UTILITY IMPACT WITH ECONOMIES OF FREQUENCY ON AIRLINE NETWORK CHOICES*

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1. Introduction

The deregulation act of the U.S. in 1978, which allows airline companies to set their own fares and routes in serving markets that they want, causes the intensive use of hub-and-spokes (hereafter HS) that are designed to decrease the costs of airlines by feeding traffic from spokes, which is called as "**economies of density**" because gathering travelers from their destination places and funneling them through hub airport in carrying to arrival places provide carriers to use larger planes. A large number of empirical and theoretical literatures that measure economies of density and explain the reasons of hubbing to emerge as the dominant strategy have developed. A few of them are the papers of Brueckner and Spiller (1991, 1994), Hendricks, Piccione and Tan (1995, 1997), Oum, Zhang and Zhang (1995) and Zhang (1996). Despite economies of density, there are many policymakers and dissatisfied travelers that discuss the disadvantages of HS network choices because transferring passengers from a hub airport directly means the increase in inconvenience and time costs of the passengers. Additionally, hub operators began to apply predatory fare strategies to deter the entrance of smaller carriers and get the market, which allows them to offer monopoly prices in the itineraries, beginning from or ending in their hub airports.

For that reason, smaller entrants developed new strategies such as offering point-to-point connections (hereafter PP) with more frequent services, which causes a decrease in inconvenience and time costs, and charging lower fares, to compete the HS operators. Bringing extra benefits to the passengers, these carriers have increased their competitiveness and enplanement shares not only in the airports on the edge but also in the concentrated hubs of the leading carriers. This trend began with an interstate carrier, "Southwest Airlines" in 1991 but it expands with other airlines such as ValuJet, Reno Air, Air South, American Trans Air, Frontier in US and Ryanair in Europe. Then the success of these low-cost, low-fare carriers in the markets and their effects on competition in airline industry are began to discuss.

Although, Dresner, Lin and Windle (1996), Windle and Dresner (1999), and Volwes (2001) indicate that low cost carriers decrease fares and increase traffic on routes they operate, Yetiskul, Matsushima and Kobayashi (2002) define and modelize the strategies of these low-cost carriers in explaining their success and expansion. The purpose of this paper is to investigate the same issues by presenting the significance of passenger utilities in airline network and strategy choice.

In the former model, some of the important points that have been ignored in the previous studies of airline network economies are captured. One is the analysis of the effects of frequency in the supply of airline services on the consumers' demand and the other is the demand complementarity inherent to airline ticket price system. At that time, a new concept, "**economies of frequency**", which arise from the increase in flight services, is utilized. Into the earlier model, the time value of passengers is included when discussing the competitive power of PP networks with "economies of frequency" against HS networks which provide economies of density and at the end, we find that airline company set his prices and number of flights in trying to cover all market. However, in the current model, we observe that the impact of economies of frequency on the airline network choices is more than that we show in the previous model because in this paper, the demand change as a result of the increase in frequency is indicated. .

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*Keywords: airline networks, economies of frequency, economies of density, hubbing, de-hubbbing

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That a carrier begins to increase the number of services on the routes, he operates, means automatically an increase in the utilities because having desired arrival and departure flight times in their trips, passengers try to choose the airline company, setting a time schedule that fits best for their desired times. Then, the carrier who knows that the increase in utilities causes an increase in demand, serves as much as flights as he can because there is a complementarity between the demands of each way of the trip. Airline companies that benefit from selling round-trip tickets, try to influence the decision of passengers by frequent flights. They know that the increase in the number of passengers on one way of the trip means the guarantee of the same passengers on the other way of the trip. Briefly, with economies of frequency, the complementarity inherent to price system causes a Thick Market Externality in airline services and an increase in demand. Then the airline company that operates PP network with frequent flights earns more profit than the other carrier because they set their prices and the number of flights according to utilities. However, in the earlier model, we find that airline companies set their prices and number of flights to capture all the passengers in the market.

2. The Model

The impact of frequency in the supply of airline services on the passengers' demand and the comparative advantages of small carriers, obtained as a result of offering frequent services and operating PP network are discussed in three steps. In the first step, the model is formulated according to the case that a monopolistic carrier chooses PP network while in the second one, it is presented in the case when the carrier operates HS network. Finally, the comparison between these two network types in terms of firm profit is interpreted. In doing so, we focus on not only the behavior of the carrier in profit maximization problem but also the behavior of customers in utility maximization problem and find the optimum ticket fares and the number of services in the equilibria solutions to compare the profits of the carrier in each case.

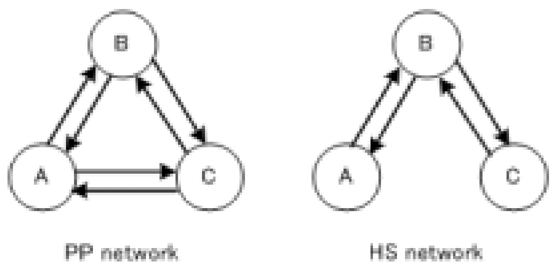

Figure 1: A Point-point Network and A Hub-Spoke Network

We consider a network economy of three cities, labeled *A, B* and *C*, and three possible city-pair markets, *AB*, *BC* and *AC* in which passengers originate in one city and terminate in the other as shown in the Figure 1. Firstly, the monopol company formalizes his choice according to the network economies. If the airline company chooses HS network, he uses the city, *B*, to transfer of the passengers and benefit from "economies of density" but if he chooses the other type of network, PP network, the company can benefit from "economies of frequency" with increasing the number of flights.

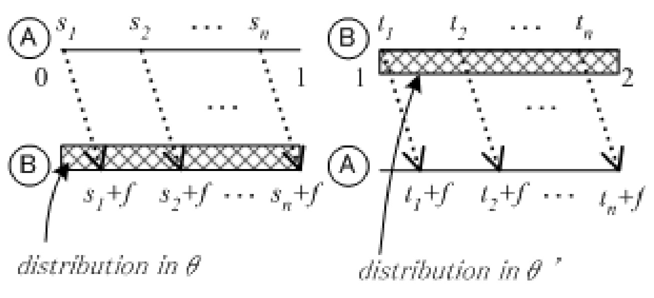

Figure 2: Distribution of θ and θ' in time scale

Firstly, we modelize the behavior of passengers who are making round-trips in the city-pair market *AB*, then extent to the other city-pairs. For each passenger, there is a fixed amount of income, *Y*, and two desired flight times in a round-trip. θ and θ' denote the desired times of a passenger when arriving in and departing from the destination city *B* and they are distributed uniformly in two time scales, $[0,1]$ and $[1,2]$, respectively. It is also assumed that each way of the trip is independently occurred.

The fare of a ticket, *p*, for each way and time residuals that arise from the differences between the desired and actual flight times determine the utility of a passenger, w and the utility is ranging from 0 to $\overline{w}$ when the later one denotes the maximum utility, obtained in the case that the passenger's desired and actual flight times are exactly same. Then the indirect utility of a passenger, making a round trip between cities A and B can be written as:

$$U(\theta, \theta', w : \mu) = Y + u(\theta) + v(\theta') \tag{1}$$

where $u(\theta)$ and $v(\theta')$ are the sub-utility functions for each way of the trip and $\mu = \{p, n, s(n), t(n)\}$ is the vector set of flight characteristics in which a single ticket price, the number of flights on that route and the departure times of the flights in each way are denoted respectively. The utility of traveling by a flight are expressed by

$$u(\theta) = \begin{cases} w - \varepsilon S(\theta) - p & \text{if } w - \varepsilon S(\theta) - p \geq 0 \\ -\infty & \text{if } w - \varepsilon S(\theta) - p < 0 \end{cases} \tag{2a}$$

$$v(\theta') = \begin{cases} w - \varepsilon T(\theta') - p & \text{if } w - \varepsilon T(\theta') - p \geq 0 \\ -\infty & \text{if } w - \varepsilon T(\theta') - p < 0. \end{cases} \tag{2b}$$

$2w$ is the total utility and ε is the value of time when $S(\theta) = \theta - s_{i^*(\theta)}$ and $T(\theta') = t_{j^*(\theta')} + f - \theta'$ are the time that covers the flight time, f, and the residual time. While $s(n)$ and $t(n)$ are the departure time sets of flights, taking off from cities A and B, respectively, $s_{i^*(\theta)}$ and $t_{j^*(\theta')}$ reflect the times of the most appropriate flights for a passenger who have θ and θ'. The decision whether to travel or not in each way for a passenger depends on the sub-utility functions, (2a) and (2b) and the trip generates when $U(\theta, \theta', w : \mu) \geq Y$.

In the discussion of airline firm behavior, the optimum numbers of flights, n^* and ticket fare, p^*, are found by maximizing the profit of the firm. Let d is airline's cost per flight on each connection between two cities. Then the profit of an airline company, offering services in the city-pair market AB with μ set , is

$$\pi(\mu) = 2\{pX(\mu) - nd\}. \tag{3}$$

where $X(\mu)$ is the total demand for each way. Considering the passenger utilities, defined in the equations (1) and (2a-b), we can find p^* and n^* that maximize the profit of the firm and the utilities of the passengers. The departure times of flights in each way, $s(n)$ and $t(n)$, are caught spontaneously after n is found because in the time scales, the intervals between the departure times are same.

In our model, the point that increase the significance of flight frequency is complementarity between the demands for each way of the trip because the airline ticket price system forces passengers to purchase round-trip tickets, which affects the demand of passengers in two ways at one time. Thus we express the demand for one flight by a formulation in which the probability that a passenger travels with that flight is firstly squared and then is multiplied by the number of flights on that route. The demand for one flight can be written as:

$$\begin{aligned} x(\mu) &= M\Phi(p)n\Phi(p) \\ &= Mn\{\Phi(p)\}^2 \end{aligned} \tag{4}$$

where M denotes the total number of potential passengers or the population of the city and $\Phi(p)$ is the probability. Because there is demand symmetry and the passengers' desired times are uniformly distributed in the time axis, the probability for each flight is same. If the condition, $w - \varepsilon(\theta - s_i) - p \geq 0$ is satisfied for a passenger, the probability for the fight i $(i=1,\ldots,n)$ is determined from the utilities obtained from traveling by that flight.

$$\begin{aligned} \Phi(p) &= \int_{s_i + f}^{min\left\{s_{i+1} + f,\, s_i + \frac{w-p}{\varepsilon}\right\}} \frac{\overline{w} - p - \varepsilon(\theta - s_i)}{\overline{w}} d\theta \\ &= min\left[\frac{1-f}{2nw}\left\{2(\overline{w} - p - \varepsilon f) - \frac{1-f}{n}\varepsilon\right\}, \frac{(\overline{w} - p - \varepsilon f)^2}{2\varepsilon w}\right] \end{aligned} \tag{5}$$

and the profit of the firm, earned from each city-pair market is

$$\pi(\mu)=\begin{cases} 2\left[\text{pMn}^{2}\left[\frac{1-f}{2nw}\left\{2(\overline{w}-p-\varepsilon f)-\frac{1-f}{n}\varepsilon\right\}\right]^{2}-\text{nd}\right] & \text{if } \frac{1-f}{n}\le\frac{w-p}{\varepsilon}-f \\ 2\left[\text{pMn}^{2}\left\{\frac{(\overline{w}-p-\varepsilon f)^{2}}{2\varepsilon w}\right\}^{2}-\text{nd}\right] & \text{if } \frac{1-f}{n}>\frac{w-p}{\varepsilon}-f \end{cases} \quad (6)$$

Maximizing the profit function of the firm, we can find the optimum price, p^* and number of services, n^*:

$$p^{*}=\frac{w-\varepsilon f}{2} \qquad n^{*}=\frac{61\varepsilon^{2}d}{(w-\varepsilon f)^{4}M} \quad (7a\text{-}b)$$

p^* and n^* are same for each city-pair market when the monopolist operates PP network but if he chooses HS network, the ticket price and the number of flights are same in the city-pair markets, *AB* and *BC* while different in the market *AC*. The reason is that both $S(\theta)$ and $T(\theta')$ include two flight times, *2f*, and waiting time at the hub and the residual times. In the choice of HS network, the utilities of the passengers, on one hand, decrease because of the raise in time costs, on the other hand, increase with cheaper tickets. The lower ticket prices are a result of the decrease in costs with HS networks so hub operator, offering direct connections only in *AB* and *BC* markets can charge lower fares. Solving the same problem for the market *AC*, the optimum price, q^* and number of flights, m^*, can be found. After finding the optimum ticket fare and the number of flights for each route in both network type, we can compare the profit of the firm when connecting the cities directly with the profit, gained by operating a HS network. In comparison, we find PP network is more profitable to operate than the HS network for the monopoly airline because with a PP network the carrier increase the number of flights easier than with a HS network. In short, the difference between n^* and m^* results in an increase in the utilities of passengers and this concludes an increase in the profit of the firm.

3. Conclusion

We investigate the comparative advantages of airline networks in monopoly case and find that if the airline company offers PP connections with more flight frequencies, he can earn more than that when offering HS network because of economies of frequency. Increase in the number of flights causes that customers get more benefit from traveling because their utilities increase as a result of the decrease in their time costs which arise from the differences between their desired and actual flight times. Due to having different desired times; passengers obtain different utilities from traveling. Thus, the method in discussing economies of frequency and the network choices of a monopolist is based on the utility differences among passengers. In short, in our modern world, the effects of time costs are observed both in the choices of passengers and in the provision of services.

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