Airline-Airport Cooperation Model in Commercial Revenue Sharing

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This study develops an evaluation model for airline-airport cooperation in commercial revenue sharing. Different combinations of cooperation between airlines and airport (“coalitions”) in a given network are analyzed. Profits of airlines and airport on every coalition are estimated based on the Nash-equilibrium outcomes of non-cooperative competition among the airlines. The result of an application example shows the same trend as the result of existing analytic approach. Commercial revenue sharing favors exclusive contract between airline and its base airport. Commercial revenue sharing can increase social welfare, but it may have negative effect on airlines that do not participate in the cooperation.

Keywords: airline-airport cooperation, commercial sharing, game theory
Classification: airline-airport relation, operation research in air transport,

1. INTRODUCTION

In the recent years, more and more airports started to form close cooperation with airlines. Both airlines and airports potentially have incentives to enter into cooperative relationship to create a win-win solution, e.g. strengthening both sides’ financial position. There are several common airline-airport types of cooperation as elaborated in Fu et al. (2011): (1) airlines as the signatory partner in the airport, (2) airline ownership over particular airport infrastructure, (3) airport’s commercial revenue sharing with airlines. While potential benefits can indeed be achieved, such cooperation can also have negative impacts. Given that airports represent one of the essential inputs for airlines, this close cooperation between an airport and a particular airline may raise anti-competitive concerns.

Recent papers by Fu and Zhang (2010) and Zhang et al. (2010) analyzed the effects of commercial revenue sharing between airlines and airports on airline competition and welfare. Airport offers to share some part of its commercial revenue, generated by the concession activities, for a fixed fee with one or more airlines. Concession activities refer to non-aeronautical operations, including shopping concessions, car parking and rental, banking and
catering, and so on. As the authors pointed out, this type of cooperation is new but becoming common.

Fu and Zhang (2010) analyze the effects of commercial revenue sharing in two situations: single airport served by single airline, and single airport served by multiple airlines. In the first case, concession revenue sharing improves welfare as well as the joint profits of the airport and airline. In the second case, there may be either equal revenue sharing, which increase the airport’s profit and welfare, or a situation where only one of the airlines shares revenues, thus increasing this airline’s profits while decreasing the outsider’s profits. Moreover, they also show that when one airline has a cost advantage, the airport will share revenue with this airline only.

Zhang et al. (2010) extended the study of commercial revenue sharing into cooperation between multiple airlines and multiple airports. The airport competition results in a higher degree of revenue sharing than would be had in the case of single airports. Moreover, they analyze the relation between the degrees of revenue sharing and how airlines’ services are related to each other (complements, independent, or substitutes). When carriers provide strongly substitutable services to each other, revenue sharing improves profit but reduces social welfare.

We aim to further study this particular airline-airport cooperation. We propose a game theory-network model that calculates outcome of commercial revenue sharing for different combination of cooperation between airport and airlines (“coalitions”). This model has practicality advantage. It can be applied to relatively realistic network involving n-number of airlines and airport. The model aims to serve as an evaluation tool to assist policy makers in assessing the effect of airline-airport cooperation. The model follows similar principles as the analytical approach developed by Fu and Zhang (2010).

The model consists of three main steps: (1) define coalitions that will be evaluated in a given network, (2) determining optimal airlines’ fares and flight frequencies for every coalition based on non-cooperative-Nash game, (3) estimating the value of coalitions, that is defined as the total additional profit gained by cooperating airport and airline(s). We provide example to illustrate model’s performance and applicability in practice.

There have been several researches that utilized network-based models with non-cooperative game theory approach. Some of them are Hansen (1990), Hong and Harker (1992), Dobson and Lederer (1993), Adler (2001, 2005), Wei and Hansen (2007), and Li et al. (2010). Other researchers used network-based model with cooperative game theory in order to evaluate airline mergers and alliances, e.g. Shyr and Kuo (2008) and Shyr and Hung (2010).

The rest of the paper is organized as follows. Section 2 explains basic set up and assumption, model formulation. Section 3 gives an application example and analysis. Section 4 concludes the study.
2. MODEL DEVELOPMENT

2.1 Network Set-up

Airlines’ network is pre-given in this model. An airline network consists of a set of nodes/airports \( n \). Each node represents an origin and also a destination. Each node is interconnected to each other by two-way arc/flight legs \( a \). A route \( k \) is defined as an airline’s path in serving a particular origin-destination pair \( m \). A route consists of set of arcs. Figure 1 illustrates a simplified airlines’ network where there are three nodes, three origin-destination (OD) pairs, and every route consists of maximum two flight legs.

Passenger flow in every route is calculated in one-directional flow. Operational profit received by airlines and airports are operational profit from one-directional process; it is assumed that arrival and departure processes generate the same amount of revenue and cost.

![Figure 1. Airline network example](image-url)

Define the coalitions that will be evaluated

Determine airlines’ optimal airfare and flight frequency in every coalition

Airlines’ market share

Airlines’ profit maximization

Estimate the value of coalitions

![Figure 2. Model steps](chart-url)
2.2 Model Formulation

The model is divided into three main steps as shown in Figure 2. The model captures interactions between passengers, airlines, and airports.

**Step 1.** Define the coalitions that will be evaluated.

Coalition is defined as different combination of cooperating airlines and airports in the given network. Each coalition is characterized by its worth/value, i.e. a real number representing the payoff or utility that the coalition can achieve if it forms. Based on the intended coalitions, define $\delta_{n}^{i}$ that represents the strategy of airline $i$ toward airport $n$. If airline $i$ decides to cooperate with airport $n$, $\delta_{n}^{i} = 1$, otherwise 0.

As an example, we analyze coalitions for every airport. Every coalition $S$ includes one airport and set of airlines that agree to cooperate with that particular airport, $S = (AP_{n}, AL_{i} \ldots AL_{I}) \forall n = 1, \ldots N; i = 1, \ldots I$, where $AP$ denotes airport and $AL$ denotes airline. The coalitions are shown in Table 1.

**Step 2.** Calculate the optimal airline frequency and airfare for every coalition based on Cournot-Nash non-cooperative game among airlines.

Airline maximizes their individual profit by competing in price and flight frequency. Decision to cooperate through commercial revenue sharing influences both airport and airline profit functions, and consequently influences the airlines’ optimal frequency and airfare. There are two sub-models in this step:

a) *Airlines’ market share*

Airline market share is determined by passenger perceptions over travel disutility of available routes and operating airlines. We follow multinomial logit formulation described by
Takebayashi and Kanafani (2005) and Li et al. (2010). The main purpose of this sub-model is to define airline’s passenger flow on every route between OD pair \((q_{mk}^i)\).

\[
q_{mk}^i = q_m \frac{\exp(-\theta u_{mk}^i)}{\sum_k \sum_i \exp(-\theta u_{mk}^i)}, \quad \forall k \in K_m^i
\]  

(1)

Parameter \(\theta\) represents the variation in passenger perceptions of travel disutility. The components that define travel disutility \((u_{mk}^i)\) are basic airfare \((p_{mk}^i)\), monetary units of travel time \((t_{mk}^i)\), scheduled delay time \((d_{mk}^i)\), and connection time \((r_{mk}^i)\) if the route consist of more than one flight leg (indirect flight).

\[
u_{mk}^i = \alpha \varphi(t_{mk}^i + \alpha d_{mk}^i + r_{mk}^i) + p_{mk}^i, \quad \forall k \in K_m^i
\]  

(2)

Travel time of a route is the sum of the travel time of all its arcs; \(\lambda_{mk_a}\) equals 1 if arc \(a\) is on route \(k\) and OD pair \(m\), and 0 otherwise. The same rule applies for passenger scheduled delay time. Passenger scheduled delay time is defined as the difference between the time at which a passenger desires to travel and the time at which he or she can actually travel due to inflexibility of the airline’s schedule. It can be approximated as a quarter of the average headway (Kanafani and Ghobrial, 1985), \(f_a^i\) denotes the flight frequency of airline \(i\) in arc \(a\).

\[
d_{mk}^i = \sum_{a \in A} d_{mk_a}^i \lambda_{mk_a}, \quad \forall k \in K_m^i
\]  

(3)

\[
t_{mk}^i = \sum_{a \in A} t_{mk_a}^i \lambda_{mk_a}, \quad \forall k \in K_m^i
\]  

(4)

\[
d_{mk}^i = T \frac{1}{4f_a^i}, \quad \forall a \in A^i, \ i \in I
\]  

(5)

To capture the response of passengers to the level of airfare and frequency, the exponential demand function is used, as has been done by Li et al. (2009, 2010).

\[
q_m = q_m^0 \exp(-\beta \varphi_m), \quad \forall m \in M
\]  

(6)

\[
\varphi_m = -\frac{1}{\theta} \ln \left( \sum_i \sum_k \exp(-\theta u_{mk}^i) \right), \quad \forall m \in M
\]  

(7)

Variable \(q_m^0\) denotes the potential passenger demand between OD pair \(m\). Parameter \(\beta\) denotes the demand sensitivity to the travel disutility by OD pair, and \(\varphi_m\) denotes the expected disutility between OD pair \(m\).

b) **Airlines’ profit maximization**

Airline profit is defined as the sum of profit gained from travel service and profit gained from agreed commercial revenue sharing with airport. Profit gained from travel service is
defined as the difference between total revenue from passenger airfares and the total costs on all of the routes that the airline operates on. Profit gained from commercial revenue sharing is dependent on the revenue shares given to the airline \((r_i^i)\).

For set of \((r_n^i, r_n^{-i})\), profit of airline \(i\) can be expressed as:

\[
\begin{align*}
\pi_i(x_i, x_{-i}) &= \sum_m \sum_k p_{mk}^i q_{mk}^i - \sum_m \sum_k \sum_a (c_a^i f_a^i \lambda_{mka}^i + g_a^i q_a^i \lambda_{mka}^i) \\
&\quad + \sum_n \delta_n^i r_n^i h_n (\sum_i q_a^i \sigma_{an}) - b_n^i (r_n^i, r_n^{-i}),
\end{align*}
\]

(8)

where \(x_i = (p_i, f_i)\) is vector of airfare and frequency of airline \(i\), and \(x_{-i} = (p_{-i}, f_{-i})\) is vector of airfares and frequencies of other airlines excluding \(i\).

Costs considered in here are direct operating costs that dependent on number of flight and passengers flown. Cost per passenger is notified as \(g_a^i\), and \(q_a^i\) represents passengers flow on arc \(a\) by airline \(i\). Cost per flight in every arc \(c_a^i\) can be defined using functions such as Cobb-Douglas or translog that capture economic density and flight distance. Swan and Adler (2006) gives practical approach to calculate cost per flight on spoke level as a function of flight distance \((D_n)\) and aircraft size \((s_a)\), as shown in Eq. (9); \(\omega_a\), \(\omega_1\) and \(\omega_2\) are parameters cost function parameters based on engineering generated data. This formulation only considered one type of aircraft on every arc, but this can be improved with minor modification.

\[
c_a^i = (D_a + \omega_a)(s_a^i + \omega_1)\omega_2, \quad \forall a \in A^i
\]

(9)

\[
q_a^i = \sum_m \sum_k q_{mk}^a \lambda_{mka}^i, \quad \forall a \in A^i, i \in I
\]

(10)

The part \(\sum_n \delta_n^i r_n^i h_n (\sum_i q_a^i \sigma_{an}) - b_n^i (r_n^i, r_n^{-i})\) represents profit gained from commercial revenue sharing, where \(r_n^i\) denotes share of airline \(i\), \(h_n\) denotes commercial revenue per passenger, and \(\sum_i \sum_a q_a^i \sigma_{an}\) represents total number of passengers that embark/disembark in the airport \(n\). Variable \(b_n^i (r_n^i, r_n^{-i})\) represents the payment paid by airline \(i\) to the airport according to the agreed revenue shares. This payment is calculated from the percentage \((w_i)\) of ‘reservation price’ \((\Delta \pi_i^C)\). Reservation price is maximum payment that airport can charge, that is when the airline is indifferent between sharing revenue or not given that all the other airlines’ decisions stay the same (Fu and Zhang, 2010).

\[
b_n^i (r_n^i, r_n^{-i}) = w_i \Delta \pi_i^C = w_i (\pi_i^C (r_n^i, r_n^{-i}) - \pi_i^0 (0, r_n^{-i}))
\]

(11)
\[
\pi_i^C(x_i, x_{-i}) = \sum_{m} \sum_{k} p^i_m q^i_k - \sum_{m} \sum_{k} \sum_{a} (c^i_a f^i_a \lambda^i_{mka} + g^i_a q^i_a \lambda^i_{mka}) + \sum_{n} \delta^i_n h^n (\sum_{a} q^i_a \sigma_{an})
\] (12)

Based on this previously defined cost, market share and commercial revenue sharing function, we can find directly the effects of cooperation on airlines’ and airport’s profit for every different coalition. Cournot-Nash non-cooperative game can be used to find airlines’ rational strategic choices of airfare and service frequency under the profit maximization assumption:

\[
\text{Max } \pi_i(x_i, x_{-i}), \forall i
\] (13)

subject to:

\[
q^i_a \leq s^i_a f^i_a, \forall a, i
\] (14)

\[
\sum_{i} \sum_{a} f^i_a \sigma_{an(d)} \leq y_{n(d)}, \forall n
\] (15)

At equilibrium, no airline has an incentive to deviate or change its decision variables given all other airlines’ decisions. Unless \( b \) is a very large number, maximization of \( \pi_i^C(x_i, x_{-i}) \) and maximization of \( \pi_i(x_i, x_{-i}) \) reach the same equilibrium. Therefore, in order to obtain \( x = (p, f) \), it is suggested to solve the maximization of \( \pi_i^C(x_i, x_{-i}) \) instead of \( \pi_i(x_i, x_{-i}) \).

The first constraint ensures the passenger flow on arc \( a \) is less than total seat capacity offered. The second constraint ensures the total number of arrivals (departures) must not exceed the available quota of the destination (origin) airports. To solve airlines profit maximization problem with constraints, we utilize Lagrangian relaxation approach and penalty function, as previously done by Li et al. (2010). The Lagrangian and penalty function incorporate the constraints into the objective function. To find the equilibrium solutions for the airlines’ airfares and service frequencies we use heuristic solution algorithm utilizing Hooke-Jeeves method. This process is done for every subset.

**Step 3.** Calculate the value of coalitions.

Airline-airport cooperation in commercial revenue sharing can be seen as cooperative game with transferable utility. It is assumed that the value of a coalition can be expressed by one number, e.g. as amount of money, which can be distributed among the members of the coalition. In this study, value of coalition is defined as total additional profit gained by cooperating airport and airline(s) based on the agreed revenue shares.

\[
v(S) = \Delta \Pi_n (r^i_n, r^{-i}_n) + \sum_i \Delta \pi_i (r^i_n, r^{-i}_n) \quad \forall n, i \in S
\] (17)

\[
\Delta \Pi_n = \Pi_n (r^i_n, r^{-i}_n) - \Pi^0_n (0, \ldots, 0)
\] (18)

\[
\Delta \pi_i = \pi_i (r^i_n, r^{-i}_n) - \pi^0_i (0, \ldots, 0)
\] (19)
Airline profit function is expressed in Eq. 8, while airport profit function for set of \((r^i, r^{-i})\), is expressed as
\[
\Pi_n = \sum_{i} \sum_{a} q^i_a z^i_n \sigma_{an} + \sum_{i} \sum_{a} f^i_a l^i_n \sigma_{an} + (1 - r^i) h_n \left( \sum_{i} \sum_{a} q^i_a \sigma_{an} \right) + b_n (r^i, r^{-i}), \forall n \tag{20}
\]
where \(z^i_n\) denotes airport aeronautical-related gain for every passenger and \(l^i_n\) denotes airport aeronautical-related gain for every flight in one-direction process. Subsequently, social welfare \((SW)\) can be calculated as follows:
\[
SW = \sum_n \Pi_n + \sum_i \pi_i + \sum_m q_m \beta \tag{21}
\]

3. APPLICATION EXAMPLE

3.1 Setup and input data

We present an application example to illustrate the ideas. We apply the proposed model into to the network shown in Figure 1. We simplify the situation by involving only two airlines and three airports in Southeast Asia. Input parameters are listed in Table 2, 3, 4. Capacity in every airport \((y_n)\) is assumed equal to 20. This capacity is considered acceptable to accommodate two airlines. The aircrafts that serve every arc are assumed to be narrow-body aircrafts that have 175 passenger seats. Airlines’ index \((i)\): 1 = Singapore Airlines (SQ); 2 = Garuda Indonesia (GA); 3 = Thai Airways (TH). Airports’ index \((n)\): 1 = SIN; 2 = CGK; 3 = BKK.

Other input parameters are obtained from previous literatures as follow: \(\alpha_{vol} = 20.5\) hour/$, and \(\alpha = 1.3\) (Hsu and Wen, 2003); \(\theta = 0.02\) (Takebayashi and Kanafani, 2005); \(\beta = 0.003\) (Li et al., 2007); \(\omega_r = 722, \omega_l = 104,\) and \(\omega_s = 0.019\) (Swan and Adler, 2006); \(g^i_a = 20\) $/passenger \(\forall a, i\) (Oum and Yu, 1998), \(T = 18\) hours, \(h_n = 100\) $/passenger.

<table>
<thead>
<tr>
<th>OD pair ((m))</th>
<th>Daily demand ((q^m_m))</th>
<th>Routes ((k))</th>
<th>Operating Airlines ((i))</th>
<th>Avg Price ((US$) (p^i_{mk}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily demand ((q^m_m))</td>
<td>Routes ((k))</td>
<td>Arcs ((a))</td>
<td>Operating Airlines ((i))</td>
</tr>
<tr>
<td>1</td>
<td>4,500</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3,000</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 3. Airport charges and capacity, flight time and airlines’ frequency

<table>
<thead>
<tr>
<th>Airport</th>
<th>(z_{n}^{1}) (\forall i) (US$)</th>
<th>(l_{n}^{1} i) (\forall i) (US$)</th>
<th>(y_{n})</th>
<th>Arcs ((a))</th>
<th>(l_{a}^{1} i) (\forall i) (hour)</th>
<th>(D_{a}) (km)</th>
<th>(f_{ia}) (i = 1)</th>
<th>(f_{ia}) (i = 2)</th>
<th>(f_{ia}) (i = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.9</td>
<td>1,238</td>
<td>20</td>
<td>1</td>
<td>1.75</td>
<td>879</td>
<td>8</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>14.5</td>
<td>992</td>
<td>20</td>
<td>2</td>
<td>2.42</td>
<td>2,295</td>
<td>8</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>13.5</td>
<td>1,125</td>
<td>20</td>
<td>3</td>
<td>3.42</td>
<td>1,409</td>
<td>-</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

3.2 Result and Analysis

3.2.1 Flight frequency and airfare

The airline’s response toward cooperation is reflected in their prices and flight frequencies. This is solved by the Hooke-Jeeves algorithm. The basic idea of the algorithm is to solve the profit maximization for each airline separately and sequentially, holding the decision variables of the other airlines fixed in turn until the sequence converges. Therefore, the price and frequency of an airline alters from no-cooperation state only if that particular airline cooperates. In other words, the price and frequency of one airline are independent from other airlines’ decisions to cooperate.

Figure 3. a, b, c. Trend of flight frequency when revenue shares \((r)\) increases

Note: \(p_{im}\) and \(f_{im}\) denotes price and frequency of airline \(i\) in OD pair \(m\)
When airline acquires a share of airport’s commercial revenue, the airline gets additional incentive for every passenger that embarks/disembarks in the particular airport. Thus, it is expected that the airline will adjust its flight frequency and airfare in order to exploit this potential benefit. As the revenue share \( r \) increases, airline has a propensity to increase flight frequency in arc that is connected to the cooperating airport. Figure 3 and 4 show the trend of flight frequency when airline cooperates with its base airport. As an increasing percentage of commercial shares, airline’s output rises while the price adjusts accordingly. For indirect flight, the price tends to decrease significantly.

### 3.2.2 Value of Coalition

Value of coalition is highly dependent on two factors: proportion of commercial revenue being shared and number of cooperating parties. A higher commercial revenue share \( r \) brings higher additional profit. However, as a higher proportion of revenue is shared, airlines may expand output (increase frequency) too much, such that their profits fall, e.g. when \( AL_1 \) cooperates with \( AP_1 \), the total additional profit at \( r = 0.9 \) is lower than at \( r = 0.8 \). The value of coalition is higher when airline cooperates with its base airport than when airline cooperates with other airport, basically because airline brings more passengers to the base. The industry profit decreases as the number of cooperating airlines increases because more airlines are motivated to bring more passengers, i.e. airlines set a competitive flight frequency and airfare. We limit our analysis to all airlines receive equal percentage of revenue shares \( r_n^i = r_{n-j} \).
Note: $\Delta \pi_i$ and $\Delta \Pi_n$ denote the airline’s and airport’s additional profit from travel service; $h_{in}$ denotes the commercial earning in airport n per airline i’s passenger.

Figure 5. a - f. Additional profits as a result of cooperation

We calculate total additional profits of airlines and airport for every 10% increase of $r$. We identify $r^*$ that gives highest additional profits (see Table 4). Airline and airport potentially agree to cooperate if their profits after cooperation are higher than their profits before cooperation. The
issue here is to divide the earnings obtained from cooperation to each member of coalition such that each member gets benefit. Variable $w_i$ is utilized to distribute the additional profit to the cooperating airline(s) and airport. The higher value of $w_i$ resulted in higher payment to the airport; $w_i = 1$ means airline pays its ‘reservation price’. For every coalition and agreed $r$, $w_i$ can be set such that all cooperating airport and airline(s) do not become worse off after cooperation ($\Delta \Pi_n \geq 0$ and $\Delta \pi_i \geq 0 \forall i, n \in S$), see Appendix.

Commercial revenue sharing increases cooperating airline’s marginal revenue and so encourages airline to expand output, which in turn benefits travelers and improve welfare. Positive effect on welfare is achieved because commercial revenue sharing allows the airport and the airline to internalize the positive demand externality between aeronautical and non-aeronautical services (Fu and Zhang, 2010). However this benefit exists at cost of competition. Airline that does not cooperate is disadvantaged, in terms of market share and profit.

Table 4. Value of coalition

<table>
<thead>
<tr>
<th>Coalition</th>
<th>$r^*$</th>
<th>$w_i$ (example)</th>
<th>Additional Profit</th>
<th>$v(S)$</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$AL_1$</td>
<td>$AL_2$</td>
<td>$AL_3$</td>
</tr>
<tr>
<td>No cooperation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>${AP_1, AL_1}$</td>
<td>0.8</td>
<td>0.9</td>
<td>47,566</td>
<td>-44,429</td>
<td>-43,838</td>
</tr>
<tr>
<td>${AP_1, AL_2}$</td>
<td>0.8</td>
<td>0.95</td>
<td>-39,343</td>
<td>19,936</td>
<td>-8,391</td>
</tr>
<tr>
<td>${AP_1, AL_3}$</td>
<td>0.9</td>
<td>0.98</td>
<td>-14,691</td>
<td>4,178</td>
<td>8,290</td>
</tr>
<tr>
<td>${AP_1, AL_1, AL_2}$</td>
<td>0.5</td>
<td>0.87</td>
<td>4,162</td>
<td>22,105</td>
<td>-18,598</td>
</tr>
<tr>
<td>${AP_1, AL_1, AL_3}$</td>
<td>0.5</td>
<td>0.925</td>
<td>11,559</td>
<td>-9,355</td>
<td>6,212</td>
</tr>
<tr>
<td>${AP_1, AL_2, AL_3}$</td>
<td>0.5</td>
<td>0.94</td>
<td>-36,818</td>
<td>18,182</td>
<td>5,952</td>
</tr>
<tr>
<td>${AP_1, AL_1, AL_2, AL_3}$</td>
<td>0.3</td>
<td>$w_1 = 0.82$; $w_2 = 0.97$; $w_3 = 0.89$</td>
<td>110</td>
<td>288</td>
<td>493</td>
</tr>
<tr>
<td>${AP_2, AL_1}$</td>
<td>0.9</td>
<td>0.97</td>
<td>11,514</td>
<td>-18,805</td>
<td>253</td>
</tr>
<tr>
<td>${AP_2, AL_2}$</td>
<td>1</td>
<td>0.88</td>
<td>-10,384</td>
<td>55,844</td>
<td>-17,566</td>
</tr>
<tr>
<td>${AP_2, AL_3}$</td>
<td>1</td>
<td>0.97</td>
<td>1,959</td>
<td>-15,106</td>
<td>12,754</td>
</tr>
<tr>
<td>${AP_2, AL_1, AL_2}$</td>
<td>0.5</td>
<td>0.957</td>
<td>14,682</td>
<td>131</td>
<td>-300</td>
</tr>
<tr>
<td>${AP_2, AL_1, AL_3}$</td>
<td>0.5</td>
<td>0.975</td>
<td>6,380</td>
<td>-16,199</td>
<td>6,089</td>
</tr>
<tr>
<td>${AP_2, AL_2, AL_3}$</td>
<td>0.5</td>
<td>0.96</td>
<td>6,495</td>
<td>1,034</td>
<td>7,426</td>
</tr>
<tr>
<td>${AP_2, AL_1, AL_2, AL_3}$</td>
<td>0.3</td>
<td>$w_1 = 0.97$; $w_2 = 0.92$; $w_3 = 0.96$</td>
<td>3,235</td>
<td>1,058</td>
<td>2,908</td>
</tr>
<tr>
<td>${AP_3, AL_1}$</td>
<td>1</td>
<td>0.97</td>
<td>9,053</td>
<td>-354</td>
<td>-16,447</td>
</tr>
<tr>
<td>${AP_3, AL_2}$</td>
<td>0.3</td>
<td>0.85</td>
<td>-23,590</td>
<td>17,945</td>
<td>-17,308</td>
</tr>
<tr>
<td>${AP_3, AL_3}$</td>
<td>1</td>
<td>0.95</td>
<td>-21,105</td>
<td>-18,971</td>
<td>16,765</td>
</tr>
<tr>
<td>${AP_3, AL_1, AL_2}$</td>
<td>0.5</td>
<td>0.87</td>
<td>1,088</td>
<td>22,361</td>
<td>-25,827</td>
</tr>
<tr>
<td>${AP_3, AL_1, AL_3}$</td>
<td>0.4</td>
<td>0.93</td>
<td>1,131</td>
<td>-5,450</td>
<td>2,225</td>
</tr>
<tr>
<td>${AP_3, AL_2, AL_3}$</td>
<td>0.5</td>
<td>0.87</td>
<td>-27,193</td>
<td>14,592</td>
<td>3,071</td>
</tr>
</tbody>
</table>
Note: $r^*_i$ represents revenue share that maximizes value of coalition (total additional profits). We set $r_i$ equal for all cooperating airlines; $w^{**}$ is calculated such that all cooperating parties do not become worse off, we set the equal value of $w$ for all airlines, except when there are more than two airlines in the coalition.

The formulations involve large number of factors that potentially affect the conclusions regarding airline-airport cooperation. Beside the revenue shares ($r$), some of the significant factors are: airport’s aeronautical charges, commercial revenue per passenger, airport capacity and airline’s cost efficiency. There is a need to do a comprehensive sensitivity analyses to see how each factor affect the model result.

Fu and Zhang (2010) have explained some of the factors’ effect analytically. Airport can enhance its profit by increasing airport’s charges, even when the positive externality of concession revenue has been internalized by commercial revenue sharing. As for airline’s cost efficiency, when an airline has lower marginal cost per passenger and/or per flight, the particular airline has the power to pay a higher price for any given revenue share ($r$). Commercial revenue per passenger ($h$) affects airlines’ marginal revenue, and consequently affects airlines and airport profits. Airport capacity limits airline’s ability to increase output.

<table>
<thead>
<tr>
<th>Coalitions</th>
<th>$r$</th>
<th>$v(S);$</th>
<th>$v(S);$</th>
<th>$v(S);$</th>
<th>$v(S);$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$h = 8$</td>
<td>$h = 25$</td>
<td>$h = 50$</td>
<td>$h = 100$</td>
</tr>
<tr>
<td>{AP1, AL1}</td>
<td>0.8</td>
<td>2,156</td>
<td>7,981</td>
<td>26,755</td>
<td>135,096</td>
</tr>
<tr>
<td>{AP1, AL2}</td>
<td>0.8</td>
<td>-157</td>
<td>3,370</td>
<td>28,657</td>
<td>39,159</td>
</tr>
<tr>
<td>{AP1, AL3}</td>
<td>0.9</td>
<td>-530</td>
<td>892</td>
<td>3,180</td>
<td>9,400</td>
</tr>
<tr>
<td>{AP1, AL1, AL2}</td>
<td>0.5</td>
<td>936</td>
<td>4,083</td>
<td>23,399</td>
<td>30,149</td>
</tr>
<tr>
<td>{AP1, AL1, AL3}</td>
<td>0.5</td>
<td>254</td>
<td>1,946</td>
<td>7,815</td>
<td>27,486</td>
</tr>
<tr>
<td>{AP1, AL2, AL3}</td>
<td>0.5</td>
<td>684</td>
<td>3,995</td>
<td>18,883</td>
<td>29,288</td>
</tr>
<tr>
<td>{AP1, AL1, AL2, AL3}</td>
<td>0.3</td>
<td>-4,931</td>
<td>-3,307</td>
<td>-998</td>
<td>1,664</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

With trends of privatization and liberalization in air transport industry, we expect more execution of airline and airport cooperation in the near future. This study offers an alternative model to evaluate airline-airport cooperation in commercial sharing. Different combination of airlines and airport (coalition) can be analyzed. The model calculates profits on every coalition based on the equilibrium outcomes of non-cooperative competition among the airlines themselves. This model can serve as an evaluation tool. Industry can use this proposed model to
help determine the amount of commercial revenue shares \((r)\) and payment \((b)\), while policy makers can assess the impact of cooperation on competition level and social welfare.

The application example presented in Section 3 shows the same notion as the previous analytical approach. Commercial sharing favors an exclusive cooperation between airport and the dominant airline (airline that brings highest number of passengers). Commercial sharing can increase social welfare, but it may have negative effect on airlines that do not participate in the cooperation.

The model proposed in this study is subject to further improvements: (1) comprehensive sensitivity analyses, (2) to capture the different network behavior of full-service carriers and low-cost carriers.

REFERENCES


**APPENDIX**

Value of $w_i$ can be calculated such that airline and airport do not become worse off after cooperation ( $\Delta \Pi_n \geq 0$ and $\Delta \pi_i \geq 0 \ \forall \ i, n \in S$ ), $w_i$ has to meet condition in A.1 and A.2 as follows:

$$\Delta \Pi_n \geq 0$$

$$\Pi_n^C (r_n^i, r_n^{-i}) + \sum_{i} w_i \Delta \pi_i^C - \Pi_n^0 \geq 0$$

$$\sum_{i} w_i \Delta \pi_i^C \geq \Pi_n^0 - \Pi_n^C (r_n^i, r_n^{-i}) \quad (A.1)$$

$$\Delta \pi_i \geq 0$$

$$\pi_i^C (r_n^i, r_n^{-i}) + w_i \Delta \pi_i^C - \pi_i^0 \geq 0$$

$$w_i \leq \frac{\pi_i^C (r_n^i, r_n^{-i}) - \pi_i^0}{\Delta \pi_i^C} \quad (A.2)$$

where,
\[ \pi_i^c(x_i, x_{-i}) = \sum_{m} \sum_{k} p_{mk}^i q_{mk}^i - \sum_{m} \sum_{k} \sum_{a} \left( c_a^i f_a^i \lambda_{nka} + g_a^i q_a^i \lambda_{nka} \right) + \sum_{n} \delta_n^i r_n^i h_n \left( \sum_{a} q_a^i \sigma_{an} \right), \]

\[ \Pi_n^c = \sum_{i} \sum_{a} q_{a}^i \sigma_{an} l_n^i + \sum_{i} f_a^i l_n^i \sigma_{an} + (1 - r_n^i) h_n \left( \sum_{a} q_a^i \sigma_{an} \right), \text{ and} \]

\[ \Delta \pi_i^c = \pi_i^c(r_n^i, r_n^{-i}) - \pi_i^0(0, r_n^{-i}) \]