Hub-airport Competition, Airline Competition and Economic Welfare*

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This paper analyzes the economic effects resulting from the hub-airport competition and the corresponding airline competition between the home country and the neighboring country. Comparing the equilibrium of a *Monopoly-hub network* where the connecting passengers only have the home country's via-hub routing choice with the equilibrium of an *Inter-hub network* where the passengers can choose the home country's or the neighboring country's via-hub routing, it is found that the competition increases the consumer surplus of the connecting passengers and improves the home country's social welfare if and only if the home country's hub-airport competes with the neighboring country's hub-airport while respecting the welfare of the passengers sufficiently well.

1 Introduction

After the airline deregulation, air carriers transform their networks into the hub-spoke type for cost-saving and strategic reasons[1]. At present, most airlines have adopted a hub-spoke type network (see Spiller (1989), Zhang and Wei (1993), Oum et al. (1995) and Zhang (1996) among many others). In a simple network linking one hub-airport and two spoke-airports, the hub-airport is in a monopoly position. But due to the development of the airlines networking, another hub-airport linking these two spoke-airports becomes possible. In this case, the hub-airport actually competes against the potential hub-airport in the connecting flight market. With the dramatic growth of hub-spoke networks, hub-airport competition becomes more likely in many areas in the world[2].

However, the theoretical literature on the hub-airport competition is sparse[3]. It seems to be an interesting question whether the home country should connect its own spoke-airport with the neighboring country's (potential) hub-airport to promote competition. Would promoting the competition with the neighboring country's hub-airport benefit the home country's connecting passengers? Moreover, would the competition improve the home country's welfare? In this article, two simple hub-spoke network models are constructed to investigate the economic effects resulting from the hub-airport competition and the corresponding airline competition.

First, let us think of the *Monopoly-hub network* linking two cities located in Japan (e.g. Sapporo and Osaka) and one destina-

* Received for publication May8, 2002. Revision accepted for publication October15, 2002. (*Editor*)

tion city located in one foreign country. One monopoly airline (e.g. Japan Airlines) operates this hub-spoke network using Osaka as its hub. The passengers traveling from Sapporo to the foreign city have only one routing choice, i.e., flying through the home country's hub. Second, the *Inter-hub network* will be constructed. Suppose that there is another city (e.g. Seoul), with Korean Airlines operating the flight between Seoul and the above destination city. If, under the bilateral agreements with the home country, Korean Airlines is allowed to fly between Seoul and Sapporo, the connecting passengers will have an alternative routing choice, i.e., flying through the neighboring country's hub. In this situation, the home country's hub-airport actually competes with the neighboring country's (potential) hub-airport, and Japan Airlines inevitably competes with Korean Airlines in the connecting market[4)].

In this paper, it is assumed that each hub-airport is owned and operated by the public sector (say the government)[5)]. In the Monopoly-hub network, the home country's hub-airport chooses the airport charge to the passengers and the landing-taking-off fee to the airline to maximize its social welfare (which is defined by the sum of the profits of the airline and the consumer surplus of the connecting passengers) in stage 1. Given the airport charge and the landing-taking-off fee of the hub-airport, the airline with the home country's national flag chooses the fare to maximize its own profits in stage 2.

In the Inter-hub network, each hub-airport chooses simultaneously its airport charge and its landing-taking-off fee to maximize its own social welfare in the hub-airport competition stage (stage 1). Given both airports' charges and the landing-taking-off fees, each airline selects simultaneously its fare to maximize its own profits in the airline competition stage (stage 2). It is assumed that the neighboring country's hub-airport has no concern about the consumer surplus of the passengers originating from the home country's city, while the home country's hub-airport may have wide consideration about the consumer surplus since the demands emerged from the home country[6)].

Comparing the Monopoly-hub network equilibrium to the Inter-hub network equilibrium, it is found that, if the home country's hub-airport competes with the neighboring country's hub-airport without any concern for the passengers, the hub-airport competition and the corresponding airline competition actually raise the full cost (the sum of the airport charge and the fare) to the connecting passengers. Thus the total traveling demand decreases, the consumer surplus decreases, and the social welfare of the home country falls. However, if the home country's hub-airport competes with its rival respecting the consumer surplus of the passengers sufficiently well, as a result of the competition, the full cost of the home country's via-hub traveling is lower, while the full cost of the neighboring country's via-hub traveling is higher than the monopoly full cost. Corresponding to the changes of the full cost, the total traveling demand increases, the consumer surplus of the passengers increase, and the social welfare of the home country actually improves.

The main economic intuition is that the first-best outcome is achieved in the equilibrium of the Monopoly-hub network. In contrast, in the Inter-hub network, the neighboring country's airport has incentive to raise its charge since it has no concern for the passengers. In response to the rival's charge-raising, the home country's hub-airport will also raise its own charge if it doesn't have any concern for the passengers. As a result the full costs of both routings rise. However, if the home country's hub-airport respects the passengers sufficiently well, the full cost of the home country's via-hub routing falls. On the other hand, even though the full cost of neighboring country's via-hub routing rises, it does not raise so high as the previous no passenger concern situation. Thus the above results hold.

The paper is organized as follows. In section 2, the demand function for the connecting passengers in each network is derived respectively. In section 3, the Monopoly-hub network model is presented and the corresponding equilibrium is derived. In section 4, the Inter-hub network model is presented, and the corresponding equilibrium is derived. The equilibrium comparison is made in section 5. Concluding remarks follow in section 6.

2 The demand of the connecting passengers

In this section, the model of *Monopoly-hub network* and that of *Inter-hub network* will be constructed, and then the corresponding demand function of the connecting passengers in each network will be derived. The *Monopoly-hub network* is depicted in Figure 1. There are three cities A, B and C, where the originating city A and the hub city B are located in the home country J, and the destinating city C is located in another country I[7]. Airline 1 (belonging to country J) operates the hub-spoke network using B as its hub. The connecting passengers who want to travel from A to C have only one routing choice, i.e., flying A to C via B.

The *Inter-hub network* is depicted in Figure 2. In this network, there is another city D located in the neighboring country K, where Airline 2 (belonging to country K) has been flying between D and C[8]. If, under the bilateral agreements between countries J and K, Airline 2 is allowed to fly between D and A, the connecting passengers will have an alternative routing choice, i. e., flying A to C via D[9]. The via-hub B connecting flight and the via-hub D connecting flight are assumed to be differentiated services[10].

A representative connecting passenger

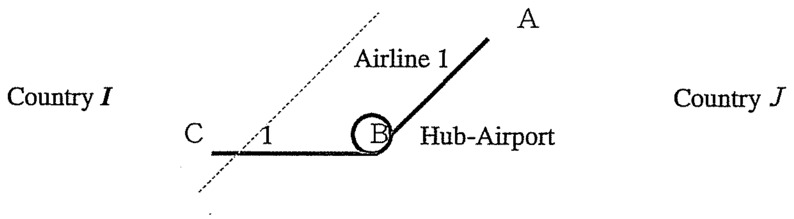

Fig. 1 *Monopoly-Hub Network*

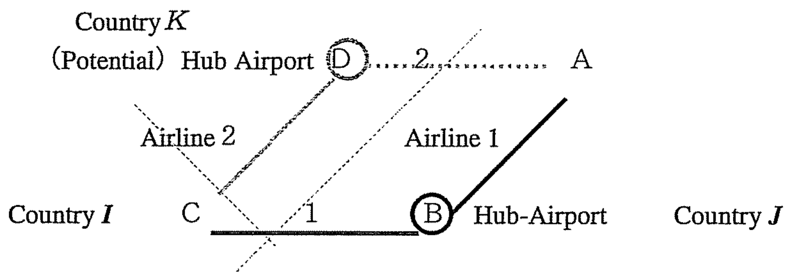

Fig. 2 *Inter-Hub network*

is considered, who has a quasi-linear utility function, which can be written as follows[11].

$$U(x_1, x_2)=\left(\frac{a}{1-b}\right)(x_1+x_2)-\frac{x_1^2+2bx_1x_2+x_2^2}{2(1-b^2)}$$

where $a>0$, and the condition for the concavity of the utility function is $0<b<1$. x_1 represents the demand of via-hub B connecting flight, and x_2 represents the demand of via-hub D connecting flight. The passenger maximizes its consumer surplus defined as $U(x_1, x_2)-[(p_1+t_B)x_1+(p_2+t_D)x_2]$, where p_i $(i=1, 2)$ represents the fare of the connecting flight provided by Airline i, t_j $(j=B, D)$ represents the airport charge of the hub-airport j. In the Monopoly-hub network, the demand function of the representative passenger can be derived by substituting $x_2=0$ into the utility-maximizing problem, since there is no via-hub D connecting flight. Solving this optimization problem, we have the following demand function (which will be used in section 3).

$$x_1^0(p_1, t_B)=(1+b)a-(1-b^2)[p_1+t_B] \quad (1)$$

In the Inter-hub network, the passenger's demand functions can be derived by solving the optimization problem where x_i $(i=1, 2)>0$. Thus, we have the following demand functions (which will be used in section 4).

$$x_1(p_1, p_2, t_B, t_D)=a-(p_1+t_B)+b(p_2+t_D) \quad (2)$$

$$x_2(p_1, p_2, t_B, t_D)=a-(p_2+t_D)+b(p_1+t_B) \quad (3)$$

3 The equilibrium in the Monopoly-hub network

In the Monopoly-hub network model, given the demand function of the representative connecting passenger as equation (1), Airline 1 chooses the fare to maximize its profits, taking the airport charge and the airport landing-taking-off fee as given. Specifically, the profits-maximizing problem for Airline 1 can be formulated as:

$$\underset{p_1}{Max} \quad \pi_1 = p_1 x_1^0 - c_1 x_1^0 - F_B \qquad (4)$$

where c_1 is the marginal cost of Airline 1's connecting flight, and F_B is the landing-taking-off fee of hub-airport B. For the convenience of calculation, let us suppose that $c_1 \equiv 0$[12]. Solving the maximization problem, the second stage equilibrium in the Monopoly-hub network can be shown as Table 1.

On the other hand, it is assumed that the hub-airport authority B (hereafter, Authority B) is owned and operated by the public sector. Authority B selects the airport charge for the passenger and the airport landing-taking-off fee for Airline 1 to maximize the social welfare, subject to the budget constraints. Specifically, Authority B's social welfare-maximizing problem can be formulated as:

$$\underset{F_B, t_B}{Max} \quad W_J^m \equiv \pi_1^m + CS^m \qquad (5)$$

$$\text{Subject to} \quad F_B + t_B x_1^m = \theta_B x_1^m \qquad (6)$$

where $\pi_1^m (= p_1^m \cdot x_1^m - F_B)$ is the net profits of Airline 1 which has the home country J's flag. θ_B is the marginal operating cost of the hub-airport B. Solving the social welfare-maximizing problem, we have the first stage equilibrium in the Monopoly-hub network as Table 2[13].

Table 1 The second stage equilibrium of the Monopoly-hub network

Fare	$p_1^m(a, b, t_B) = \frac{1}{2}\left[\frac{a}{1-b} t_B\right]$
Demand	$x_1^m(a, b, t_B) = (1-b^2) \cdot p_1^m$
Consumer Surplus	$CS^m(a, b, t_B) = \frac{1-b^2}{4}\left[\frac{a}{1-b} - t_B\right] \cdot p_1^m$

Table 2 The first stage equilibrium of the Monopoly-hub network

Charge of Hub-airport B	$t_B^{m*}(a, b, \theta_B) = 2\theta_B - \frac{a}{1-b}$
Fare of Airline 1	$p_1^{m*}(a, b, \theta_B) = \frac{1}{1-b}[a-(1-b)\theta_B]$
Full cost for passengers	$p_1^{m*} + t_B^{m*} = \theta_B$
Demand	$x_1^{m*}(a, b, \theta_B) = (1+b) \cdot [a-(1-b)\theta_B]$
Consumer Surplus	$CS^{m*}(a, b, \theta_B) = \frac{1+b}{2(1-b)} \cdot [a-(1-b)\theta_B]^2$
Landing-taking-off fee	$F_B^{m*}(a, b, \theta_B) = \frac{1+b}{(1-b)} \cdot [a-(1-b)\theta_B]^2$
Profits of Airline 1	$\pi_1^{m*} = p_1^{m*} \cdot x_1^{m*} - F_B^{m*} = 0$
The social welfare of Country J	$W_J^{m*} = CS^{m*}$

4 The equilibrium in the Inter-hub network

In the Inter-hub network model, the demand functions of the representative connecting passenger are given by equations (2) and (3). In stage 1, each hub-airport authority simultaneously chooses its airport charge and its landing-taking-off fee to maximize its own social welfare, subject to the budget constraints. In stage 2, each airline simultaneously selects its fare to maximize its own profits, taking the airport charges and the landing-taking-off fees of two hub-airports as given. The subgame perfect equilibrium of these two stages game can be derived under the above suppositions.

Specifically, in stage 2 (airline competition stage), the profits-maximizing problems for Airline 1 and 2 can be formulated as follow, respectively,

$$\underset{p_1}{Max} \quad \pi_1 = p_1 x_1 - c_1 x_1 - F_B \tag{7}$$

$$\underset{p_2}{Max} \quad \pi_2 = p_2 x_2 - c_2 x_2 - F_D \tag{8}$$

where c_2 is the marginal cost of Airline 2's connecting flight. For simplification, let us assume $c_1 = c_2 \equiv 0$. F_D is the landing-taking-off fee of hub-airport D. The first order condition for the profits-maximization of each firm $(\partial \pi_i / \partial p_i = 0\ (i=1, 2))$ may be respectively expressed as:

$$a - 2p_1 - t_B + bp_2 + bt_D = 0 \tag{9}$$

$$a - 2p_2 - t_D + bp_1 + bt_B = 0 \tag{10}$$

Under the assumption that both Airline 1 and 2 act like the Bertrand-Nash behaviors, we have the second stage equilibrium of the Inter-hub network as Table 3.

In stage 1 (the hub-airport competition stage), the social welfare maximization problem of Authority B can be specifically formulated as follow:

$$\underset{F_B, t_B}{Max} \quad W_J^I \equiv \pi_1^I + \beta \cdot CS^I \tag{11}$$

$$\text{Subject to} \quad F_B + t_B x_1^I = \theta_B x_1^I \tag{12}$$

where $\pi_1^I (= p_1^I \cdot x_1^I - F_B)$ is the net profits of Airline 1 and $\beta (\beta \geq 0)$ is a constant parameter used to weight the consumer surplus of the connecting passenger. If $\beta = 0$, Authority B have no concern about the consumer surplus of the connecting passenger originating from the home country. If $\beta > 0$, Authority B respects the consumer sur-

Table 3 The second stage equilibrium of the Inter-hub network

Fare of Airline 1	$p_1^I(a, b, t_B, t_D) = \dfrac{(2+b)\cdot a - (2-b^2)\cdot t_B + b\cdot t_D}{4-b^2}$
Fare of Airline 2	$p_2^I(a, b, t_B, t_D) = \dfrac{(2+b)\cdot a - (2-b^2)\cdot t_D + b\cdot t_B}{4-b^2}$
The demand of via-Hub B routing	$x_1^I(a, b, t_B, t_D) = p_1^I$
The demand of Via-Hub D routing	$x_2^I(a, b, t_B, t_D) = p_2^I$
Consumer Surplus	$CS^I = U(x_1^I, x_2^I) - (p_1^I + t_B)x_1^I - (p_2^I + t_D)x_2^I$

plus of the passenger. On the other hand, it seems reasonable to consider that the hub-airport authority D (hereafter, Authority D) has no concern for the consumer surplus of the home country's passenger. Thus, the social welfare maximization problem of Authority D may be specifically formulated as follow:

$$\underset{F_D, t_D}{Max} \quad W_K^I \equiv \pi_2^I \tag{13}$$

$$\text{Subject to} \quad F_D + t_D x_2^I = \theta_D x_2^I \tag{14}$$

where $\pi_2^I(=p_2^I \cdot x_2^I - F_D)$ is the net profits of Airline 2 which has the neighboring country K's flag. θ_D is the marginal operating cost of the hub-airport D. For simplification, let us assume that $\theta_B = \theta_D \equiv \theta$.

Under the assumption that both Authority B and D act like Bertrand-Nash behaviors, the first order condition for the maximization problem of Authority B ($\partial W_J^I / \partial t_B = 0$) and Authority D ($\partial W_K^I / \partial t_D = 0$) can respectively expressed as:

$$\begin{aligned}&(2+b)[b^2-(2+b)\beta]\cdot a-[(8-4b^2)\\&-(4-3b^2)\beta]\cdot t_B+b^3(1-\beta)t_D\\&+(2-b^2)(4-b^2)\theta_B=0\end{aligned} \tag{15}$$

$$\begin{aligned}&(2+b)b^2\text{a}+b^3 t_B-4(2-b^2)t_D\\&+(4-b^2)(2-b^2)\theta_D=0\end{aligned} \tag{16}$$

Solving these two equation system, we have the first stage equilibrium of the Inter-hub network as Table 4. According to Table 4, we have following lemma:

Lemma 1:

a) If $\beta=0$, the equilibrium values of both airlines and both airport authorities are the same by symmetry.

b) If $\beta>0$, then $t_D^{I*}>t_B^{I*}$, $p_2^{I*}<p_1^{I*}$, and $(p_2^{I*}+t_D^{I*})>(p_1^{I*}+t_B^{I*})$.

Proof. See Appendix A

Lemma 1-b implies that in the equilibrium, the charge of hub-airport D is higher than the charge of hub-airport B because Authority D has no concern for the consumer surplus of the passenger, and then Airline 2 has to lower its fare because of the higher charge of its hub-airport D. The passenger's full cost of via-hub D is higher than that of via-hub B.

5 Equilibrium Comparison

In this section, two simple cases (the cases of $\beta=0$ and $\beta=1$) will be discussed to examine the economic effects on the home country resulting from the hub-airport competition (and the corresponding airline competition). When $\beta=0$, the first stage equilibrium of the Inter-hub network can be obtained directly from Table 4. When $\beta=1$, the equilibrium values can be rewritten as Table 5[14].

Comparing the equilibrium of each case in the Inter-hub network with the equilibrium of Monopoly-hub network, we have the results shown by Table 6 (all comparisons have been done in Appendix B).

In the case of $\beta=0$, comparing the equilibrium of the Inter-hub network to the equilibrium of the Monopoly-hub network, we have the following propositions:

Table 4 The first stage equilibrium of the Inter-hub network

Charge of Hub-airport B	$t_B^{I*}=\dfrac{[b^2\cdot(4+2b-b^2)-(8+8b+0b^2-2b^3-b^4)\beta]\cdot a+(2-b^2)\cdot[(2-b)(4+2b-b^2)-b^3\beta]\cdot\theta}{E-F\beta}$
Charge of Hub-airport D	$t_D^{I*}=\dfrac{b^2\cdot[(4+2b-b^2)-2(1+b)\beta]\cdot a+(2-b^2)\cdot[(2-b)(4+2b-b^2)-(4-3b^2)\beta]\cdot\theta}{E-F\beta}$
Fare of Airline 1	$p_1^{I*}=\Phi\cdot(2-b^2)\cdot[(4+2b-b^2)+b(1+b)\beta]$
Fare of Airline 2	$p_2^{I*}=\Phi\cdot(2-b^2)\cdot[(4+2b-b^2)-2(1+b)\beta]$
The full cost of via-Hub B routing	$p_1^{I*}+t_B^{I*}=\dfrac{[2(4+2b-b^2)-(8+6b+2b^2-b^3)\beta]\cdot a+(2-b^2)[(4+2b-b^2)-b\beta]\cdot\theta}{E-F\beta}$
The full cost of via-Hub D routing	$p_2^{I*}+t_D^{I*}=\dfrac{[2(4+2b-b^2)-4(1+b)\beta]\cdot a+(2-b^2)[(4+2b-b^2)-(2-b^2)\beta]\cdot\theta}{E-F\beta}$
Demand of via-Hub B routing	$x_1^{I*}=p_1^{I*}$
Demand of via-Hub D routing	$x_2^{I*}=p_2^{I*}$
Landing-taking-off fee of Hub-airport B	$F_B^{I*}=\Phi^2\cdot[L\beta^2+M\beta-N]$
Landing-taking-off fee of Hub-airport D	$F_D^{I*}=\Phi^2\cdot(-b^2)(2-b^2)\cdot[(4+2b-b^2)-2(1+b)\beta]^2$
Profits of Airline 1	$\pi_1^{I*}=[\Phi^2/2]\cdot[-(Q\beta^2+R\beta-S)]$
Profits of Airline 2	$\pi_2^{I*}=\Phi^2\cdot 2(2-b^2)\cdot[(4+2b-b^2)-2(1+b)\beta]^2$
Consumer Surplus	$CS^{I*}=\Phi^2\cdot\dfrac{(2-b^2)^2}{2(1-b)}\times\begin{bmatrix}2(4+2b-b^2)^2\\-2(1+b)(2-b)(4+2b-b^2)\cdot\beta\\+(1+b)(4-3b^2)\cdot\beta^2\end{bmatrix}$

where $E\equiv(4+2b-b^2)(4-2b-b^2)$

$F\equiv(8+0b-8b^2+0b^3+b^4)$

$\Phi\equiv\left[\dfrac{a-(1-b)\theta}{E-F\beta}\right]$

$L\equiv b(1+b)(2-b^2)(8+8b+0b^2-2b^3-b^4)>0$

$M\equiv(2-b^2)(4+2b-b^2)(8+8b+0b^2-3b^3-2b^4)>0$

$N\equiv b^2\cdot(2-b^2)(4+2b-b^2)^2>0$

$Q\equiv 2b(1+b)(2-b^2)(8+6b-2b^2-b^3)>0$

$R\equiv 2(2-b^2)(4+2b+b^2)(8+4b-4b^2-b^3)>0$

$S\equiv 4(2-b^2)(4+2b-b^2)^2>0$

Proposition 1 : If the home country's hub-airport authority competes with the neighboring country's hub-airport authority without any concern for the consumer surplus, then the hub-airport competition and the corresponding airline competition will
a) raise the hub-airport charge, lower the fare, and actually raise the full cost to the connecting passenger. Correspondingly, the total demand (the sum of both routing

Table 5 The first stage equilibrium of the Inter-hub network ($\beta=1$)

Charge of Hub-airport B	$t_B^{I*}=(2-b)\theta-(1+b)a$
Charge of Hub-airport D	$t_D^{I*}=\dfrac{b^2a+(4+0b-b^2+b^3)\cdot\theta}{4}$
Fare of Airline 1	$p_1^{I*}=[(4+3b)/4]\cdot[a-(1-b)\theta]$
Fare of Airline 2	$p_2^{I*}=[(2-b^2)/4]\cdot[a-(1-b)\theta]$
The full cost of via-Hub B routing	$p_1^{I*}+t_B^{I*}=\dfrac{-ba+(4+b-b^2)\theta}{4}$
The full cost of via-Hub D routing	$p_2^{I*}+t_D^{I*}=\dfrac{a+(1+b)\theta}{2}$
Demand of via-Hub B routing	$x_1^{I*}=p_1^{I*}$
Demand of via-Hub D routing	$x_2^{I*}=p_2^{I*}$
Landing-taking-off fee of Hub-airport B	$F_B^{I*}=[(1+b)(4+3b)/4]\cdot[a-(1-b)\theta]^2$
Landing-taking-off fee of Hub-airport D	$F_D^{I*}=-[b^2(2-b^2)/16]\cdot[a-(1-b)\theta]^2$
Profits of Airline 1	$\pi_1^{I*}=-[b(4+3b)/16]\cdot[a-(1-b)\theta]^2$
Profits of Airline 2	$\pi_2^{I*}=[(2-b^2)/8]\cdot[a-(1-b)\theta]^2$
Consumer Surplus	$CS^{I*}=[(20+20b-3b^2-5b^3)/(32(1-b)]\cdot[a-(1-b)\theta]^2$

Table 6 The effect of hub-airport competition and airline competition

	$\beta=0$	$\beta=1$
Charge of Hub-airports	$t_B^{I*}=t_D^{I*}>t_B^{m*}$	$t_D^{I*}>t_B^{I*}>t_B^{m*}$
Fare of Airlines	$p_1^{I*}=p_2^{I*}<p_1^{m*}$	$p_2^{I*}<p_1^{I*}<p_1^{m*}$
Full cost to passengers	$(p_1^{I*}+t_B^{I*})=(p_2^{I*}+t_D^{I*})$ $>(p_1^{m*}+t_B^{m*})=\theta$	$(p_1^{I*}+t_B^{I*})<(p_1^{m*}+t_B^{m*})$ $(p_2^{I*}+t_D^{I*})>(p_1^{m*}+t_B^{m*})$
Demand	$x_1^{I*}=x_2^{I*}<x_1^{m*}$	$x_2^{I*}<x_1^{I*}<x_1^{m*}$
Total demand	$(x_1^{I*}+x_2^{I*})<x_1^{m*}$	$(x_1^{I*}+x_2^{I*})>x_1^{m*}$
Landing-taking-off fee of Hub-airports	$F_B^{I*}=F_D^{I*}<F_1^{m*}$	$F_D^{I*}<F_B^{I*}<F_1^{m*}$
Profits of Airlines	$\pi_1^{I*}=\pi_2^{I*}>\pi_1^{m*}(=0)$	$\pi_1^{I*}<0,\ \pi_2^{I*}>0$
Consumer Surplus	$CS^{I*}<CS^{m*}$	$CS^{I*}>CS^{m*}$
Social welfare of country J	$W_J^{I*}<W_J^{m*}$	$W_J^{I*}>W_J^{m*}$

demands) will decrease.
b) decrease the consumer surplus of the passenger, and will decrease the social welfare of the home country.

Proposition 1-a and 1-b can be explained as follows. In the Monopoly-hub network, it is assumed that Authority B tries to maximize the home country's social welfare. As a result, the first-best (the full cost is equal to marginal cost) outcome is achieved in the equilibrium. However, in the Inter-hub network, the distortion of pricing arises because of the activities of the neighboring country's Authority D. In the first stage, each hub-airport authority has the incentive to raise its own airport charge, since each one does not care about the consumer surplus. In the second stage each airline lowers its fare because of the charge-raising of its hub-airport. As a result, the full cost for passengers rises since the airport charge-rising dominates the fare-falling. Corresponding to the changes of the full cost, the total traveling demand decreases, and the consumer surplus decreases. Even though, the profits of Airline 1 increase due to the lower landing-taking-off fee of its hub-airport B, it is dominated by the decrease of consumer surplus, thus the social welfare of the home country decreases.

In the case of $\beta=1$, comparing the equilibrium of the Inter-hub network to the equilibrium of the Monopoly-hub network, we have the following propositions :

Proposition 2 : If the home country's hub-airport authority competes with the neighboring country's hub-airport authority respecting the consumer surplus of the passenger as well as the profits of Airline 1, then the hub-airport competition and the corresponding airline competition will
a) raise the hub-airport charge, lower the fare. Moreover, the full cost of the home country's via-hub routing is lower, while the full cost of the neighboring country's via-hub routing is higher than the monopoly full cost. Corresponding to these full costs change, the total demand (the sum of both routing demands) increases.
b) increase the consumer surplus of the passenger, and will improve the social welfare of the home country.

Proposition 2-a and 2-b can be explained as follows. Even though Authority D has incentive to raise its own charge, Authority B does not raise its charge since Authority B has sufficient concern for the consumer surplus[15]. Thus, the charge of Authority B is lower than Authority D. Because of the lower hub-airport charge, Airline 1 can price higher than Airline 2. As a result, proposition 2-a holds. On the other hand, even though the profits of Airline 1 are negative, it is dominated by the increase of consumer surplus. Thus the social welfare of the home country improves[16,17].

Table 2-b The first stage equilibrium of the Monopoly-hub network (hub- airport B simply maximizes profit)

Charge of Hub-airport B	$t_B^{m*}(a, b, \theta_B)=\theta_B$
Fare of Airline 1	$p_1^{m*}(a, b, \theta_B)=\frac{1}{2(1-b)}\left[a-(1-b)\theta_B\right]$
Full cost for passengers	$p_1^{m*}+t_B^{m*}=\frac{a+(1-b)\theta_B}{2(1-b)}$
Demand	$x_1^{m*}(a, b, \theta_B)=\left(\frac{1+b}{2}\right)\cdot\left[a-(1-b)\theta_B\right]$
Consumer Surplus	$CS^{m*}(a, b, \theta_B)=\frac{1-b}{8(1-b)}\cdot\left[a-(1-b)\theta_B\right]^2$
Landing-taking-off fee	$F_B^{m*}(a, b, \theta_B)=0$
Profits of Airline 1	$\pi_1^{m*}=p_1^{m*}\cdot x_1^{m*}-F_B^{m*}=\frac{1+b}{4(1-b)}\cdot\left[a-(1-b)\theta_B\right]^2$
The social welfare of Country J	$W_J^{m*}=\pi_1^{m*}\cdot CS^{m*}=\frac{3(1+b)}{8(1-b)}\cdot\left[a-(1-b)\theta_B\right]^2$

Table 6-b The effect of hub-airport competition and airline competition (hub-airport B simply maximizes profit in both networks)

	$\beta=0$
Charge of Hub-airport	$t_B^{I*}=t_D^{I*}>t_B^{m*}$
Fare of Airlines	$p_1^{I*}=p_2^{I*}<p_1^{m*}$
Full cost to passengers	$(p_1^{I*}+t_B^{I*})=(p_2^{I*}+t_D^{I*})<(p_1^{m*}+t_B^{m*})$
Demand	$x_1^{I*}=x_2^{I*}<x_1^{m*}$
Total demand	$(x_1^{I*}+x_2^{I*})>x_1^{m*}$
Landing-taking-off fee of Hub-airports	$F_B^{I*}=F_D^{I*}<F_1^{m*}(=0)$
Profits of Airlines	$(0<)\pi_1^{I*}=\pi_2^{I*}<\pi_1^{m*}$
Consumer Surplus	$CS^{I*}>CS^{m*}$
Social welfare of country J	$W_J^{I*}>W_J^{m*}$

6 Conclusion

In this article, models for the simple *Monopoly-hub network* where there is no hub-airport competition and corresponding airline competition between the home country and the neighboring country, and the *Inter-hub network* where the home country's hub-airport (and airline) competes against the neighboring country's hub-airport (and airline), are constructed to examine the economic effects resulting from the hub-airport competition and airline competition. It is found that compared with the equilibrium of the Monopoly- hub network, if the home country's hub- airport authority competes with the neighboring country's hub-airport authority ignoring the consumer surplus of the passengers, the competition hurts the social welfare of the home country. However, if the home country's authority competes with its rival respecting the consumer surplus sufficiently well, the competition improves its social welfare.

Some interesting directions are considerable in the future research. For example, the network models study in the present article assumed that the fare decision of airlines are independent of the airport landing-taking-off fees. It seems desirable to extend the analysis to that the airlines do not only compete with fare but also the frequency of movement, given the landing-taking-off fees. The congestion problem in the hub-airport has not been addressed in this paper. If the capacity of the home country's hub-airport is constraint, linking the home country's spoke-airport to the neighboring country's hub-airport seems likely to reduce the externality costs caused by the congestion in the hub-airport. Then different welfare implication of the hub-airport competition would be obtained, although the analysis becomes much more complex.

Acknowledgments

My grateful thanks are due to Nobuhiro Okuno, Hikaru Ogawa, Jirou Nemoto, and Tatsuaki Kuroda for helpful comments and suggestions. My thanks also go to Masayuki Doi of Tsukuba University for his remarks made at the Annual conference of the Japanese Economic Association at Hirosima syuudou University, 19 May 2001. Any remaining errors are sole responsibility of the author.

Notes

1) The cost advantage of the hub-spoke network has been argued by Bittlingmayer (1990), Brueckner and Spiller (1991). Levine (1987), Oum et al. (1990) concluded that the dominance of hub-spoke networks is the result of airlines' exploiting economies of traffic density. Hendricks et al. (1995) indicated that the reason for the emergence of hub-spoke network is the economies of density, too. Oum et al. (1995) asserted that besides the cost (including both airline and passenger inconvenience costs) saving, switching from a linear to a hub-spoke network is a dominant strategy in an oligopolistic setting or will be useful in deterring entry. Borenstein (1989), Berry (1990) investigated empirically the relationships between hub-spoke network structures and market power.

2) For example, in East Asia, Japanese major airport Kansai-International-Airport (Osaka) competes with the neighboring major airport Intyon (Seoul). Langner (1996) indicated that Schiphol (Amsterdam) is the potential rival of the most popular European airport Heathrow (London).

3) Oum et al. (1996) deals with the socially optimal pricing in 'one hub and n-spokes network', taking the complementarity between the hub-airport and the spoke-airports into

account. Kuroda and Yagi (1999) illustrate and examine a specific situation in which neighboring countries compete for international hub airport, focusing on the airport financial system and no airline-related consideration.

4) Including Seoul, Singapore or Taipei may be another potential rival of Osaka. Then Japan Airlines may competes against with Singapore Airlines or China Airlines in the corresponding connecting market.

5) Langer (1996) indicated that airports were considered to be natural monopolies, and today airports in most countries are in public ownership. Similarly, Oum et al (1996) indicated that in many countries including Canada, Australia, and many Asian and developing countries in other continents, airports are owned and operated by the governments. Although recently some countries including Canada and Australia have adopted new policies to defederalize or even to privatize some of their major airports, in this paper we assume that the hub-airport in the Asian country is owned and operated by the public sector (the government).

6) As Langner (1996. pp23) indicated that the main task of the hub-airport is to process passengers from one spoke-airport to another. It seems plausible to suppose that the potential hub-airport does not care about the nationality of passengers, thus has no concerns about the consumer surplus. However, it may be necessary to argue that the home country's hub-airport would still respect the consumer surplus of passengers as well as the Monopoly-hub case. In the Inter-hub network, we suppose that the consumer surplus of passengers will be weighted by a constant parameter (by the home country's hub-airport), and two essential cases will be discussed.

7) For the previous example, one can think of cities A and B to be located in Japan, where B is the hub city (Osaka), and C is one foreign city. Or for one European example, cities A and B are located in Great Britain, where B is Heathrow (London), and C is another appropriate foreign city.

8) In our Asian example, city D may be Seoul, Singapore or Taipei. In our European example, city D may be Schiphol (Amsterdam), or another appropriate hub-city.

9) The network of this type is similar to the inter-hub network developed by Bruncker and Spiller (1991), and has been used by Zhang and Wei (1993), Zhang (1996). Except the hub-airports and the connecting (AC) market, there are two spoke-airports and direct monopoly city-pair markets in both networks. To simplify and concentrate on the analysis of hub-airport competition, only the hub-airports and the connecting market are considered.

10) It seems natural to assume that the connecting passengers differentiate the (home country's) via-*hub B connecting flight* from the (neighboring country's) via-*hub D connecting flight* because of different airport services and/or different airline flight services. For example, the schedule delay time costs for the connecting passengers may be different if the departure time of Airline 1 and Airline 2 are different. Or the connecting time costs may be different between hub-airport B and D. The assumption that passengers differentiate the flight services by the different time costs has been made by Encaoua et al. (1996).

11) This type of quasi-linear utility function has been used in Singh and Vives (1984), Furth and Kovenock (1993). The corresponding linear demand functions have been used in Economides and Salop (1992). Although this specified function is restrictive, it yields a number of suggestive conclusions that are like-

ly to hold true in general.

12) The simplification that the marginal cost is zero has been made in duopoly studies where products of firms are differentiated. The results are identical for positive constant marginal cost, where "fare" reinterpreted as differences between fare and the marginal cost.

13) In the equilibrium, the full cost of passengers is equal to the marginal cost, and the profits of Airline 1 are zero. The equilibrium fare and demand are assumed to be positive, i. e., $a>(1-b)\theta_B$ holds.

14) It is noted that the landing-taking-off fees of both hub-airports are negative in Table 4 (where $\beta=0$). The charge of Hub-airport B may be negative, and the landing-taking-off fee of Hub-airport D is negative in Table 5. The above results may likely occur when the hub-airport authority subsidizes its airline (or its passengers) to compete with its rival.

15) Note, when $\beta=1$ the reaction function of Authority B (equation (15)) is independent of Authority D. When $\beta>1$, in response to the charge-raising of Authority D, Authority B will lower its charge.

16) From equation (B10) in Appendix B, it can be easily shown that the optimal β, where the improvement of social welfare of country J is maximal, exists. It can also be numerically shown that the value of the optimal β is increasing to parameter b (the index of product differentiation), and it is a value from 0.68 to 1.04 corresponding to $0<b<1$.

17) The analysis of another possible case where Hub-airport B simply maximizes the profits in the Monopoly-hub network has been made. The corresponding equilibrium in this stage is shown as Table 2-b. Comparing with the equilibrium of the Inter-hub network where each hub-airport simply maximizes the profits (Table 4 where $\beta=0$)), we have some different results shown as Table 6-b. In this case, the hub-airport competition and the corresponding airline competition will lower the full cost of each routing, increase total demand (the sum of both routing demands), thus increase the consumer surplus of passengers. On the other hand, even though the profits of Airline 1 decrease, it is dominated by the increase of the consumer surplus. As a result, the social welfare of the home country improves (all comparisons have been done in Appendix C).

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Appendix A: Comparison in Equilibrium I*

$t_D^{I*} - t_B^{I*} = \Phi\cdot(2+b)^2\cdot(2-b^2)\cdot\beta$ (A1)

$p_2^{I*} - p_1^{I*} = \Phi\cdot[-(1+b)(2+b)(2-b^2)]\cdot\beta$ (A2)

$(p_2^{I*} + t_D^{I*}) - (p_1^{I*} + t_B^{I*}) = \Phi\cdot(2+b)(2-b^2)\cdot\beta$ (A3)

Appendix B: Comparison of equilibrium I* (where $\beta \geq 0$) and Equilibrium m*

$t_B^{I*} - t_B^{m*} = [1/(1-b)]\cdot\Phi\times$
$[(16+0b-8b^2-2b^3-2b^4+b^5)-(16+0b-16b^2-2b^3+2b^4+b^5)\cdot\beta]$ (B1)

$t_D^{I*} - t_B^{m*} = [1/(1-b)]\cdot\Phi\times$
$[(16+0b-8b^2-2b^3-2b^4+b^5)-(8+0b-6b^2+0b^3-b^4)\cdot\beta]$ (B2)

$p_1^{I*} - p_1^{m*} = [1/(1-b)]\cdot\Phi\times$
$[-(8+4b-2b^2-4b^3-2b^4+b^5)+(8+2b-8b^2-3b^3+b^4+b^5)\cdot\beta]$ (B3)

$p_2^{I*} - p_1^{m*} = [1/(1-b)]\cdot\Phi\times$
$[-(8+4b-2b^2-4b^3-2b^4+b^5)+(4+0b-2b^2+0b^3-b^4)\cdot\beta]$ (B4)

$(p_1^{I*} + t_B^{I*}) - (p_1^{m*} + t_B^{m*}) = \Phi\cdot[2(4+2b-b^2)-(8+6b-2b^2-b^3)\beta]$ (B5)

$(p_2^{I*} + t_D^{I*}) - (p_1^{m*} + t_B^{m*}) = \Phi\cdot[2(4+2b-b^2)-4(1+b)\beta]$ (B6)

$(x_1^{I*} - x_1^{m*}) = \Phi\times[-(8+12b-6b^2-10b^3+0b^4+b^5)+(1+b)(8+2b-8b^2-b^3+b^4)\cdot\beta]$ (B7)

$(x_1^{I*} + x_2^{I*}) - x_1^{m*} = (1-b)\cdot\Phi\times$
$[-b(8+8b-6b^2+0b^3-b^4)+(1+b)(4+6b+0b^2-b^3)\cdot\beta]$ (B8)

$CS^{I*} - CS^{m*} \equiv \triangle CS = [\Phi^2/2]\cdot[-(T\beta^2 - V\beta + W)]$ (B9)

where $T \equiv (1+b)^2\cdot(48+0b-52b^2+0b^3+12b^4+0b^5-b^6) > 0$

$V \equiv 2(1+b)(4+2b-b^2)(24+12b-20b^2-8b^3+2b^4+b^5) > 0$

$W \equiv (4+2b-b^2)^2\cdot(8+8b-4b^2-4b^3-b^4) > 0$

when $\beta = 0$ $\triangle CS = [\Phi^2/2]\cdot[-W] < 0$

$\beta = 1$ $\triangle CS = [a-(1-b)\theta]^2\cdot[(4+8b+5b^2)/32] > 0$

$W_J^{I*} - W_J^{m*} \equiv \triangle W_J = [\Phi^2/2]\cdot[-(X\beta^2 - Y\beta + Z]$ (B10)

where $X \equiv (1+b)(48+80b-28b^2-76b^3-4b^4+16b^5+b^6-b^7) > 0$

$Y \equiv 2(4+2b-b^2)(8+28b+8b^2-22b^3-10b^4+2b^5+b^6) > 0$

$Z \equiv b(4+2b-b^2)^2\cdot(8+0b-4b^2-b^3) > 0$

when $\beta = 0$ $\triangle W_J = [\Phi^2/2]\cdot[-Z] < 0$

$\beta = 1$ $\triangle W_J = [a-(1-b)\theta]^2\cdot[(4-b^2)/32] > 0$

Appendix C: Comparison of equilibrium I* (where $\beta = 0$)
and equilibrium m* (where Hub－airport B simply maximize profit)

$(t_B^{I*} - t_B^{m*})_{\beta=0} = [b^2/(4-2b-b^2)]\cdot[a-(1-b)\theta] > 0$ (C1)

$$(p_1^{I*}-p_1^{m*})_{\beta=0}=-\frac{b(8+8b-8b^2+5b^3+2b^4)}{2(1-b)\cdot E}<0 \tag{C2}$$

$$[(p_1^{I*}+t_B^{I*})-(p_1^{m*}+t_B^{m*})]_{\beta=0}=-[(2-b)/2(1-b)(4-2b-b^2)]\cdot[a-(1-b)\theta]<0 \tag{C3}$$

$$(x_1^{I*}-x_1^{m*})_{\beta=0}=-[b(1-b)(2+b)/2(4-2b-b^2)]\cdot[a-(1-b)\theta]<0 \tag{C4}$$

$$[(x_1^{I*}+x_2^{I*})-x_1^{m*}]_{\beta=0}=[(4-2b-b^2+b^3)/2(4-2b-b^2)]\cdot[a-(1-b)\theta]>0 \tag{C5}$$

$$(CS^{I*}-CS^{m*})_{\beta=0}\equiv(\triangle CS)_{\beta=0}= [(16+0b-12b^2+0b^3+3b^4-b^5)/8(1-b)(4-2b-b^2)^2]\cdot[a-(1-b)\theta]^2>0 \tag{C6}$$

$$(\pi_1^{I*}-\pi_1^{m*})_{\beta=0}\equiv(\triangle\pi_1)_{\beta=0}=-\frac{b[4(1-b)(4+b-b^2)+b^3+b^4]}{4(1-b)(4-2b-b^2)^2}\cdot[a-(1-b)\theta]^2>0 \tag{C7}$$

$$(W_J^{I*}-W_J^{m*})_{\beta=0}\equiv(\triangle W_J)_{\beta=0}= \frac{(1-b)[4(1-b)(4-b^2)+8b^3+5b^4]+2b^5}{8(1-b)(4-2b-b^2)^2}\cdot[a-(1-b)\theta]^2>0 \tag{C8}$$

Q. E. D