Service Quality's Effects on the Selection of a Partner Airline in the Formation of Airline Alliances*

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Abstract Airline alliance has become a prominent feature in the competitive airline industry. However, most research in this field focuses on the revenue management or pricing mechanism, rather than the initial intent of an airline alliance: providing a network of connectivity and convenience for international passengers and convenient marketing branding to facilitate travelers making inter-airline codeshare connections within countries. The main concern in this paper is how an airline's service quality might affect the selection of its partner airline during the formation of airline alliances. The main contribution is to show the strategic effects of the service quality on the proposed complementary airline alliances following a three-stage analysis framework, where the pre-alliance industry of the potential alliance members can either be monopoly or duopoly. We find that an airline will cooperate with the one which has the same service quality level if the pre-alliance service quality distribution of the airlines in the whole market differs greatly, while it tends to choose the one with similar (either higher or lower) service quality level as its partner if the distribution is approximately uniform.

Keywords: airline alliances, service quality, three-stage analysis framework.

1. Introduction

An airline alliance is an agreement between two or more airlines to cooperate on a substantial level (e.g., codeshare flights, ticketing systems, maintenance facilities, ground handling personnel, check-in and boarding staff, and etc.) to provide a network of convenient and seamless connectivity for passengers. At present, most major airlines belong to one of the three big airline alliances: *Star Alliance*, *Oneworld*, and *SkyTeam*. One of the fundamental building blocks of an airline alliance is the codeshare flights. Codeshare is an aviation business agreement where two or more airlines share the same flight. A seat purchased from one airline's ticketing system is actually operated by its partner airline under a different flight number or code. Take three big Asian airlines of Star Alliance as an example, passengers' demand from Tokyo (NRT) to Beijing (PEK) can be satisfied either by a direct flight under ANA (NH), or an optional transit flight with the first leg Tokyo (NRT) to Seoul (ICN) by Asiana Airlines (OZ), and the second leg Seoul (ICN) to Beijing (PEK)

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by Air China (CA). Under codeshare agreement, this interline product is marketed by both Asiana Airlines and Air China, and generates profit for both carriers.

Airline alliances can be categorized from different aspects, i.e., commercial or strategic, passenger or cargo, and etc. From the competitiveness of the pre-alliance market, it can be classified as parallel or complementary (Park, 1997). A parallel alliance refers to collaboration between two or more airlines competing on the same route. The pre-alliance market is duopoly or oligopoly. The complementary alliance refers to the case where two airlines link up their existent networks providing an interline service to the passengers, where the pre-alliance market might be monopoly. In reality, two airlines might form both a parallel and a complementary alliance. The example of Asiana Airlines (OZ) and Air China (CA) mentioned above is complementary, while in fact the second leg is usually under a codeshare flight by Asiana Airlines (OZ) and Air China (CA), in this case, the two airlines are parallel from Seoul (ICN) to Beijing (PEK). In this paper, we focus on the complementary alliance, and leave parallel alliance as a future extension.

The existing literature on airline alliance is quite sparse and limited. One classical research is to provide hypothesis and reasons under which hub-and-spoke networks are equilibrium structures, i.e., Hendricks et al., 1997; Berry et al., 2006; Aguirregabiria and Ho, 2012. Recent trend is focusing on the revenue management and sharing aspect, i.e., Vinod, 2005; Chen et al., 2010; Wright et al., 2010. However, little attention has been paid to the initial intent to form an airline alliance: better service quality for passengers. The delivery of high service quality is essential for airlines' survival and competitiveness. One of the distinguishing features of our paper is to discuss about the service quality's effects on the formation of airline alliances.

Service quality is a consumer's overall impression of the relative inferiority and superiority of the organization and its services (Bitner and Hubbert, 1994). Airline service quality is different from services in other industries, comprising tangible and intangible attributes, i.e., seat pitch and size, in-flight service, service frequency, on time performance, and etc. It can be evaluated by the five-star quality rating system. The idea that the service quality has an important effect on the selection of alliance partners came from the member airlines' service quality rating data for the three big alliances[1]:

Table 1: Service quality rating data.

Rating	*Star Alliance* (28 members)	*Oneworld* (12 members)	*SkyTeam* (19 members)	Other
5-Star	40%	20%	0%	40%
4-Star	29.03%	12.9%	12.9%	45.17%
3-Star	13.93%	4.91%	9.01%	72.15%
2-Star	0%	0%	0%	100%
1-Star	0%	0%	0%	100%

The rest of the industry belongs to none of the airline alliances above. We can see that these three main alliances do not accept airlines rating lower than

[1] Data source: IATA, as of June 2012

3 as its member, and the average service quality rate of Star Alliance is obviously higher than that of the other two alliances, which indicates that the service quality of an airline affects to some extent on the alliance formation. Airlines with high service quality tend to cooperate with each other. As to the literature we know, this is the first paper analyzing its effect on the selection of alliance partners by our proposed three-stage analysis framework, namely pre-alliance equilibria analysis, alliance equilibria analysis and criteria verification.

Colonques and Fillol, 2005 analyzes the profitability of two alliances from the pricing aspect. Their model is less general because of the specific assumption of monopoly pre-alliance market. Another feature of our paper is a general network topology allowing for both monopoly and duopoly pre-alliance market. The analysis and conclusion for oligopoly pre-alliance market is similar but a little bit complicated compared to that of the duopoly one, which is an important extension to pursue in the future.

The rest of our paper is organized as follows: in Section 2, we describe our general network model. Section 3 exposes the three-stage analysis framework for three types of pre-alliance market: Monopoly–Monopoly, Monopoly–Duopoly, and Duopoly–Duopoly. The optimal strategy for each airline is discussed in Section 4, and our concluding remarks and extensions are presented in Section 5.

2. General network model

2.1. Network

We consider a simple network with 3 airports A, B, and C. There is direct flight(s) between airport A and B, also B and C, but no direct flight between A and C. Passengers wishing to fly from A to C (or C to A) have to transit once in airport B. The airline industry of A–B, and B–C can either be monopoly or duopoly, then three types of basic pre-alliance markets are formed as below:

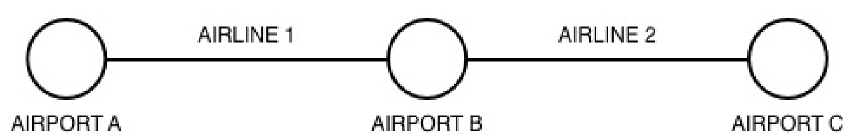

Fig. 1: Monopoly–Monopoly

There are two airlines in the Monopoly–Monopoly case, where each airline owns monopoly power in their respective market.

For the Monopoly–Duopoly case, the market of airline 1 is monopoly, while airlines 2 and 3 are competing on the same route B–C.

Finally for the Duopoly–Duopoly case, airlines 1 and 4, and airlines 2 and 3 are competing on the same route, respectively.

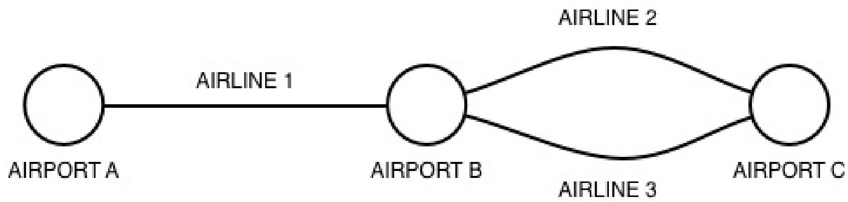

Fig. 2: Monopoly–Duopoly

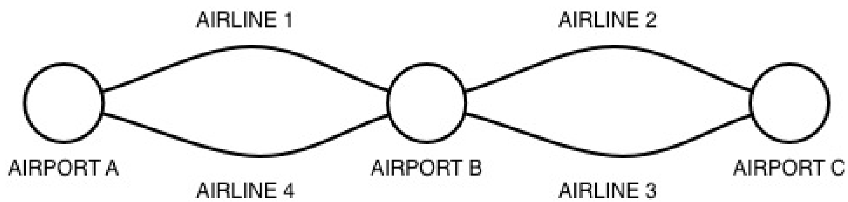

Fig. 3: Duopoly–Duopoly

2.2. Notation

We denote by $\mathcal{A}$ the set of airlines, which we index by $i = 1, 2, 3, 4$ in the analysis. Some notation that we will use to model the structure of the alliance is shown as below:

-d_i: passengers' demand for airline i.

-d_{ij}: the pre-alliance passengers' demand for market A–C, where i is the airline of market A–B, and j of market B–C.

-$d^{a_{ij}}$: passengers' demand for alliance $i - j$ if airlines i and j form an alliance. It does not include the demand for each airline's self-operated market. We assume that each airline's strategy and demand in their respective individual market are not affected by the decision of the alliance. The superscript a is used to denote quantities associated with *Alliance*.

-C_i: the overall operational cost for airline i.

-Π_i: the pre-alliance profit of airline i. Π_i^* denotes the equilibrium profit.

-$\Pi^{a_{ij}}$: the joint profit of alliance $i-j$ if airlines i and j form an alliance, including the profit generated in each airline's self-operated market. $\Pi^{a_{ij}*}$ denotes the equilibrium joint profit.

-$\Pi_i^{a_{ij}*}$,$\Pi_j^{a_{ij}*}$: the profit allocated to airline i, j respectively, if airlines i and j form an alliance.

-p_i: the fare charged for passengers by airline i.

-$p^{a_{ij}}$: the fare decided and charged jointly by alliance $i - j$ if airlines i and j form an alliance.

-$q_i = q_g$ or q_b: the service quality of airline i, which is assumed to be either q_g or q_b in this paper. The subscript g and b are used to denote "good" and "bad" service quality, respectively.

-m: a positive parameter that measures the market size.

-γ^d: a positive parameter in the demand function which measures the effect of service quality on the demand. The superscript d is used to denote the quantity associated to *Demand*. Assuming identical passengers, this effect does not differ among airlines.

-γ_i^c: a positive parameter in the cost function which measures the effect of service quality on the cost of airline i. The superscript c is used to denote quantities associated to *Cost*. We assume that $\gamma_i^c = \gamma_g^c$ if $q_i = q_g$, and $\gamma_i^c = \gamma_b^c$ if $q_i = q_b$.

θ: a positive parameter measuring the improvement of the alliance service quality over two individually operated airlines, assuming $\theta \in (1/2, 1)$.

-$\beta_i^{a_{ij}}$, $\beta_j^{a_{ij}}$: the fraction of the joint profit $\Pi^{a_{ij}*}$ collected by airline i, j respectively, if airlines i and j form an alliance, where $\beta_i^{a_{ij}} + \beta_j^{a_{ij}} = 1$. We denote by $\mathcal{R}$ the profit allocation rule, and $\mathcal{R}_p$ the proportional rule.

The rest of the notation will be introduced in the corresponding sections.

2.3. Demand and cost function

Definition 1. The demand function for airline i is linear as follows:

Monopoly market:

$$d_i = m - p_i + \gamma^d q_i \tag{1}$$

Duopoly market of airlines i and k:

$$d_i = m - p_i + p_k + \gamma^d q_i - \gamma^d q_k \tag{2}$$

In the monopoly market, the demand of airline i is decreasing with the fare it charged for passengers, and increasing with its service quality. In the duopoly market, the demand of airline i is increasing with the fare its rival k charged, and decreasing with the rival's service quality. For simplicity, we assume linear demand functions and the parameter measuring the effect of price is assumed to be 1.

Definition 2. The pre-alliance demand function of passengers between airport A and C is:

$$d_{ij} = m - (p_i + p_j) + \gamma^d (\frac{q_i + q_j}{2}) \tag{3}$$

where airline i operates route A–B, and airline j operates route B–C.

Before forming any alliance, the perceived service quality for passengers between A and C is assumed to be the average service quality of the two airlines.

Definition 3. The demand function for alliance $i - j$ is:

$$d^{a_{ij}} = m - p^{a_{ij}} + \gamma^d \theta (q_i + q_j) \tag{4}$$

where $\theta \in (1/2, 1)$.

If airlines i and j form an alliance, the perceived service quality for passengers of market A–C is higher than that before forming an alliance, for reasons like no necessity of luggage claim during transit, faster mileage accumulation, and etc. Thus we assume $\theta \in (1/2, 1)$.

Definition 4. The cost function for airline i is:

$$C_i = \gamma_i^c q_i \tag{5}$$

The alliance formation cost is neglectable compared to the operational cost, i.e., the integration of the ticketing system, share of check-in and boarding staff, and etc. It is assumed to be 0 in this paper.

2.4. Assumptions about profit allocation

In general, the proration scheme $\mathcal{R}$ used by the alliance will influence both the overall profit of the alliance and the allocated profit to each airline. We assume that the ultimate aim of each airline is to maximize its own profit. It is reasonable to assume that airlines are seeking a strategy that increases the joint profit by forming an alliance. The profit allocation mechanism is actually a bargaining problem, which is left as a future extension work. In this paper, we assume that the proportional rule $\mathcal{R}_p$ has already been chosen by the alliance, and primarily focus on examining how the service quality affects the selection of a partner airline.

Definition 5. The proportional rule $\mathcal{R}_p$ is defined as:

$$\begin{aligned}\beta_i^{a_{ij}} &= \frac{{\Pi_i}^*}{{\Pi_i}^* + {\Pi_j}^*} \\ \beta_j^{a_{ij}} &= \frac{{\Pi_j}^*}{{\Pi_i}^* + {\Pi_j}^*}\end{aligned} \tag{6}$$

2.5. Decision criteria

The fundamental questions faced by airline i with service quality q_i are:
-Whether to cooperate with another airline to form an alliance.
-If yes, which airline should be chosen as the partner.

For the first question, airline i will form an alliance with airline j only if the cooperation is to bring more profit for i than that of the pre-alliance equilibria. Both collective and individual rationality should be satisfied.

Definition 6. Collective rationality. For two airlines i and j, they are to form an alliance only if the joint profit of the alliance is more than the sum of their pre-alliance profit.

$$\Pi^{a_{ij}*} > \Pi_i^* + \Pi_j^* \tag{7}$$

Definition 7. Individual rationality. For two airlines i and j, they are to form an alliance only if the alliance profit allocated to each of them is more than that of their respective pre-alliance profit.

$$\begin{aligned}\Pi_i^{a_{ij}*} &> \Pi_i^* \\ \Pi_j^{a_{ij}*} &> \Pi_j^*\end{aligned} \tag{8}$$

However, as the proportional rule $\mathcal{R}_p$ is assumed to be adopted as the proration scheme in this paper, these two criteria coincide with each other. Only the collective rationality is to be checked in the following analysis.

For the second question, if airline i has two options, namely airlines j and k, it will select the one which brings more profit to itself as the partner. The stability of each proposed formation should be checked, and the more stable alliance will be formed.

Definition 8. Stability. For airline i with two potential partner airlines j and k, the stability of alliance $i - j$ is higher than that of alliance $i - k$ if and only if

$$\Pi_i^{a_{ij}*} > \Pi_i^{a_{ik}*} \tag{9}$$

3. Analysis: a three-stage framework

As mentioned above, we proceed to the analysis for the equilibria of three types of pre-alliance market: Monopoly–Monopoly, Monopoly–Duopoly, and Duopoly–Duopoly by our proposed three-stage framework.

3.1. Monopoly–Monopoly

For the pre-alliance Monopoly–Monopoly situation, airlines 1 and 2 both own monopoly power for the route A–B and B–C, respectively. From the service quality's perspective, each airline's rate could either be q_g or q_b, thus three cases will be analyzed:

-Case 1: $q_1 = q_g, q_2 = q_g$
-Case 2: $q_1 = q_b, q_2 = q_b$
-Case 3: $q_1 = q_g, q_2 = q_b$

It is easy to estimate that the equilibria of the first two cases are the same. Let us first give the analysis for the alliance of two airlines with high service quality.

Case 1: $\boldsymbol{q_1 = q_g, q_2 = q_g}$

Pre-alliance equilibria. We start by defining the total profit for airline i:

$$\Pi_i = p_i(d_i + d_{12}) - C_i \tag{10}$$

where d_{12} is defined by equation (3).

By differentiation, we get:

$$\Pi_1^* = \Pi_2^* = \frac{8}{25}(m + \gamma^d q_g)^2 - \gamma_g^c q_g \tag{11}$$

Alliance equilibria. If airlines 1 and 2 form an alliance, the total profit that the alliance might receive is:

$$\Pi^{a_{12}} = p_1 d_1 + p_2 d_2 + p^{a_{12}} d^{a_{12}} - C_1 - C_2 \tag{12}$$

where $d^{a_{12}}$ is defined by equation (4).

We get the following result:

$$\Pi^{a_{12}*} = \frac{12}{25}(m + \gamma^d q_g)^2 + (\frac{m}{2} + \theta\gamma^d q_g)^2 - 2\gamma_g^c q_g \tag{13}$$

The proportional rule $\mathcal{R}_p$ is applied to make the profit allocation, where $\beta_1^{a_{12}} = \beta_2^{a_{12}} = 1/2$. It yields,

$$\Pi_1^{a_{12}*} = \Pi_2^{a_{12}*} = \frac{\Pi^{a_{12}*}}{2} \tag{14}$$

Criteria verification. The Monopoly–Monopoly case is the simplest one in which neither of the airlines has an optional potential partner. Hence only the collective rationality needs to be verified. Straightforward calclulation shows that

$$\Pi^{a_{12}*} - \Pi_1^* - \Pi_2^* > 0 \tag{15}$$

is satisfied. This cooperation is to bring more profit for both airlines.

For **case 2** and **case 3**, following the same three-stage analysis framework, the collective rationality can be verified and we get the same conclusion.

3.2. Monopoly–Duopoly

We consider the pre-alliance Monopoly–Duopoly network, in which airlines 2 and 3 are competing in the B–C market, while airline 1 still enjoys the monopoly power as in the previous section. For a passenger of market A–C, there are two options:
- A–B by airline 1, B–C by airline 2.
- A–B by airline 1, B–C by airline 3.

These two options are assumed to be competitive with each other no matter for the pre-alliance market, or the re-formed market if airline 1 cooperates with another airline. In the Monopoly–Duopoly setting, where airlines 2 and 3 differ in service quality, which one is to be selected as airline 1's partner becomes our main concern. Note that there are 8 possible combinations here, only two representative cases will be analyzed:
-Case 1: $q_1 = q_g, q_2 = q_g, q_3 = q_b$
-Case 2: $q_1 = q_b, q_2 = q_g, q_3 = q_b$

Let us first discuss the case when 1 and 2 are airlines with high service quality, while 3 with low service quality.

Case 1: $\boldsymbol{q_1 = q_g, q_2 = q_g, q_3 = q_b}$

Pre-alliance equilibria. Passengers' demand for market A–C is defined as:

$$\begin{aligned} d_{12} &= m - (p_1 + p_2) + (p_1 + p_3) + \gamma^d(\frac{q_1 + q_2}{2}) - \gamma^d(\frac{q_1 + q_3}{2}) \\ d_{13} &= m - (p_1 + p_3) + (p_1 + p_2) + \gamma^d(\frac{q_1 + q_3}{2}) - \gamma^d(\frac{q_1 + q_2}{2}) \end{aligned} \tag{16}$$

The definition above suggests that before any alliance is formed, the fare and service quality of airlines 2 and 3 interactively affect A–C passengers' choice.

The total profit for each airline is defined as:

$$\begin{aligned} \Pi_1 &= p_1(d_1 + d_{12} + d_{13}) - C_1 \\ \Pi_2 &= p_2(d_2 + d_{12}) - C_2 \\ \Pi_3 &= p_3(d_3 + d_{13}) - C_3 \end{aligned} \tag{17}$$

The equilibria solutions by differentiation are:

$$\begin{aligned} \Pi_1^* &= \frac{1}{4}(3m + \gamma^d q_g)^2 - \gamma_g^c q_g \\ \Pi_2^* &= 2(m + \frac{1}{4}\gamma^d(q_g - q_b))^2 - \gamma_g^c q_g \\ \Pi_3^* &= 2(m - \frac{1}{4}\gamma^d(q_g - q_b))^2 - \gamma_b^c q_b \end{aligned} \tag{18}$$

Alliance equilibria. If airlines 1 and 2 form an alliance, passengers' demand for market A–C will be:

$$d^{a_{12}} = m - p^{a_{12}} + (p_1 + p_3) + \gamma^d\theta(q_1 + q_2) - \gamma^d(\frac{q_1 + q_3}{2}) \tag{19}$$

The journey of two tickets issued by airlines 1 and 3 separately is still a competitive option for alliance 1-2. The total profit of alliance 1-2 is defined the same as in equation (12) and we can get $\Pi^{a_{12}*}$, the maximum alliance profit. Applying the proportional rule $\mathcal{R}_p$, the profit allocated to each airline under the cooperation scheme of 1-2 is:

$$\begin{aligned}\Pi_1^{a_{12}*} &= \beta_1^{a_{12}}\Pi^{a_{12}*}\\ \Pi_2^{a_{12}*} &= \Pi^{a_{12}*} - \Pi_1^{a_{12}*}\end{aligned} \tag{20}$$

The calculation under the cooperation scheme of 1-3 can be done similarly.

Criteria verification. Let us verify the collective rationality first, assume $q_b = \alpha q_g$, where $\alpha \in (0, 1)$:

$$\Pi^{a_{12}*} - \Pi_1^* - \Pi_2^* > 0 \tag{21}$$

is satisfied if and only if

$$q_g \in (\omega_{m-d}^{a_{12}}(m, \gamma^d, \theta, \alpha), +\infty) \tag{22}$$

where $\omega_{m-d}^{a_{12}}(m, \gamma^d, \theta, \alpha) \in R^+$. It indicates that an airline will consider forming an alliance with another if and only if its service quality reaches a certain level, i.e., low accident rate. Otherwise, it is difficult for any other airline to accept it as a partner. Also the airline itself is focusing on improving its service quality and rarely has spare capital to invest in alliance formation. For the stability of formation,

$$\Pi_1^{a_{12}*} - \Pi_1^{a_{13}*} > 0 \tag{23}$$

is satisfied if and only if

$$\alpha \in (0, \upsilon_{m-d}(m, \gamma^d, q_g)) \tag{24}$$

where $\upsilon_{m-d}(m, \gamma^d, q_g) \in (0, 1)$ and is close to 1. The alliance structure of 1-2 is more stable than that of 1-3, and vice versa if $q_g \in (\omega_{m-d}^{a_{13}}(m, \gamma^d, \theta, \alpha), +\infty)$, and $\alpha \in (\upsilon_{m-d}(m, \gamma^d, q_g), 1)$, 1-3 is more stable.The conclusion of **case 2** is opposite to that of **case 1**.

3.3. Duopoly–Duopoly

In this section, we consider the network with four airlines shown in Fig. 3, where the service quality of the two airlines competing on the same route differs as in the previous section. This topology represents a typical situation of the airlines in or to-be-in the three big airline alliances. Before examining the specific strategy to be adopted by the three-stage analysis framework, we describe a simple example of two big airlines in Taiwan: EVA Air (BR) and China Airlines (CI). The network coverage of the two airlines is nearly the same. In other words, they are competing nearly on each route. China Airlines joined *SkyTeam* in 2011, and EVA Air is to join *Star Alliance* later in 2013. As is known that China Airlines has records of many incidents and accidents since its formation, and was announced as the one with worst safety record among 60 international airlines by *Jet Airliner Crash Data Evaluation Centre (JACDEC)* in January, 2013. On the contrary, Eva Air has not had any aircraft losses or passenger fatalities in its operational history. From the perspective of the most important factor of service quality, safety, China Airlines' rate definitely cannot exceed that of EVA Air. Referring the three big airline alliances' service quality rating data, *Star Alliance* is doing better than *SkyTeam* as well. The analysis in this section can also be viewed as providing a theoretical support for the member selection criteria by the three big airline alliances. Let's take *Star Alliance* as an airline with high service quality, *SkyTeam* as one with low service quality, and start the analysis from the pre-alliance equilibria.

The representative case: $q_1 = q_g, q_2 = q_g, q_3 = q_b, q_4 = q_b$

Pre-alliance equilibria. A–C Passengers' demand for the first option is defined as:

$$\begin{aligned} d_{12} = m &- (p_1+p_2) + (p_1+p_3) + (p_4+p_2) + (p_4+p_3) \\ &+ \gamma^d(\frac{q_1+q_2}{2}) - \gamma^d(\frac{q_1+q_3}{2}) - \gamma^d(\frac{q_4+q_2}{2}) - \gamma^d(\frac{q_4+q_3}{2}) \end{aligned} \tag{25}$$

d_{13}, d_{42}, and d_{43} can be defined similarly as d_{12}.

The pre-alliance profit for airline 1 is:

$$\Pi_1 = p_1(d_1 + d_{12} + d_{13}) - C_1 \tag{26}$$

Π_2, Π_3, and Π_4 can be defined respectively as well. We use $\Pi_1^*, \Pi_2^*, \Pi_3^*$ and Π_4^* to denote the equilibria solutions. The calculation is simple, and we are not to present the long results here.

Alliance equilibria. If the alliance structure is 1-2 (high-high) and 4-3 (low-low), passengers' demand for market A–C will become:

$$\begin{aligned} d^{a_{12}} &= m - p^{a_{12}} + p^{a_{43}} + \gamma^d\theta(q_1+q_2) - \gamma^d\theta(q_4+q_3) \\ d^{a_{43}} &= m - p^{a_{43}} + p^{a_{12}} + \gamma^d\theta(q_4+q_3) - \gamma^d\theta(q_1+q_2) \end{aligned} \tag{27}$$

It is reasonable assuming passengers will not choose the option constituted by two airlines from different alliances. The alliance profit is defined the same as in equation (12). For alliance structure of 1-3 and 4-2, follow the same pattern above to make the definitions. By assuming $q_b = \alpha q_g, \gamma_b^c = \alpha\gamma_g^c$, where $\alpha \in (0,1)$, we can get the equilibria solutions of $\Pi^{a_{12}*}, \Pi^{a_{43}*}, \Pi^{a_{13}*}$ and $\Pi^{a_{42}*}$. Applying the proportional rule $\mathcal{R}_p$, the profit allocated to each airline under different cooperation schemes can be denoted as $\Pi_1^{a_{12}*}, \Pi_2^{a_{12}*}, \Pi_4^{a_{43}*}, \Pi_3^{a_{43}*}, \Pi_1^{a_{13}*}, \Pi_3^{a_{13}*}, \Pi_4^{a_{42}*}$ and $\Pi_2^{a_{42}*}$.

Criteria verification. Let us verify the collective rationality first:

$$\begin{aligned} \Pi^{a_{12}*} - \Pi_1^* - \Pi_2^* > 0 \\ \Pi^{a_{43}*} - \Pi_4^* - \Pi_3^* > 0 \end{aligned} \tag{28}$$

are satisfied if and only if

$$q_g \in (\omega_{d-d}^{a_{12}-a_{43}}(m, \gamma^d, \theta, \alpha), +\infty) \tag{29}$$

where $\omega_{d-d}^{a_{12}-a_{43}}(m, \gamma^d, \theta, \alpha) \in R^+$. For the stability of formation,

$$\begin{aligned} \Pi_1^{a_{12}*} - \Pi_1^{a_{13}*} > 0 \\ \Pi_2^{a_{12}*} - \Pi_2^{a_{42}*} > 0 \\ \Pi_3^{a_{43}*} - \Pi_3^{a_{13}*} > 0 \\ \Pi_4^{a_{43}*} - \Pi_4^{a_{42}*} > 0 \end{aligned} \tag{30}$$

are satisfied if and only if

$$\alpha \in (0, \upsilon_{d-d}(m, \gamma^d, q_g)) \tag{31}$$

where $\upsilon_{d-d}(m, \gamma^d, q_g) \in (0, 1)$ and is close to 1. The alliance structure of 1-2 and 4-3 is more stable than that of 1-3 and 4-2, and vice versa the structure of 1-3 and 4-2 is more stable if

$$\begin{aligned} &q_g \in (\omega_{d-d}^{a_{13}-a_{42}}(m, \gamma^d, \theta, \alpha), +\infty) \\ &\alpha \in (\upsilon_{d-d}(m, \gamma^d, q_g), 1) \end{aligned} \tag{32}$$

where $\omega_{d-d}^{a_{13}-a_{42}}(m, \gamma^d, \theta, \alpha) \in R^+$.

4. The optimal strategy

Proposition 1. *For a pre-alliance Monopoly–Monopoly network consisted of airlines i and j, for any $q_i, q_j \in R^+$, assuming the proration scheme $\mathcal{R}$ is proportional, then*

$$\begin{aligned} \Pi_i^{a_{ij}*} &> \Pi_i^* \\ \Pi_j^{a_{ij}*} &> \Pi_j^* \end{aligned} \tag{33}$$

The optimal strategy of the two airlines is cooperation with each other.

This proposition indicates that for a Monopoly–Monopoly market, the cooperation will always bring more profit for each of its member, mainly due to the extension of network coverage for each airline, and demand increment because of the more convenient service during transit.

Proposition 2. *For a pre-alliance Monopoly–Duopoly network consisted of airlines i, j and k, in which airline i's market is monopoly, for any $q_k = \alpha q_i = \alpha q_j$, where $\alpha \in (0, 1)$, assuming the profit allocation rule $\mathcal{R}$ is proportional, then if $q_i = q_j \in (\omega_{m-d}^{a_{ij}}(m, \gamma^d, \theta, \alpha), +\infty)$, and $\alpha \in (0, \upsilon_{m-d}(m, \gamma^d, q_g))$*

$$\begin{aligned} \Pi_i^{a_{ij}*} &> \Pi_i^* \\ \Pi_i^{a_{ij}*} &> \Pi_i^{a_{ik}*} \end{aligned} \tag{34}$$

Airline i's optimal strategy is to select airline j as its partner in the alliance formation. Vice versa, if $q_i = q_j \in (\omega_{m-d}^{a_{ik}}(m, \gamma^d, \theta, \alpha), +\infty)$, and $\alpha \in (\upsilon_{m-d}(m, \gamma^d, q_g), 1)$, the equilibrium alliance structure should be $i - k$.

If the pre-alliance service quality distribution differs greatly, the airline in the monopoly market will choose the one with the same service quality level as its partner, while if the distribution is approximately uniform, a combination of service quality and price competitiveness tends to be formed.

Proposition 3. *For a pre-alliance Duopoly–Duopoly network consisted of airlines i, j, k and l, in which airlines i and l, airlines j and k each form a duopoly market, for any $q_k = q_l = \alpha q_i = \alpha q_j$, where $\alpha \in (0, 1)$, assuming the proration scheme $\mathcal{R}$ is proportional, then if $q_i = q_j \in (\omega_{d-d}^{a_{ij}-a_{lk}}(m, \gamma^d, \theta, \alpha), +\infty)$, and $\alpha \in (0, \upsilon(m, \gamma^d, q_g))$*

$$\begin{aligned} \Pi_i^{a_{ij}*} &> \Pi_i^{a_{ik}*} \\ \Pi_j^{a_{ij}*} &> \Pi_j^{a_{lj}*} \\ \Pi_k^{a_{lk}*} &> \Pi_k^{a_{ik}*} \\ \Pi_l^{a_{lk}*} &> \Pi_l^{a_{lj}*} \end{aligned} \tag{35}$$

The equilibrium alliance structure should be $i-j$, and $k-l$. Vice versa, if $q_i = q_j \in (\omega_{d-d}^{a_{ik}-a_{lj}}(m,\gamma^d,\theta,\alpha),+\infty)$, and $\alpha \in (\upsilon(m,\gamma^d,q_g),1)$, the equilibrium alliance structure should be $i-k$, and $l-j$.

This conclusion is intuitive. If the difference between airlines with high service quality and low service quality is large, airlines tend to form an alliance with another with the same service quality level. An airline with high service quality will not accept one with poor service quality to degrade itself too much. Whereas if the difference is relatively small, an airline with high service quality tends to select the one with price competitiveness as its partner, even if this kind of cooperation might reduce the overall rate of service quality a little bit.

5. Concluding remarks and extensions

Airline alliances are selling increasing numbers of interline products. The service quality rating data for the three big airline alliances suggests the need to understand the impact of service quality during the alliance formation. This paper is the first to propose a framework studying service quality's effects on the selection of a partner airline. In particular, we model the optimal strategy decision process by a three-stage analysis framework. In the first stage, analyze the pre-alliance equilibria that each airline manages its own market in a non-cooperative fashion so as to maximize its expected profit. In the second stage, analyze the alliance equilibria under different cooperation schemes assuming a particular profit allocation rule. In the third stage, verify the collective rationality and stability to finalize the decision process.

The three main insights can be corroborated by airlines of the three big alliances, i.e., China Airlines and Eva Air. Basically airlines prefer to play with the one with the same service quality level. When the service quality of the airlines in the whole market does not differ too much with each other, the trend becomes a combination of service quality and price competitiveness. Of course this conclusion is more or less depending on the assumption of the demand functions.

In studying the effects of service quality, we find that the optimal strategy of an airline is, to some extent, sensitive to the particular profit allocation rule. We assume for simultaneous move in this paper. If we assign airline i, who owns monopoly power in its pre-alliance market in the Monopoly–Duopoly section, with the privilege to move first, the conclusion deviates from proposition 2 such that equilibrium alliance structure is always $i-j$.

An important feature of this study is the more general network topology. It suggests an extension of the oligopoly pre-alliance market, which is more close to the real situation. This is more complicated compared to the analysis of the duopoly market, in this respect, our results can be viewed as the first step to understand how airlines with different service quality will act assuming a particular allocation scheme.

Another aspect of the model deserves some attention is the profit allocation rule. In the first stage, the proportional rule is assumed to be applied in our analysis. For the future research, the application of strong Nash equilibrium or the equilibrium of bargaining game is an important extension to pursue.

Finally, in our model only complementary alliance is considered, the real situation is the coexistence of complementary and parallel alliances among partner airlines. Such a scheme, however, requires more factors, i.e., the fleet size, the capacity, service frequency and etc., to be included in the model for analysis. Describing service quality's strategic effects under the coexistence scheme will also be an interesting area of further study.

References

Aguirregabiria, V. and C. Y. Ho (2012). *A Dynamic Oligopoly Game of the US Airline Industry: Estimation and Policy Experiments*. Journal of Econometrics, **168 (1)**, 156–173.

Berry, S., M. Carnall and P. Spiller (2006). *Airline hubs: costs, markups and the implications of customer heterogeneity*. Advances in Airline Economics, Vol. 1: Competition Policy and Antitrust (Lee, D., eds), 183-â-214. Elsevier Press, Amsterdam.

Bitner, M. J. and A. R. Hubbert (1994). *Service quality: New directions in theory and practice.* In: Encounter satisfaction versus overall satisfaction versus quality (Rust, R. T. and R. Oliver, eds), pp., 77. Thousand Oaks, California: Sage Publications.

Chen, L. and T. Homem-de-Mello (2010). *Re-solving stochastic programming models for airline revenue management*. Annals of Operations Research, **177**, 91–114.

Colonques, R. M. and R. F. Fillol (2005). *Strategic Effects Of International Airline Alliances*. Working Papers. Serie AD 2005–15, Instituto Valenciano de Investigaciones Económicas, S.A. (Ivie).

Hendricks, K., M. Piccione and G. Tan (1997). *Entry and exit in hub-spoke networks*. Rand Journal of Economics, **28**, 291–303.

Park, J. (1997). *The effect of airline alliances on markets and economic welfare*. Transportation Research, Part E, **33**, 181–195.

Vinod, B. (2005). *Alliance revenue management*. Journal of Revenue and Pricing Management, **4**, 66–82.

Wright, C. P., H. Groenevelt and R. Shumsky (2010). *Dynamic revenue management in airline alliances.* Transportation Science, **44**, 15–37.