welfare	$SW^{NN} = \frac{8(c+2)}{-\alpha^2+4\alpha+9c+14} R^2$

4.2 NL

In this subsection, we assume that the national government owns airport 1 without loss of generality. The national government decides the airport charge k_1 to maximize the welfare expressed in (9). Airport 2, which is owned by the local government, sets k_2 to maximize

$$W_2 = \frac{1}{2}(q_1 + q_2)^2 + \frac{\pi_1 + \pi_2}{2} + k_2(f_1 + f_2) - (f_1 + f_2)^2. \tag{11}$$

As a result, we can obtain following reaction functions:

$$k_1 = -k_2 + \frac{+(3+\alpha+(\alpha-1)c}{-2\alpha^2+8\alpha+37+9c}R, \tag{12}$$

$$k_2 = -\frac{2\alpha^2-8\alpha-46}{-5\alpha^2+17\alpha+94}k_1 + \frac{-\alpha^3+4\alpha^2+25\alpha-4}{-5\alpha^2+17\alpha+94}R. \tag{13}$$

From equations (12) and (13), we find that k_1 and k_2 are strategic substitutes. When k_i increases, the flight frequency of each airline decreases. Consequently, the welfare in region j (or the national welfare) decreases. In order to improve welfare, the local government of region j (or the national government) must lower the airport charge and let each airline increase its flight frequency.

Solving the above system, we can obtain that

$$k_1^{NL} = \frac{-2\alpha^3+10\alpha^2+(23-21c)\alpha-115+33c}{3(2\alpha^2-8\alpha-37-9c)}R, \tag{14}$$

$$k_2^{NL} = \frac{2\alpha^3-10\alpha^2+(3c-41)\alpha+61-15c}{3(2\alpha^2-8\alpha-37-9c)}R. \tag{15}$$

The other outcomes are listed in table 2.

Table 2: Solutions of NL case

Flight frequency	$f_A^{NL} = f_B^{NL} = \frac{2(\alpha-2)}{-2\alpha^2+8\alpha+9c+37}R$
Demand	$q_A^{NL} = q_B^{NL} = \frac{3(c+5)}{-2\alpha^2+8\alpha+9c+37}R$
Airline profit	$\pi_A^{NL} = \pi_B^{NL} = \frac{2(-2\alpha^2(3c+11)+2\alpha(9c+29)+9c^2+78c+197)}{(-2\alpha^2+8\alpha+9c+37)^2}R^2$
Airport profit	$\Pi_1^{NL} = \frac{4(\alpha-2)(2\alpha^3-10\alpha^2+(9c-23)\alpha-9c+115)}{3(-2\alpha^2+8\alpha+9c+37)^2}R^2$
	$\Pi_2^{NL} = \frac{4(2-\alpha)(-2\alpha^3+10\alpha^2-\alpha(3c-29)+15c-37)}{3(-2\alpha^2+8\alpha+9c+37)^2}R^2$
Regional welfare	$SW_1^{NL} \frac{4(2\alpha^4-14\alpha^3-36\alpha^2+248\alpha+27c^2+270c+403)}{3(-2\alpha^2+8\alpha+9c+37)^2}R^2$
	$SW_2^{NL} = \frac{-2\alpha^4+14\alpha^3-12(c+2)\alpha^2+8(6c-1)\alpha+27c^2+222c+707}{3(-2\alpha^2+8\alpha+9c+37)^2}R^2$
Social welfare	$SW^{NL} = \frac{8(c+5)}{-2\alpha^2+8\alpha+9c+37}R^2$

4.3 *LL*

In this case, each local government decides the airport charge to maximize its regional welfare.

$$W_j = \frac{1}{2}(q_A+q_B)^2 + \frac{\pi_1+\pi_2}{2} + k_j(f_A+f_B) - (f_A+f_B)^2. \tag{16}$$

Solving the welfare maximization problem by k_j, the following reaction function is derived:

$$k_j = -\frac{-2\alpha^2 + 8\alpha + 46}{5\alpha^2 - 17\alpha - 94} k_{-j} + \frac{\alpha^3 - 4\alpha^2 - 25\alpha + 4}{5\alpha^2 - 17\alpha - 94} R. \tag{17}$$

Equation (17) expresses that each airport charge is a strategic substitute. The underlying reasoning is similar to that with NL.

Here, comparing the results obtained in previous studies, we realize that the congested charge should be lower when considering the supplement characteristics of the airports[8].

Solving the above system, the following airport charge is obtained:

$$k_1^{LL} = k_2^{LL} = \frac{\alpha^3 - 4\alpha^2 - 25\alpha + 4}{7\alpha^2 - 25\alpha - 140} R. \tag{18}$$

The other outcomes are listed in table 3.

Table 3: Solutions of LL case

Flight frequency	$f_A^{LL} = f_B^{LL} = \frac{4(\alpha-2)}{-7\alpha^2+25\alpha+140} R$
Demand	$q_A^{LL} = q_B^{LL} = \frac{\alpha^2-3\alpha-52}{7\alpha^2-25\alpha-140} R$
Airline profit	$\pi_A^{LL} = \pi_B^{LL} = \frac{2(5\alpha^4-30\alpha^3-227\alpha^2+784\alpha+2416)}{(7\alpha^2-25\alpha-140)^2} R^2$
Airline profit	$\Pi_1^{LL} = \Pi_2^{LL} = \frac{8(-\alpha^4+6\alpha^3+9\alpha^2-22\alpha-24)}{(7\alpha^2+25\alpha-140)^2} R^2$
Regional welfare	$SW_1^{LL} = SW_2^{LL} = \frac{4(\alpha^4-6\alpha^3-143\alpha^2+504\alpha+2512)}{(7\alpha^2-25\alpha-140)^2} R^2$
Social welfare	$SW^{LL} = \frac{8(\alpha^4-6\alpha^3-143\alpha^2+504\alpha+2512)}{(7\alpha^2-25\alpha-140)^2} R^2$

5 Comparison of the outcomes

5.1 Airport charge

First, we compare Airport 1's pricing for each case. Fig. 1 expresses the result of this comparison.

[8]The result for $k_j = 0$ corresponds with the results obtained in the previous studies.

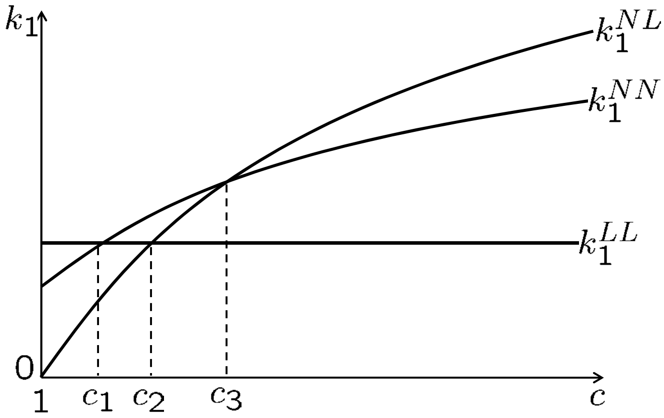

Figure 1: Comparison of airport 1's pricing

Here, $c_3 \equiv \frac{1}{72}(-5\alpha^2 + 11\alpha + 124 + \sqrt{121\alpha^4 - 782\alpha^3 - 2991\alpha^2 + 13912\alpha + 38032})$, $c_1 \equiv \frac{1}{6}(-\alpha^2 + 3\alpha + 22)$, and $c_2 \equiv \frac{1}{12}(-\alpha^2 + 3\alpha + 28)$. From Fig. 1, we obtain Proposition 1.

Proposition 1 *Comparing airport 1's charge for each case, we have (1) when* $1 \leq c \leq c_1$, $k_1^{LL} \geq k_1^{NN} \geq k_1^{NL}$*; (2) when* $c_1 < c \leq c_2$, $k_1^{NN} > k_1^{LL} \geq k_1^{NL}$*; (3) when* $c_2 < c \leq c_3$, $k_1^{NN} \geq k_1^{NL} > k_1^{LL}$*; and (4) when* $c > c_3$, $k_1^{NL} > k_1^{NN} > k_1^{LL}$.

Next, we compare airport 2's pricing. Fig. 2 expresses the result.

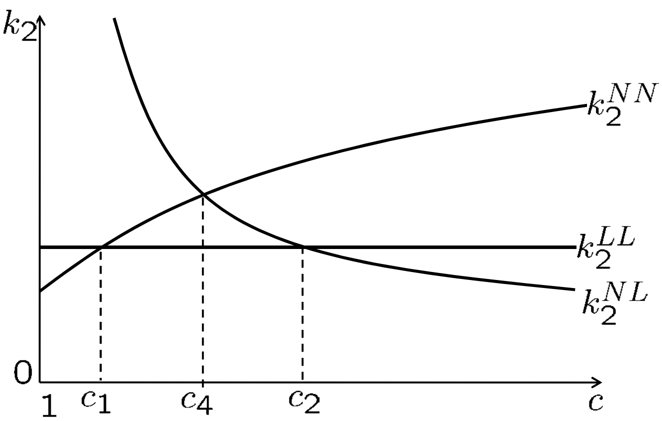

Figure 2: Comparison of airport 2's pricing

Here, $c_4 \equiv \frac{1}{72}(\alpha^2 - 7\alpha + 28 + \sqrt{97\alpha^4 - 686\alpha^3 - 2631\alpha^2 + 13384\alpha + 37264})$. We thus have Proposition 2.

Proposition 2 *Comparing airport 2's charge for each case, we have (1) when $1 \leq c \leq c_1$, $k_2^{NL} \geq k_2^{LL} > k_2^{NN}$; (2) when $c_1 < c \leq c_4$, $k_2^{NL} > k_2^{NN} \geq k_2^{LL}$; (3) when $c_4 < c \leq c_2$, $k_2^{NN} \geq k_2^{NL} > k_2^{LL}$; and (4) when $c > c_2$, $k_2^{NN} > k_2^{LL} > k_2^{NL}$.*

When c is sufficiently small (that is, $c \leq c_1$), if the national government owns an airport, it can set a lower airport charge. Then, if the other airport is owned by the local government, the national government sets a higher airport charge since the pricing of airport 1 and that of airport 2 are strategic substitutes. Since the national government can expect the local government's reaction, it sets a lower airport charge. Similarly, the local government expects the national government's reaction and sets a higher airport charge.

If both airports are owned by the national government, there is no strategic relationship. Consequently, in airport 1, the national government need not set an airport charge that is lower than that for NL; in airport 2, the national government sets a lower airport charge. If each airport is owned by its respective local government, each local government does not consider the influence of the other region's airport congestion. Consequently, they set a higher airport charge.

When c is slightly large (that is, $c_1 < c \leq c_2$), if the national government owns the airport, it sets a slightly higher airport charge. Then, if the other airport is owned by the local government, the same logic as mentioned above holds. As a result, in airport 1, k_1^{NL} is still the lowest. However, when the national government owns both airports, the airport charge is higher due to the higher managing cost. As a result, k_i^{NN} is larger than k_1^{LL} $(i = 1, 2)$. In addition, if $c_1 \leq c \leq c_4$, k_2^{NL} is still the highest due to the strategic relationship. Otherwise, k_2^{NN} is the highest because of the higher managing cost. Finally, it is apparent that k_2^{LL} is the lowest in both ranges, because the managing cost under local ownership is small.

When c increases even further (that is, $c_2 < c \leq c_3$), if the national government owns the airport, it sets a higher airport charge. Then, if the other airport is owned by the local government, it must lower the airport charge due to the strategic relationship. As a result, k_2^{NL} is the lowest and k_1^{NL} is larger than k_1^{LL}. If both airports are owned by the national government, k_1^{NN} is the largest because of the higher managing cost.

When c is very large (that is, $c > c_4$), if the national government owns one airport, it sets a very high airport charge. Consequently, if the local government owns the other airport, it must set a very low airport charge. Therefore, k_2^{NL} is the lowest. Given this expectation, the national government sets a higher airport charge. As a result, k_1^{NL} is the highest. Finally, since the managing cost under national ownership is higher than that under the local government, it is apparent that $k_i^{NN} > k_i^{LL}$.

5.2 Airline profit

This subsection compares airline profit for three cases. Before this analysis, we compare the flight frequency for each case because the airline profit mainly depends on the flight frequency. Lemma 2 expresses the result.

Lemma 2 *Comparing the flight frequency for each case, we have (1) when* $1 \leq c \leq c_1$, $f_i^{NN} > f_i^{NL} \geq f_i^{LL}$; *(2) when* $c_1 < c \leq \frac{23}{6}$, $f_i^{NN} \geq f_i^{LL} > f_i^{NL}$; *and (3) when* $c > c_2$, $f_i^{LL} > f_i^{NN} > f_i^{NL}$.

These results depend on the total airport charge. That is, the higher the total airport charge, the lower is the flight frequency. Consider the case where c is small. In NL, although the local-ownership airport sets a high airport charge, the national-ownership airport sets a very low airport charge. As a result, the total airport charge for NL is the lowest. In LL, since both the local-ownership airports do not consider the other airport, both set a high airport charge. Consequently, the total airport charge for LL is the highest.

When c increases, the charge set by the national-ownership airport is high. Consequently, when c is moderate, the total airport charge for NN is higher than that for LL; when c is large, the total airport charge for NL is higher than that for LL.

Then, comparing the airline profit for each case, we have Fig. 3.

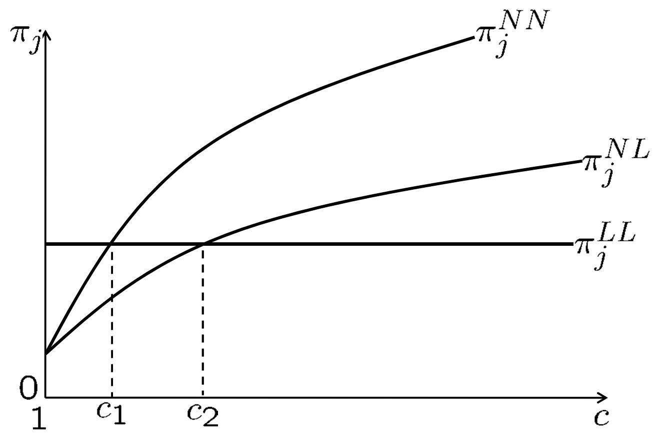

Figure 3: Comparison of airline profit

From Fig. 3, we obtain Proposition 3.

Proposition 3 *Comparing the airline profit for the three cases, we have (1) when* $1 \leq c \leq c_1$, $\pi_i^{LL} \geq \pi_i^{NN} \geq \pi_i^{NL}$; *(2) when* $c_1 < c \leq c_2$, $\pi_i^{NN} > \pi_i^{LL} \geq \pi_i^{NL}$; *and (3) when* $c > c_2$, $\pi_i^{NN} > \pi_i^{NL} > \pi_i^{LL}$.

In order to interpret Proposition 3, we need to understand the influence of flight frequency. When the flight frequency increases, the scheduling effect increases the airline profit, but the damage from congestion decreases it. In addition, because of the congestion cost, a higher flight frequency increases the airline cost. Therefore, a higher flight frequency results in lower airline profit. Using Lemma 2 and this logic, we can easily realize Proposition 3.

5.3 Airport profit

In this subsection, we compare the airport profit for the three cases. We first analyze the profit of airport 1. Fig. 4 expresses the result of the comparison.

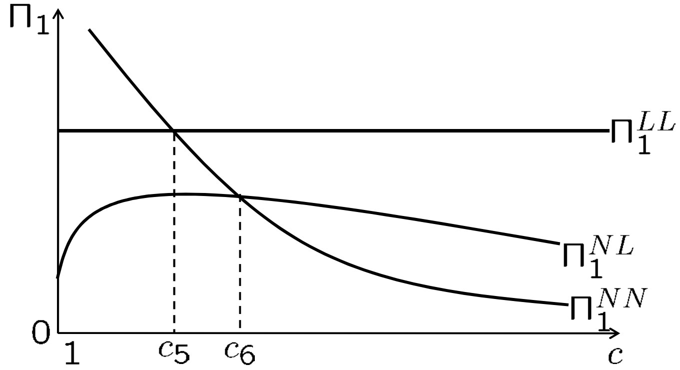

Figure 4: Comparison of airport 1's profit

Here, because of the high degree of complexity, we omit the detailed values of c_5 and c_6. Fig. 4 yields Proposition 4.

Proposition 4 *Comparing airport 1's profit for each case, we have (1) when* $1 \leq c \leq c_5$, $\Pi_1^{NN} \geq \Pi_1^{LL} > \Pi_1^{NL}$*; (2) when* $c_5 < c \leq c_6$, $\Pi_1^{LL} > \Pi_1^{NN} \geq \Pi_1^{NL}$*; and (3) when* $c > c_6$, $\Pi_1^{LL} > \Pi_1^{NL} > \Pi_1^{NN}$.

First, compare Π_1^{LL} and Π_1^{NL}. Given that airport 2 is owned by the local government, if the national government owns airport 1, the charge of airport 1 becomes very low, which is realized by Proposition 1. Since the difference in the total airport charge (and flight frequency) between LL and NL is somewhat small, this results in a profit loss from the viewpoint of airport 1. However, if airport 1 is owned by the local government, this profit loss does not occur. Consequently, for any c, Π_1^{LL} is larger than Π_1^{NL}.

Then, we compare Π_1^{NN} with Π_1^{NL} given that airport 1 is owned by the national government. When c is smaller than c_6, if the local government owns airport 2, the charge of airport 1 is low; if the national government owns airport 2, the charge of airport 1 is slightly high. On the other hand, the difference between the total airport charges (and flight frequencies) under NN and NL is not much. Consequently, airport 1's profit for NN is larger than that for NL. However, when c is larger than c_6, the total airport charge for NN is very high because of the higher managing cost. In that case, airport 1's profit for NL is larger than that for NN.

In the following, we compare Π_1^{NN} with Π_1^{LL}. When c is smaller than c_5, the total airport charge for LL is higher than that for NN. The higher the airport charge, the lower is the airline flight frequency. As a result, Π_1^{NN} is larger than Π_1^{LL}. However, when c is large, the total airport charge for NN increases, and so does the managing cost. Both reduce airport profit. Consequently, Π_1^{LL} is larger than Π_1^{NN}.

Next, we compare airport 2's profit for each case. Fig. 5 gives us the result.

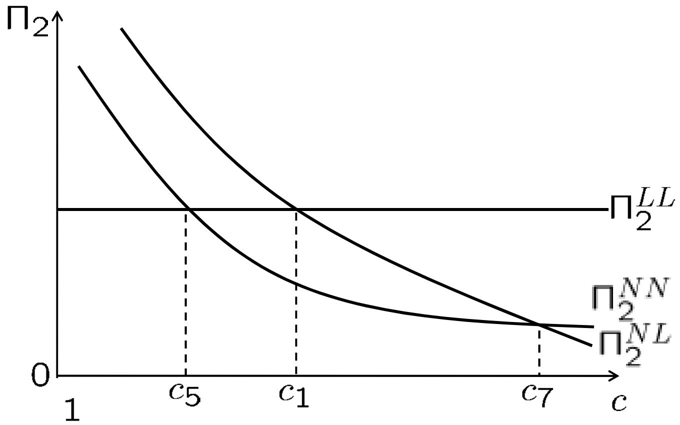

Figure 5: Comparison of airport 2's profit

Here, because of the high degree of complexity, we omit the detailed value of c_7. From Fig. 5, we have Proposition 5.

Proposition 5 *Comparing airport 2's profit, we have (1) when* $1 < c \leq c_5$, $\Pi_2^{NL} > \Pi_2^{NN} \geq \Pi_2^{LL}$; *(2) when* $c_5 < c \leq c_1$, $\Pi_2^{NL} > \Pi_2^{LL} > \Pi_2^{NN}$; *(3) when* $c_1 < c \leq c_7$, $\Pi_2^{LL} > \Pi_2^{NL} \geq \Pi_2^{NN}$; *and (4) when* $c > c_7$, $\Pi_2^{LL} > \Pi_2^{NN} > \Pi_2^{NL}$.

Here, note that Proposition 5-(4) holds (that is, c_7 appears in the meaningful area) only when $\alpha > 3$.

First, we compare Π_2^{NN} with Π_2^{NL}. When c is smaller than c_7, the airport charge for NL is higher than that for NN and/or the airport managing cost for NL is lower than that for NN. As a result, airport 2's profit for NL is higher than that for NN. On the other hand, when c is higher than c_7, the airport charge for NL is very low and the total airport charge for NL is high. Consequently, airport 2's profit for NL is lower than that for NN.

Next, we compare Π_2^{LL} with Π_2^{NL}. When c is smaller than c_5, the airport charge for NL is higher than that for LL. As a result, Π_2^{NL} is higher than Π_2^{LL}. On the other hand, when c is larger than c_5, the airport charge for NL is low and the airline flight frequency also decreases due to the higher total airport charge. As a result, Π_2^{LL} becomes larger than Π_2^{NL}.

Finally, we compare Π_2^{NN} with Π_2^{LL}. Because this interpretation is the same as in airport 1's case, we omit the details here.

6 Socially preferable airport ownership

Comparing the social welfare for the three cases (NN, NL, and LL), this section analyzes which is the socially preferable airport ownership. Fig. 6 expresses the social welfare for each case.

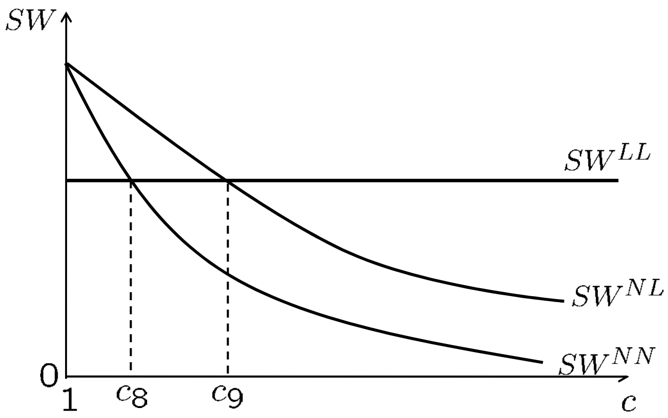

Figure 6: Comparison of social welfare

Here, $c_8 \equiv \frac{-\alpha^4+6\alpha^3+63\alpha^2-232\alpha-1008}{8(5\alpha^2-17\alpha-94)}$, and $c_9 \equiv \frac{-\alpha^4+6\alpha^3+43\alpha^2-164\alpha-632}{4(5\alpha^2-17\alpha-94)}$. From Fig. 6, we obtain Proposition 6.

Proposition 6 *The socially preferable ownership pattern is (1) NL when $1 \leq c \leq c_9$ and (2) NN case when $c > c_9$.*

In the national-ownership airport, the managing cost is higher than that in the local-ownership airport, which is inefficient from the viewpoint of social welfare. If both airports are owned by the national government, we have double inefficiency when c is small, which is socially wasteful. Therefore, NN is never socially preferable. Comparing SW^{NL} with SW^{LL}, when c is small, we get that NL is socially preferable. Airport 1 is owned by the national government. Therefore, airport 1's charge is decided considering the total social welfare. Though the airport managing cost is slightly high, which worsens the total social welfare, airport 1's charge improves total social welfare as compared to the airport charge under LL. However, when c becomes large, the improvement effect is smaller than the increase in the airport management cost. Consequently, LL becomes socially preferable.

Here, it is noteworthy that when $c = 1$, the social welfare for NN and NL is the same. For NL, the national government decides airport 1's charge to consider the local government's reaction. Since the national government has an incentive to maximize social welfare, it can internalize the inefficiency from the local government's decision. As a result, when $c = 1$, the social welfare for NN and NL is the same.

7 Comparison of regional welfare

In this section, the regional welfare for each case is compared. First, we compare region 1's social welfare for each case. Figure 7 expresses the result

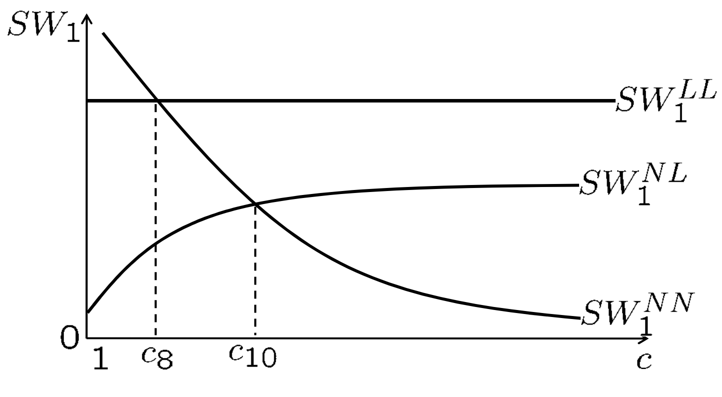

Figure 7: Comparison of region 1's welfare

Here, $c_{10} \equiv \frac{1}{27}\left(-\alpha^2 + \alpha + 29 + \sqrt{19\alpha^4 - 128\alpha^3 - 489\alpha^2 + 2398\alpha + 6628}\right)$. From Fig. 7, we obtain the following proposition.

Proposition 7 *When c is smaller than c_8, NN is socially preferable for region 1. When c is larger than c_8, LL is socially preferable for region 1.*

When $c \leq c_8$, airport 1 sets the lowest airport charge under NL. However, because airport 2 sets a higher charge, airport 1's low airport charge almost has no influence on the flight frequency. As a result, airport 1's revenue decreases, which worsens region 1's welfare. For LL, both airports set a too high airport charge, which decreases the airline flight frequency. As a result, the regional welfare worsens. For NN, the airport charge is appropriate (i.e., not too high and not too low). As a result, for region 1, region 1's welfare for NN is the highest.

When c is high, the airport profit for NN and NL decreases. In addition, the airport charge increases and the flight frequency decreases in these cases. On the other hand, for LL, there is no influence on c. As a result, LL is socially preferable. Here, we note that the airport profit for NN decreases due to the too high total airport charge and the inefficient airport management.

Next, we compare region 2's welfare. Figure 8 expresses the result.

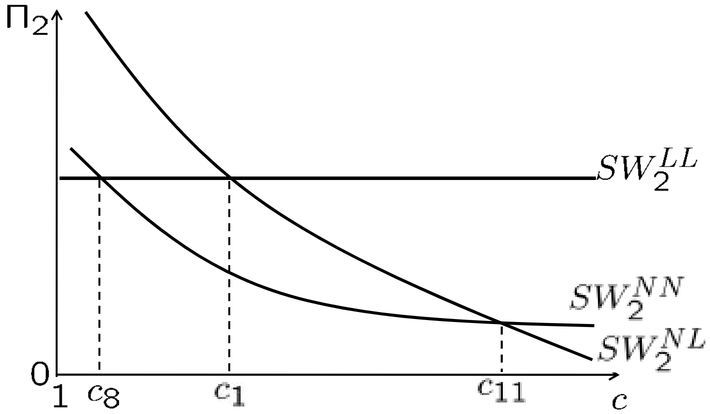

Figure 8: Comparison of region 2's welfare

Here, $c_{11} \equiv \frac{1}{9}\left(-3\alpha^2+9\alpha+57+\sqrt{3}\sqrt{5\alpha^4-32\alpha^3-123\alpha^2+554\alpha+1504}\right)$. Fig. 8 yields the following proposition.

Proposition 8 *When c is smaller than c_1, NL is socially preferable for region 2. When c is larger than c_1, LL is socially preferable.*

When $c \leq c_1$, under NL, airport 2's charge is high and airport 1's charge is low. Therefore, airport 2 enjoys a larger airport profit, and NL is socially preferable. However, when $c > c_1$, under NL, the airport charge become low. Then, under LL, the airport charge increases, which increases the profit of airport 2. Here, it is noteworthy that a higher airport profit increases region 2's welfare. Consequently, LL is socially preferable.

Finally, we analyze how the socially optimal airport ownership pattern influences the welfare of both regions. Using the relationships $c_8 < c_9 < c_{10}$ and $c_8 < c_9 < c_1$, we obtain following lemma.

Lemma 3 *In the range where NL is socially preferable, region 1's welfare is the worst; in region 2, the welfare is the highest. In the range where LL is socially preferable, region 1's welfare is the highest; in region 2, if the managing cost is moderate, LL is not socially preferable, and if it is high, LL is socially preferable.*

When c is small, region 1 sacrifices its welfare and imposes a lower airport charge. That is, region 1 reduces its airport revenue. On the other hand, because region 2 gains more airport profit, region 2's welfare is the highest. Consequently, in this case, each region wants to manage the airport.

When c is moderate, region 2's welfare becomes low, because region 2 cannot obtain higher airport profit under LL. In this case, both regions wish that the other region's airport is managed by the national government. Therefore, in both cases, the national government must adjust the concern between regions to improve the total social welfare.

8 Concluding Remarks

This paper analyzed airport pricing under three different airport ownership patterns (NN, NL and LL). As a result, the following conclusions were obtained. With regard to airport 1's pricing, when the managing cost under national ownership is small, the airport charge for LL is the highest and that for NL is the lowest. When the cost increases a little, the charge for NN is larger than that for LL. Then, when the cost increases much, the charge for NL is larger than that for LL. When cost is very large, the charge for NL is the highest and that for LL is the lowest. With regard to airport 2's pricing, when the managing cost is small, the airport charge for NN is the smallest and that for NL is the highest. When the cost increases, the charge for NN is larger than that for LL. Then, when the cost increases even further, the charge for NN is larger than that for NL. When the cost is very large, the charge for NN is the highest and that for NL is the smallest.

In airport 1, when the managing cost is small, the airport profit for NN is the highest and that for NL is the lowest. When the cost increases, the profit for LL is the highest and that for NN is the lowest. In Airport 2, when the managing cost is small, the profit for NL is the highest and that for LL is the lowest. When the cost increases, the profit for LL is higher than that for NL. Finally, when the cost is large, the profit for LL the highest and that for NL is the lowest.

Finally, we compare the social welfare for the tree cases. When the managing cost is small, NL is socially preferable; when the cost is large, LL is socially preferable. In addition, in the range where NL is socially preferable, region 1's welfare is the worst; in region 2, the welfare is the highest. In the range where LL is socially preferable, region 1's welfare is the highest; in region 2, if the managing cost is moderate, LL is not socially preferable.

This paper has some restrictions. First, for NL, this paper assumes the ownership pattern. However, this point is very important. In particular, which airport, hub airport, or non-hub airport should be under national ownership (local ownership)? Second, this paper presumes a two-city (two-airport) model. If we relax this assumption and more cities (airports) are presumed, does the result obtained in this paper hold?

Then, we must consider the airport privatization problem. This paper omits this possibility. However, all over the world, airport privatization is increasingly becoming prevalent. Then, is it socially preferable that national-ownership airports be privatized? Alternatively, is it socially preferable that local-ownership airports be privatized?

Finally, this paper ignores the commercial operations of airports. In recent times, the revenue from commercial operations has become a major component for the airports. Interestingly, in Japan, the aeronautical sector is owned by the government; the commercial sector is owned by the private firm. Is this ownership pattern efficient? Perhaps, this pattern is inefficient. Therefore, we want to analyze this using a theoretical model. Then, we argue that vertical integration is required to improve social welfare.

In the future, I plan to deal with some of the above problems.

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