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GRADUATE SCHOOL OF ENGINEERING

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STRUCTURAL CHANGES IN DEREGULATED AIR TRANSPORTATION SYSTEMS

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by

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1 INTRODUCTION

Airline industry is one of the vulnerable industries that are affected from globalization. Besides technological innovation, globalization and internationalization force the network industries, most notably transport, energy and communications to be deregulated. The regulatory regimes during the 1950s until the early 1980s are monopolies. However, these firms used the advantages of being monopolies by offering high prices. Deregulation ends the tyranny of state or private monopolies and increases competition, which causes an increase in the number of commodities and brands in the market. The direct result of this reflected in the prices and capacity and service levels.

Liberalization in airline industry begins from the US's deregulation of its domestic passenger market in 1978, which is enlarged on the international aviation in 1979. In Europe, the airline industry was deregulated in 1990s as a result of the creation of a single EU market. In addition to these institutional reforms, rising incomes and having more leisure times have concluded the growth of demand with accelerated paces. Additionally, technological improvements that affect the load factors belonging to the aircraft sizes and landside systems steps up the increase in air travel. As a result, a lower in airfares and an improvement in service options had observed in airline industry like in other network industries after deregulation.

Getting allowance to do what they want in offering their services, air carriers possessed the opportunity to rearrange their resources and made structural changes in their network systems as well as their operating strategies so intensive use of hub and spoke networks, brand loyalty programs, travel agent commissions and strategic alliances arise and expand from U.S. mega carriers to all over the world. Developing hub-and-spoke operations, carriers increase the average number of passengers per flight and thereby reduce costs. This lets the carrier take the advantage of the economies of density, which is the proportional decrease of costs in output as a result of the use of larger planes and centralizing maintenance. As a direct connection between the hub city and one additional city in a hub-and-spoke network automatically means the completion of connections to other spoke markets, there can be a quadratic benefit in the total market.

On one hand, airlines with well-developed hub-and-spoke networks discourage potential competitors and get the market power, which causes high prices and hub premium in direct routes from hub cities as a result of gaining a large degree of control over airport operations and advantages from frequent flyer plans and travel agent commissions. On the other hand, they began to merge with others. Most of the mergers have not caused much affair till the mergers between the carriers that served many routes in common from the same hub airport because they increased the market power. Finally, the broader scales of mergers, alliances which are the mutual agreements between airlines, have been formed every year in 1990s. These agreements in linking networks are to enhance services and get the advantages of marketing in the increasingly competitive markets. When the complementary effects of cost and demand factors among the traffic levels in each carrier are observed, the parallelism between HS networks and alliances is also recognized.

The hub-and-spoke system was designed to maximize the revenues and manage capacities. However, to fill the available seats and utilize large aircrafts, the carriers cause an increase in the number of dissatisfied passengers who are waiting at the gates for other passengers who arrive with smaller feeder aircrafts. Additionally, the complex operating systems that are developed to manage different fare classes and travel agents result in a conflict in demand and a decline in productivity. When size becomes a complexity, diseconomies of scale arise in the vertical layers of management and horizontal division of specialized employees and geographical organization (Rhoades, 2003). If in the environment, there are young and fast competitors, the impact of the diseconomies of scale increases.

Besides, the stock value of the major U.S. carriers has dropped sharply, many into the single digits. With the exception of The Southwest, these carriers have been downgraded below the junk bond level of BBB. The industry's debt leverage rate has risen to almost 93%, meaning that 93 cents on dollar is now borrowed at a rate of interest that is above the current returns to assets and equity earned by the industry. At this stage, it not early to declare that mega-carrier concept in North America is dead with following trailing waves;

> *"The first overtaking change that is already rapidly overtaking the mega-carrier concept is the growth of low-cost carriers who are likely to double their market share in the U.S. (and Europe) in the next decade. ……… The second change is the flight of the traditional business traveler away from the high fare-high restriction traditional carriers and toward either less travel overall or lower costs carriers (Rhoades, 2003)".*

The success and the development of new low cost and low fare carriers are emphasized by the Secretary of Transportation in 1996 with these following worlds;

> *"In the past year, American consumers have saved an estimated $6.3 billion in airline fares because of the competition brought about by new low cost, low fare airlines- up from only $1 billion in savings eight years ago……….. Indeed, there has been a revolution going on in American airline travel (US DOT, 1996)".*

Adapting low-cost strategy, new entrants afford very low fares. In markets that do not involve a dominated network hub, low cost service results in average fare savings of $46 per passenger while in markets that do involve dominated network hubs, fare savings of $70 per passenger (US DOT, 1996). Additionally, low fare stimulates demand. Thus, consumer savings are very large.

Although this trend began with the US interstate carrier "Southwest Airlines" in 1991, it expands with the entry of new carriers such as ValuJet, Reno Air and Frontier in US and Ryanair in Europe. In Canada, WestJet has grown rapidly and most recently JetsGo has entered the market while Australia has Virgin Blue (Gillen and Morrison, 2003). In Japan Skymark Airlines and Hokkaido International Airlines which were the first new entrants in Japanese airline industry in 35 years were born in 1998. Their common strategy, which is the source of their success in entering the market, is to offer frequent services with direct connections in short haul markets, providing lower operating costs while major, large airlines have been offering services with their hub-spoke network systems.

This PhD dissertation has come out of following reasons;

i. The aviation transport industry, which is the representative of network industry, is also deregulated. However, most notably airlines on average fail to cover their full attributable long-run costs. Additionally, airlines have to be more competitive for long term business success. Then, the emergence of low cost entrants is one of the most important developments of the post-deregulation airline industry. To provide information about deregulated air travel markets on the nature of competition, comparative advantages of low cost airlines are focused on.

ii. Although in the literature there are some empirical studies and research that analyze the direct and competitive impacts of the entry of a low-cost carrier or Southwest Airlines on prices and traffic in any market, none of them explain the success of these new entrants within a theoretical model.

iii. The impact of scheduling is rising today, compared to the past. Having many business activities to be reached in limited time intervals as well as wishing to arrange more leisure activities, consumers force themselves to plan their schedules so they are looking for time flexibility in their choices and the effect of time costs on travelers' preferences are increasing.

iv. Scheduling decisions are also important for airline companies because flight frequency fixes an airline's cost with a large proportion and the routes the airline can offer and determines the demand level in the market due to the impact of service quality on passengers' preferences.

v. Firm behavior in airline industry has been amply analyzed in the literature. Most of the theoretical ones have been based on homogenous product oligopoly models in which airlines compete in quantities or prices. There are only a few analyses which discuss the airline market structure with respect to time or service quality in consumers' preferences. However, passengers have different incomes, tastes or preferences so their choices also depend on not only pecuniary costs but also other service variables. Hence, air transport markets have to be considered in two dimensional.

vi. For some recommendations in developing policies for the academicians and politicians of the airline industry in the network competition and for the carriers that face pressures to become more efficient and grow their proportion of passengers available in the market.

It is hypothesized that the impact of scheduling is strong enough to change the consumers' preferences as well as airlines' choices. Hence, PhD Dissertation generally refers to trip scheduling and time flexibility when investigating the comparative advantages of low cost airlines over against major national airlines. In this research, the economy of scale which occurs as a result of the increase in consumers' flexible time is called "economies of frequency". Under scale economies, thick market externality, arising from a positive feedback mechanism between the increase in the number of flights in the market and the increase in the possibility that the consumers take trips, explains the market strategy of new entrants.

Dissertation is organized in three sections, in the first section empirical and theoretical background about the changes in airline industry after the deregulation is given in detail. In the second section the model is introduced as a case of monopoly while in last section, frequency and airfare competition (the case of duopoly) is analyzed. The first section, i.e., review starts with empirical studies (Ch. 2), which is organized to enlighten the profile of the airline industry after the deregulation. The impacts of deregulation are categorized into two main groups: the operational change to hub-spoke networks; entrant activity and the empirical literature that investigates the emergence and the development of hub-spoke networks after the 1980s laissez-faire antitrust policies and the competitive effects and comparative advantages of new entrants after 1990s are reviewed. The last section in Chapter 2 describes deregulation policies in Japan and impacts of them on fares, competition and efficiency. Chapter 3 is designed to summarize theoretical models that enlighten the changes after deregulation. After the failure of the contestable- market structure, theoretical research about airline industry follows imperfect competition models because aviation industry is highly oligopolistic in general and duopolistic on routes. Thus, we choose an analytic approach and review the models with respect to firm behaviors.

Chapter 4 defines and models the strategies of low-cost carriers in explaining their success and expansion. The comparative advantages of a point-to-point network over against a hub-and-spoke one and scheduling decisions of airlines according to networks are highlighted. While hub-and-spokes are designed to decrease the costs of airlines by feeding traffic from spokes, which is called as "economies of density", the advantages of point-to-point ones are discussed with "economies of frequency". Chapter 5 is to show the impact of thick market externality on the network choice of a monopoly airline. As the travel demand in aviation market is for two-way trips and the possibility of a potential passenger to take a trip depends on her schedule on both legs. Economies of scale are captured by positive externality of the market thickness so new entry with a point-to-point service to the market becomes profitable.

In the last section, i.e., duopoly, Chapter 6 offers an explanation for flight frequency and airfare competition between two major carries. Equilibrium solutions are analyzed in a duopoly market in which two carriers sell differentiated products and compete in a city-pair market for two types of potential passengers who are also differentiated with respect to their preference for brands. Chapter 7 analyzes how regional carriers can enter into the aviation market and survive. The potential passengers as well as airlines are distinguished between two with respect quality levels, they offer and passenger preferences for quality. In former chapter, the location type model of horizontal differentiation while in the latter one, the model of vertical differentiation is used. Additionally, in both duopoly models, passenger types have different time-flexibility so a complete characterization of flight frequency and ticket price choices in a duopoly model is presented. The last chapter highlights the importance of time flexibility and trip scheduling in the context of the airline network structure and competition and resultant effects on demand and supply sides.

The figure below gives logical commencement of the PhD Dissertation.

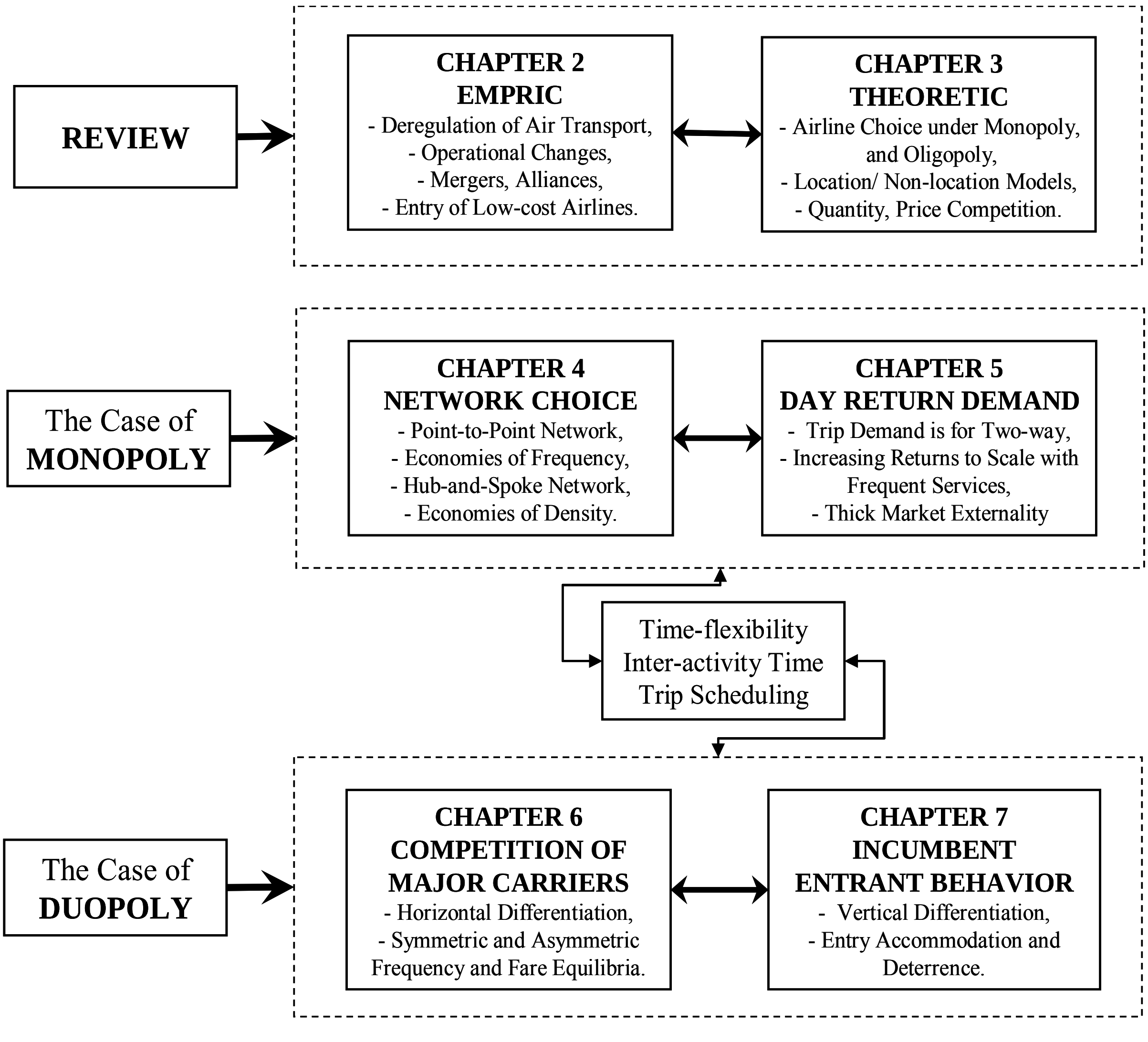


Figure 1-1 Logical commencement of the PhD dissertation

2 THE EVOLUTION OF AIRLINE DEREGULATION

2.1 Introduction

Regulatory reform has become a widespread trend in most of the countries over the past two decades. Even though the intensity of regulation and the instruments, applied, have varied between sectors, reform includes the markets such as transportation, telecommunications, banking and financial services, broadcasting and energy services. Under government intervention, services hadn't been improved at the pace of technological advances and regulators had failed to control prices and observe the true production cost due to information asymmetries. Thus, governments realized that competition might improve social welfare. Although, the airline industry exhibits different characteristics compared to other sectors, the deregulation of airline industry is also welfare improving.

An important case in aviation industry is the US's deregulation of its domestic passenger market in 1978 while this approach enlarged on the international aviation in 1979. Many European countries follow the United States in air transport regulation and leave air carriers largely free from economic regulation since the middle of 1997 (Button and Stough, 2000). The universe of a Single European Market from 1993 also accelerates the liberalization of international air transport within Europe. Regulatory reform in Europe has taken two forms: bilaterally negotiated reform of Air Service Agreements and multilateral reform initiated by the European Commission (Schipper, 2001). After the US initiatives for open skies agreements with many European countries have been successfully concluded in mid 1990s, the US Department of Transportation has shifted their focus to Asia (Oum and Park 1997). Besides, the US and Canada signed their "Open Skies" agreement in 1995. There have been agreed liberal bilateral Air Service Agreements with Japan, France and Korea in 1998 although they are outside of the Open Skies framework (Button and Taylor, 2000). Australia markets have also been regulated with Two Airline Policy in 1990 (Schipper, 2001).

The Airline Deregulation Act in 1978 proposed relaxation of the Civil Aeronautics Board's regulation of the industry. The Board's authority over routes was to end in 1981 and its authority over fares in 1983. The Board would cease operations entirely in 1985 and transfer the remaining tasks of international negotiation and small community air service to the Department of Transportation (Bailey et al, 1985). The Act that allowed air carriers to do what they want in offering their services resulted in an increase in competition. Thus, a lower in airfares and an improvement in service options and load factors had observed. Additionally, this laissez-faire policy caused many unpredicted changes in the airline industry: intensive use of hub and spoke networks, brand loyalty programs, travel agent commissions and strategic alliances. The main body of this chapter is designed to outline these changes and make them clear with the results of empirical studies that developed after the liberalization of airlines.

Fares are the focus of the discussions about the success of the regulatory reforms in airline industry. According to the US data used by Morrison and Winston, 2000, it can be said that the benefits of the decision of Washington in 1978 exceed its costs because travelers' fares in this deregulated environment were immediately lower than they would have been had they continued to be regulated. As shown in Figure 2.1, there are stable fare reductions of roughly 27 percent since 1994 and during 1998, 80 percent of passengers, accounting for 85 percent of passenger miles, paid fares that were lower than the estimate of regulated fares. According to Morrison and Winston (2000), deregulation has affected not only fares but also service quality because in Morrison and Winston (1995), it is found that hub-and-spoke system gives passengers from spokes and from the hub more frequent service than would be possible with single-plane service. Furthermore, after deregulation airlines began to serve all markets, which causes an increase in service quality. Thus the annual net benefits to travelers from airline deregulation are measured at $20 billion when fare and service quality are accounted (Morrison and Winston, 2000).

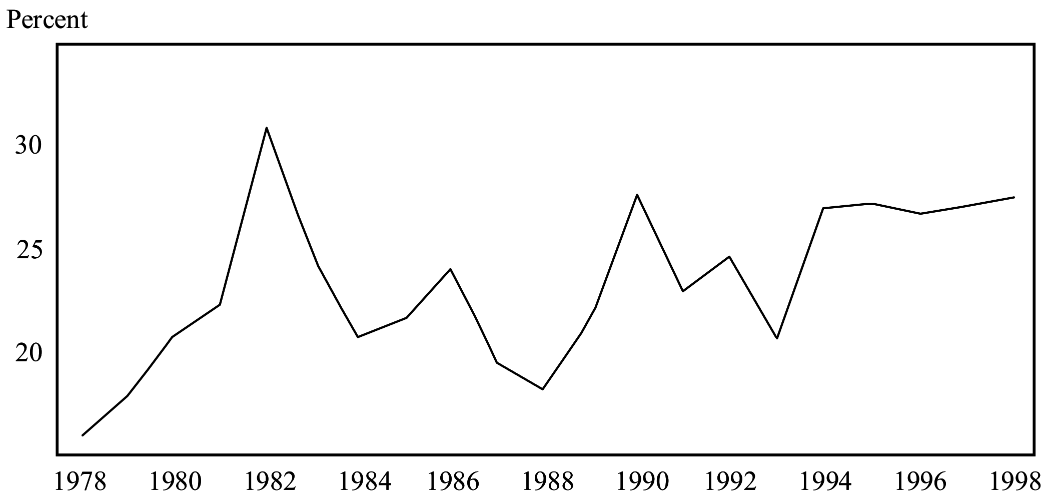


Figure 2-1 Percentage reduction in fares relative to regulated fares (Morrison, 2000, p.2)

The other leading indicator in measuring the success of deregulation is the competition in industry. According to transport officers of US, more operated at the end of 1993 (seventy-six) than at the end of 1978 (forty-three). According to Morrison and Winston (1995), misleading arises from assigning equal importance to a small carrier and a giant so then they calculate the number of competitors at the national level of US, using the inverse of Herfindahl index. As shown in Figure 2.2, the number of competitors increases from fever than nine in the fourth quarter of 1978 to a peak of more than twelve in 1985. The sharp reduce that makes the number of competitors slightly fewer than had existed before deregulation is a result of mergers.

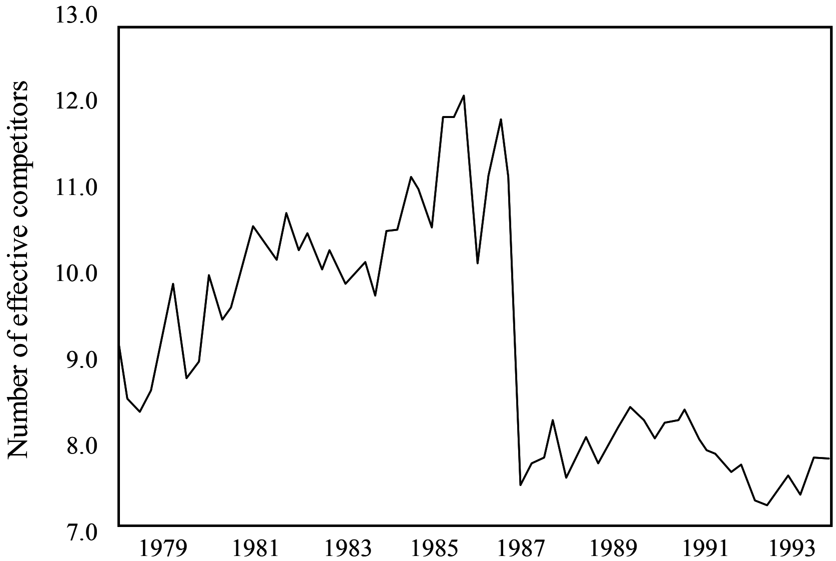


Figure 2-2 Airline industry effective competitors, US national (Morrison and Winston, 1995, p.9)

Additionally, Morrison and Winston (1995) calculate the number of effective competitors on each route to measure competition at the route level. They averaged over all routes, weighting both by passengers and by passenger miles. It is found that at the route level airlines are clearly more competitive than they were under regulation, which is shown in Figure 2-3. But as the differences between the passenger-weighted and passenger-mile-weighted figures suggest, competition has not been uniform on short and long routes.

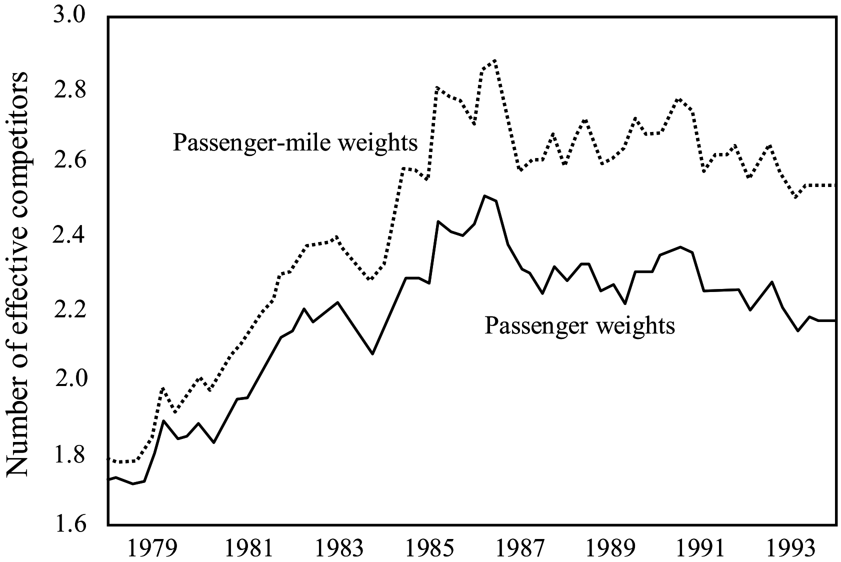


Figure 2-3 Airline industry effective competitors, route level (Morrison, 1995, p.10)

After a short look about the impacts of airline deregulation on fares and competition, this chapter proceeds in Section 2.2, with the emergence and growth of hub-and-spoke networks, which is one of the two most important operational developments that have taken place after deregulation. Firstly an explanation about the intensive use of hub-and-spoke networks is offered: "economies of density" and secondly the impact of hub-and-spoke networks on fares, traffic volumes and competition is discussed in Section 2.2. As the parallelism between mergers/alliances and hub-and-spoke systems is observed, Section 2.2.3-4 are designed to involve in the effects of mergers/alliances on airline industry. Then, we identify the new entrant activity, which is the other operational development after airline deregulation. Section 2.3 describes the competitive effects and advantages of new entrants. Lastly, deregulation policies in Japan and impacts of them on fares, competition and efficiency are discussed.

2.2 Growth of Hub-and-Spoke Networks

Following deregulation, carriers have seized the opportunity to redeploy their resources and have made major changes in their route networks. Almost all of the carriers have emphasized connecting service by developing hub-and-spoke operations. Hub-and-spoke network is defined as "a system of routing air traffic in which a major airport serves as a central point for coordinating flights to and from other airports or spokes" (Merriam-Webster Internet Dictionary). By combining passengers with different origins and destinations, a carrier can increase the average number of passengers per flight and thereby reduce costs. The broader scope of operation lets the carrier take the advantage of the economies of density.

The point in the explanation to "economies of density" lies in the proportional decrease of costs in output, which arises from the use of larger planes and centralizing maintenance. In other way, a direct connection between the hub city and one more city in the network automatically means the completion of connections to other spoke markets and quadratic benefit in the total market. HS networks provide carriers to increase their market size easier and faster than any other type of network such as point-to-point networks and circular ones. An airline with a well-developed hub-and-spoke network can discourage potential competitors by increasing the scale of entry.

2.2.1 Economies of Density

There has been considerable empirical research about hubs. Some of these studies (Caves, Christensen and Tretheway (1984), Brueckner et al (1992), Brueckner and Spiller (1994)) estimate an airline cost function and suggest that hub-and-spoke networks reduce costs and clarify “economies of density” as the major reason why the carriers choose HS networks as an optimal network. Airline costs can be broken into three categories: overhead, flight costs and passenger costs. Overhead cost includes the cost of the firm’s capital, like aircraft, as well as general and administrative expenses and advertising. Flight costs are those related with operating a flight including salaries of the flight crew, fuel, maintenance, landing fee and services provided to the aircraft while it is on the ground, such as cleaning and fueling. Passenger costs are those associated with services such as providing schedule information and taking reservations. They also consist of the costs of collecting tickets at the gate, food service on board and passenger baggage. Nearly 60 percent of the trunks’ costs of operation were flight specific costs; about 17 percent of the costs were overhead or fixed costs. The remaining 22 percent were passenger costs; reservations and sales expenses accounted for one-half of them (Bailey *et al* 1985).

Caves et al (1984) formulate a general model of airline costs by using data which consist of annual observations on all the trunk and local service airlines from 1970 through 1981 in U.S. Domestic Airlines. They estimate an airline cost function with five categories of inputs: labor, fuel, flight equipment (value shares on the annual cost to lease one plane of the appropriate type), ground property and equipment and other inputs and find increasing returns to density and constant returns to scale for both trunk and local airlines. “Returns to density” is the variation in unit costs caused by increasing transportation services within a network of given size while “returns to scale” is the variation in unit costs with respect to proportional changes in both network size and the provision of transportation services. In other words; in the former one, the proportional increase in output is found by holding network size, distance and load factors and input prices fixed whereas in the later, the proportional increase in output and network size is found by holding the other factors fixed.

According to the results (Caves et al, 1984) a 1% increase in output leads to a 0.80% increase in cost. This means unit costs decline as airline traffic density increases. Additionally, they show that differences in scale have no role in explaining the cost differences between large and small airlines while the density of traffic is the primary factor. Even though, they ignore the distinctions between route structures or network types (hub-and-spoke networks vs. linear networks) and only employ the number of points served as an attribute of an airline network, their findings about the output and cost relation support economies of density and infer the network characteristic of hub and spokes.

Brueckner et al (1992) Brueckner and Spiller (1994) criticize this study because of the omission of route structure and take a more disaggregated approach to fill this gap in the literature with using data of the U.S. Department of Transportation’s Origin and Destination Survey for the fourth quarter of 1985. In both studies, their evidence depends on the airfares and traffic levels on a given route because if cost per passenger declines as airline traffic density increases and if a competition occurs in a market, then fares should be low on routes where traffic density is high and in a market where competition occurs.

The basic findings of the regression analysis of the former study (1992), with dependent variable “fare”, support the empirical hypotheses. Fares are low, when the market is served by a large network or/and when the network serves large cities. To measure the effects of competition, the total number of carriers competing with the observed carrier in the market is computed and the result shows that addition of the first competitor to a monopoly market lowers fares by 7.7% and addition of a second or third competitor reduces fares by a further 3.4%, while the addition of an extra competitor beyond three lowers fares by a further 0.6%.

The aim of the latter one is to investigate the link between fares, marginal costs and actual spoke traffic levels so round trip flight fares are observed totally. Consider three spoke cities *X, Y, Z* and a hub city, *H*. In the first article, the number of passengers in four-segment city pair markets (q_{XY}, q_{XZ}, q_{YZ}) is focused on while in the second one, passengers on spoke markets, which equal the sum of traffic levels on the two spokes ($Q_X=q_{XY}+q_{XZ}+q_{HX}$, $Q_Y=q_{YZ}+q_{XY}+q_{HY}$, $Q_{XY}=Q_X+Q_Y$), are taken into consideration. Then, if fares are sensitive to the marginal cost of a passenger, which equals $c'(Q_X)+c'(Q_Y)$ in market *XY*, the fare must be a decreasing function of these two spoke densities. For example, the itinerary New York-Chicago-San Diego shares a spoke with New York-Chicago-Seattle. If economies of density are present, it is expected that an increase in demand for the airline’s New York-San Diego service, reduces the marginal cost of providing service in the New York-Seattle market and the fares.

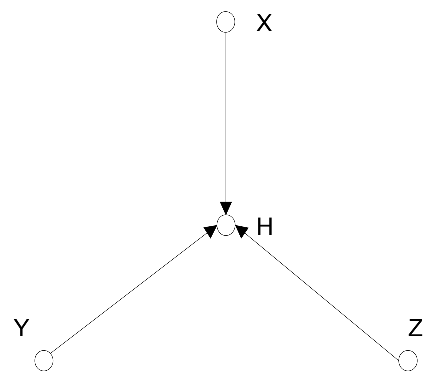


Figure 2-4 A simple hub-and-spoke network (Brueckner and Spiller, 1994, p.388)

The results show that marginal cost falls by about 3.75 percent for every 10 percent increase in spoke traffic. This density effect is stronger than that estimated by Caves et al (1984). The marginal cost of carrying an extra passenger in a high-density network is 13% below the cost in a moderate-density network and 25 % below the cost in a low-density network, giving the high-density carrier a distinct cost advantage. Additionally, Brueckner and Spiller (1994) observe the increase in national concentration because they find that the equivalent number of airline firms at the national level decreased from 8.9 in 1978 to 8.0 in 1988.

2.2.2 Concentrated Hubs and Market Power

Deregulation dramatically changed the structure of the airline industry. Competition exploded in the late 1970s and early 1980s as People Express, Air Florida and other new carriers challenged the established airlines (Morrison and Winston, 1995). This was relatively short-term expansion, however the later 1980s the industry underwent severe consolidation as the effects of the recession and higher fuel prices. Then, many of the new entrants and the pre-deregulation smaller carriers either merged with a major carrier or declared bankruptcy and ceased operations. Table 2-1 shows the measures of US domestic airline industry concentration since deregulation. Even though there is an increase in competition in 1982, concentration increased between 1982 and 1990.

Morrison and Winston (1995) measure the share of enplanements of the US dominant carrier at concentrated hub airports. It is observed that hubbing increases and one or two airlines dominate hub airports. For example, at Atlanta and Cincinnati hubs, the enplanement share of Delta increases from 49.7 percent to 83.5 and from 35.1 to 89.8 during 1978- 1993 period. At Salt Lake City, in 1993, Delta served with a share of 71.4 percent while Western Airlines served with 39.6 percent enplanement in 1978.

Table 2-1 Measures of US domestic airline concentration (Borenstein, 1992, p.47)

	1977	*1982*	*1987*	*1990*
4-firm Concentration Ratio	56.2%	54.2%	64.8%	61.5%
8-firm Concentration Ratio	81.1%	80.4%	86.5%	90.5%
Herfindahl Index	0.106	0.093	0.123	0.121

The dominance of incumbent airlines at hubs causes high prices and hub premium in direct routes from hub cities and exclusion of competitors from city-pair markets because gaining a large degree of control over airport operations and advantages from frequent flyer plans and travel agent commissions, hub operators exercise “market power”. Borenstein (1989) investigates the route and airport dominance in determining the degree of market power and indicates that an airline’s share of passengers on a route and at the endpoint airports significantly influences its ability to mark up price above cost.

In the estimation, two different approaches are presented with a sample data that includes observations on the nine largest domestic airlines in the U.S. (as of the third quarter of 1987) for service on 5,428 routes.

Table 2-2 Share of enplanements of the US domestic carriers (Morrison and Winston, 1995, p.45)

	1978		*1993*	
Airport	*Share*	*Carrier*	*Share*	*Carrier*
Atlanta	49.7	Delta	83.5	Delta
Charlotte	74.8	Eastern	94.6	USAir
Cincinnati	35.1	Delta	89.8	Delta
Dayton	35.3	TWA	40.5	USAir
Denver	32.0	United	51.8	United
Detroit	21.7	American	74.8	Northwest
Greensboro	64.5	Eastern	44.9	USAir
Memphis	42.2	Delta	76.3	Northwest
Minneapolis-St. Paul	31.7	Northwest	80.6	Northwest
Nashville	28.5	American	69.8	American
Pittsburgh	46.7	Allegheny	88.9	USAir
Raleigh-Durham	74.2	Eastern	80.4	American
St. Louis	39.4	TWA	60.4	TWA
Salt Lake City	39.6	Western	71.4	Delta
Syracuse	40.5	Allegheny	49.5	USAir

In the first approach, a carrier's markup over cost is estimated while in the second one the ratio of two observed airlines' prices on a route as a function of the ratios of the airlines' costs, service qualities, and shares of traffic is estimated. The first set of regressions indicate that *ceteris parabus*, a dominant airline on a route with a 70% share of the traffic might be able to charge from 2% to 12% higher prices than its rivals that only have 10% shares. The results from the relative-price regressions indicates that an airline with 50% of the traffic at each endpoint of a route charges high-end prices about 12% above those of a competitor with 10% of the traffic at each endpoint.

In Borenstein (1992), the correlation between "airport fare premium" and "airport concentration" is found as 0.44 with the passenger data of domestic trips in U.S. The percentages of passengers that are using the airport, one of the largest 30 hub airports in US, are listed according to the data of second quarter, 1990. This fare premium is caught by the comparison of the average fares on local routes at these airports with on national routes of the same distance. One of the explanations for this result is the market power and the other is the customer loyalty advantage that a locally dominant airline can easily gain by the use of frequent flyer and travel agent commission programs because Borenstein (1991) introduces directional city-pair effects, differentiating the routes such as into and out of the hub city and finds higher prices on flights out of the hub, which is explained with the effect of loyalty advantages. In addition, he demonstrates that the advantage of the dominant carrier at an airport is great on business-oriented routes.

Berry (1990 and 1992) and Berry et al (1997) represent a differentiated products model to reconcile the cost reducing (economies of density) and market power views in hubbing papers because he argues that traditional model of market power predicts high prices with low output however, airlines that dominate the traffic at hubs and charge higher prices than other firms on the same routes also serve a larger number of passengers. Thus, he explains the airline industry in terms of product differentiation and concludes that hubs provide two major competitive advantages to companies: they reduce costs and allow for higher markups on hub originating passengers. The markups that are paid by some customers arise from the services and the marketing programs of the dominant airline. While the former include flight frequency, more convenient gates and better departure times, the latter are frequent flyer programs and travel agent commission overrides.

The empirical methodology in Berry (1992) uses the entry decisions of airlines as indicators of underlying profitability. The simple descriptive results of Berry (1992) support the idea that airport presence is correlated with entry decisions into airline city pair markets and is also consistent with important differences in firm profitability across markets. The city pair routes that connect the fifty largest U.S. cities in the first quarter of 1980 are compared with in the third quarter of 1980 and it is observed that new entry occurs in over 20% of the markets while exit occurs in about 14% of the 1219 markets. The positive correlation between exit and new entry is consistent with the presence of heterogeneity between firms within the markets. To observe if some firms systematically enter new entrants while other firms systematically exit markets, the number of markets newly entered and exists by the largest 15 firms is listed. The correlation across firms between percentage of markets newly entered and existed is strongly positive at 0.695, which means that firms are heterogeneously suited to serve different markets.

In the structure of the model (1997), the cost side is developed with an approach similar to Brueckner and Spiller (1994) and the effect of density on the marginal costs of each spoke in the network is observed. In demand side, a discrete choice model of consumer behavior (logit model) is adopted. Assuming that prices are set according to a static Nash equilibrium in prices, they construct markups for various products. On demand side, airline customers are separated as tourist travelers with high price sensitivity, low willingness to pay for frequent-flyer programs and low disutility from connecting flights, and business travelers with low price sensitivity, high willingness to pay for frequent-flyer programs and high disutility from connecting flights.

Following the earlier studies of spoke density, Brueckner et al (1992) and Brueckner and Spiller (1994), Berry et al (1997) use the data from the fourth quarter of 1985. Their findings confirm that hubs are an important production and marketing tool for airlines. Their first result like the previous studies is about the existence of economies of density, which implies that hubs provide important cost savings. Second result is about hub-premium. During the months of fourth quarter of 1985, it is found that tourists using a dominant hub carrier paid anywhere from 1-5 percent above passengers whose flights were booked with non-hub carriers and business travelers flying hub carriers, however, paid nearly 20 percent more than their counterparts using non-hub carriers. Berry et al (1997) mention that the welfare consequences of this hub premium need not be negative because developing a hub-spoke network provides that the airline carrier becomes more attractive, more direct flights, more frequent flights, more connections and this attraction gives ability to the carrier for marking up prices because customers are willing to pay for.

Lijesen et al (2001) address the question whether Europe’s main carriers charge higher prices from flights originating from their hubs. They select ten European origins and five non-European destinations with the fares and flight frequencies of February, 2000 and find that Lufthansa, Swissair and Air France charge significant premiums of about fifteen percent for direct flights from their hubs. These results for these European Airlines are consistent with those of Borenstein (1989 and 1991).

2.2.3 Mergers

Before Airline Deregulation Act, airlines’ mergers requests were almost always denied except for the case that merger was designed to keep one of the carriers from going bankrupt by US Civil Aeronautics Board. However, since deregulation there have been more than forty airline mergers (Morrison, 1996). Most of these mergers have not raised concerns except for the mergers between Northwest Airlines (NW) and Republic Airlines (RC) and between Trans World Airlines (TW) and Ozark Airlines (OZ) in 1986 because the merging carriers served many routes in common from a particular hub airport. Borenstein (1990) analyzes the effects of these two controversial airline mergers that resulted in airport dominance to measure the market power.

To test the market power, Borenstein (1990) compares the merging firms’ prices before and after the mergers. The data are from the third quarters of 1985, 1986 and 1987. While the first period is before the merger, the second is after agreement on the mergers and the third is nearly a year after the mergers took place. Minneapolis and St. Paul (MSP) for Norwest’s merger and St. Louis (STL) for Trans World Airlines are major hub airports. Borenstein (1990) finds no evidence that TWA/OZ merger had a systematic impact on these carriers’ prices on STL routes and others; however, consistent and convincing evidence for the NW/RC merger at Minneapolis. NW/RC’s price increases were significant not just on routes that both airlines had served prior to the merger, but also on routes where only one of the two merger partners competed with another airline or operated without active competition.

According to the results of Borenstein (1990), capacity at these airports seems to have declined following the merger. NW/RC capacity on the flight to and from MSP fell 7.6 percent following the merger, though a 3.3 percent increase in MSP service by other carriers caused the overall change to be a 5.5 percent decrease.

At St. Louis, overall capacity declined 11.4 percent with TWA/OZ service falling 11.1 percent and the capacity of all other carriers falling 12.4 percent. At STL, TWA's capacity decrease was met with decreases by other carriers and overall decreases so the capacity change explains the small price changes at STL.

The study of Morrison (1996) examines those two mergers and the merger between USAir (US) and Piedmont Aviation (PI) that occurred in October 1987 to investigate the effects of airline mergers. Arguing that in airline industry adjustments take a long time, Morrison (1996) criticizes the previous study that had been limited to tracing the effects for about a year after the mergers so uses data of the 1000 most heavily traveled routes in US from the forth quarter of 1978 to third quarter of 1995 and compare the coefficients of the route dummy variables from the regression for a short time after a merger with those from the regression for a long time after the merger. He finds that fares on routes affected by a merger can be nearly 30 percent higher than on comparable rotes some years before the merger, and as much as 18 percent lower than fares on comparable routes years afterwards. Results show that fare increases of 2.5 percent on the routes of the NW/RC merger and fare decreases of 15.3 percent for the TWA/OZ merger. Routes involved in the US/PI merger had long-run fare increases averaging nearly 23 percent. Thus, Morrison (1996) concludes that mergers have idiosyncratic effects and more work needs to be undertaken.

Mentioning the difficulty in explaining the effects of an airline merger and need to find the effects on travelers' welfare, Morrison and Winston (2000) investigate why carriers merge and categorize three broad explanations: operational and financial motives, anticompetitive motives and industry wide forces. Carriers can benefit from economies of scale, density or scope when they are merged. If there is compatibility between their labors and capitals, they may be inclined toward merger and mergers may also provide distressed firms to restructure their debt and regain financial health. Additionally, carriers prefer being merged to end competition with their rivals. To take the advantage of expected improvements in economic growth and increase capacity, mergers occur. According to the findings, Morrison and Winston (2000) result that operational and financial motives account for 72 percent of merger activity during the 1978-95 period, industry wide forces 22 percent and anticompetitive motives just 6 percent.

Table 2-3 Portion of merger activity attribute to variables (Morrison, 2000, p.18)

Variable	1978-1995	1995
Operational and financial considerations		
Route density	3.4	2.8
Foreign routes	36.9	33.7
Aircraft types	2.7	1.8
Unions	3.5	1.7
Assets	21.5	28.1
Cash flow	3.6	3.7
Anticompetitive influences		
Price (revenue) increases	4.8	6.2
Common routes with fare wars	1.3	1.6
Industrywide variables		
Interest rates (2 national carriers)	1.0	0.3
Interest rates (1 or more major carriers)	17.3	16.2
Predicted GDP	3.9	3.8

Even though, Morrison and Winston (2000) conclude that mergers in total had a small negative anticompetitive effect, Borenstein (1990 and 1992) find the short-run welfare effect of the horizontal mergers was significantly negative and there was an increase in market power. Maybe it is difficult to estimate the long-run effect of mergers because if there were no mergers, many of the firms would probably have failed within few years.

2.2.4 Alliances

The other major structural transformation in airline industry as a result of trade and transport liberalization is mutual agreements between airline firms, which are referred to as alliances. These agreements in linking networks are to enhance services and get the advantages of marketing in the increasingly competitive markets. When the complementary effects of cost and demand factors among the traffic levels in each carrier are observed, the parallelism between HS networks and alliances like that in mergers is also recognized. While merger is an activity to combine two businesses into one, alliance is a union or agreement to cooperate. Due to having the same characteristics and motivations, an alliance can be thought a wider form of HS system. On the other hand, Morrison and Winston (2000) mention hubs as the root of current airline mischief while mergers as the seeds.

Airline alliances typically involve “code sharing”, a practice in which a particular flight will receive the designations of two airlines in the computerized systems used by travel agents (Bamberger et al, 2001). Under a code sharing agreement the connecting flights being operated by two separate airlines may be listed as being a “single carrier” service. This means that a passenger buying a ticket from one airline using that airline’s flight number system may end up flying in an aircraft operated by a different airline. Code sharing is firstly seen between trunk and regional carriers, then between international airlines. In 1986, British Island Airways and Air Florida established the first international code sharing arrangement (Oum et al, 1996).

An alliance allows a carrier to offer service on at least some city pairs that it does not fly between, by combining one leg of a flight on one of its planes with a second leg of a flight on which its alliance partner provides service. Thus Park et al (2001) mentions that the partner airlines reduce costs by coordinating activities: joint use of ground facilities such as lounges, gates and check-in counters; code sharing; joint advertising and promotion; exchange of flight attendants; and so on. Benefits of alliances to costumers are also listed: to minimize travelers’ waiting time between flights; to eliminate the need to retrieve and re-check baggage at connecting places; and to offer greater choices. Additionally, according to Oum et al (1996), the costumers also benefit from higher frequency services and carriers increase their market share because of the traffic feeding. Thus, more than 50 new alliances have been formed every year since 1994, and the number of alliances as of 1997 reached 502 (Park et al, 2001).

As most of the major alliances enjoy antitrust immunity that is mentioned in Brueckner and Whalen (2000), Brueckner (2001 and 2003a), and allows the partners to collaborate in pricing decisions, enhancing their ability to function as a single airline, some observers have argued that airline alliances can reduce competition and lead to higher fares in these markets. Brueckner (2001) clarify that an alliance may lead to higher fares in the “inter-hub” city-pair markets, however, an offsetting effect may arise for interline passengers. The passengers who fly on two carriers can benefit from alliances because under antitrust immunity, alliance partners set the overall fare in cooperative fashion, focusing on joint profit. With non-cooperative behavior, each carrier would ignore the negative impact on the other airline’s profit from raising its own subfare. The passengers who originate and terminate at the partners' hub airports can be harmful, leading to higher fares like the passengers who use airlines, linking up their parallel services as an alliance.

The parallel alliance refers to a situation where two companies, prior to their alliance, are competitors on the same routes of their networks. The other type of airline alliances is complementary alliance that refers to a case where two airline companies link up their networks to provide connecting services. While most of the transatlantic carriers like KLM and Northwest, United and Lufthansa have used complementary alliance type, Delta and Sebena signed parallel alliance on the New York-Brussels route.

The effects of airline alliances have previously been investigated elsewhere. An analytical model of international code sharing is developed by Oum et al (1996) and applied to a panel data of 57 transpacific air routes for 1982- 92 period to measure the non-market leaders on the market leader's price and passenger volume. Data consist of 30 North America/East Asia routes, 24 East Asia/Oceania routes, and 3 North America/Oceania routes, involving 7 North American, 7 East Asian and 4 Oceania origin and destination cities. The following three questions are investigated: First, is there any "competitive" or "collusive" effect of code sharing between non-market leaders on the market leader's pricing conduct; Second, will the leader gain or lose traffic as a result of code sharing; Third, will the equilibrium price of the market leader increase or decrease following code sharing?

Considering that the market leader operates non-stop services, the effect of code sharing between non-leaders is estimated so the study focuses on complementary code sharing. The empirical results of Oum et al (1996) show that a complementary code sharing makes the market leader behave more competitively because the annual equilibrium quantity of the market leader increases by 10,052 passengers while the leader's equilibrium price decreases \$83 per passenger. The traffic-enhancing effect is statistically significant. The explanation of this enhancing effect is given as: first, code sharing between non-leaders often leads to the replacement of an existing single carrier service (at times non-stop services) by the code shared connecting services; second, for the case where code sharing improves services by replacing interline services, the service improvement may increase prices as the improved services are capitalized. This study supports the idea that code sharing between non-leader carriers increase competition by strengthening the weaker competitors and reduce prices by creating "artificial competition".

Park and Zhang (1998) analyze the effects of international airline alliances on partner airlines' outputs by comparing traffic changes on alliance routes with those on non-alliance routes and use a panel data from the North Atlantic gateway routes for the 1992- 1994 period. Traffic changes for four major alliances that are formed in either 1993 or 1994 and operate in the North Atlantic markets are examined. British Airways (BA)/USAir, Delta/Sabena/Swissair, KLM/Northwest and Lufthansa/United Airlines are the four alliances and each of them is allied in a complementary form. Table 2-4 shows overall traffic changes on the alliance and non-alliance routes. The results show partner airlines' traffic increased on the alliance routes more than on the non-alliance routes during 1993- 1994 period. By contrast, Oum et al (1996) show that the equilibrium quantity of the market leader increases after code sharing when the code sharing is between non-leaders. Maybe the change in the traffic volumes depends on the market share of airline because the four alliances, used in the model of Park and Zhang (1998), account for more than 60 percent of the entire North Atlantic market in terms of scheduled-revenue passengers. On the other hand, both conclude that code sharing/airline alliances may improve competitiveness.

Table 2-4 Traffic changes after international alliance (Park and Zhang, 1998, p.253)

ALLIANCE			ΔQ	Q_{1992}	$\Delta Q/Q_{1992}$
1.BA/USAir	Alliance routes		59,890	879,722	0.068
	Non-alliance routes		3,982	354,766	0.011
2.DL/SN/SR	Alliance routes	DL+SN	21,659	71,469	0.303
		DL+SR	18,975	118,592	0.160
	Non-alliance routes	DL	32,287	354,116	0.091
		SN	11,374	40,725	0.279
		SR	4,607	182,193	0.025
3.KLM/NW	Alliance routes	KLM	38,843	306,663	0.127
		NW	80,628	120,626	0.668
	Non-alliance routes	KLM	6,863	215,202	0.032
		NW	-21,127	387,679	-0.054
4.LH/UA	Alliance	LH	19,270	175,007	0.110
		UA	6,138	139,841	0.044
	Non-alliance routes	LH	-6,541	256,692	-0.025
		UA	1,679	762,801	0.002

Park et al (2001) investigates the same issues with more general demand and cost specifications and for two kinds of alliances (complementary and parallel) separately. In the demand and cost specification, non-ticket cost of travel, schedule delay cost, is also discussed to measure the quality effect of alliances. The predictions of the model are tested by using panel data of trans-Atlantic alliance routes for the 1990- 1994 period. Among the routes form the combination of the selected 17 US and 12 European gateway cities, four major alliances that are the same as those used in Park and Zhang (1998), took place on seventeen routes. While complementary alliances took place on 12 out of the 17 alliance routes, parallel alliances occurred on three out of seventeen. Alliances on the other two routes had both characteristics of complementary and those of parallel alliances.

The test results of Park et al (2001) confirm that each of the complementary alliance partners increases its traffic after the alliance. For parallel alliance partners' outputs, all coefficients are estimated as negative, implying that demand shift effects on the partners' outputs are weak. The coefficients of complementary alliances are estimated as highly significant under the demand and cost specifications, which means that collaboration in a complementary alliance is likely to improve the quality of their connecting services and to decrease the air fares of their connecting services. The coefficients of parallel alliance under the specifications are estimated as negative and significant. In addition, test results reveal that a complementary alliance increases total output by an average of 11-17%, whereas a parallel alliance decreases total traffic by an average of 11-15%. Park et al (2001) conclude that in both alliances, partner airlines generally increase profits because a complementary alliance enables to improve their services while a parallel alliance enables to reduce operating costs through joint operations.

Bamberger et al (2001) investigate the competitive effects of two US domestic alliances (Continental/America West, CO/HP, and Northwest/Alaska, NW/AS) with a series of "before-and-after" regression studies and compare changes in average fares and total traffic. While the third quarter of 1994 and 1995 are the before-and-after periods of CO/HP alliance, the third quarters of 1994 and 1996 are for NW/AS alliance. They find that both of the alliances benefited consumers – average fares fell and total traffic increased after the creation of the alliances on those city pairs affected by the alliances.

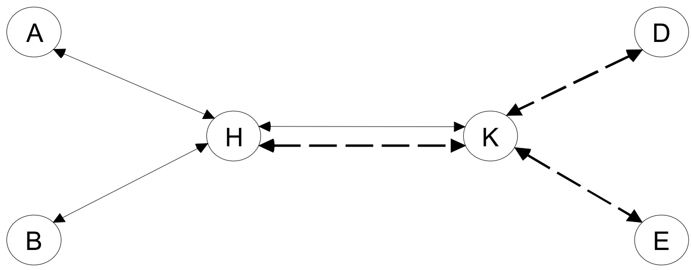


Figure 2-5 Network structure (Brueckner, 2001, p.1479)

Brueckner and Whalen (2000) provide evidence on the effect of international airline alliances on fares. The key assumption of the analysis that is also mentioned in Brueckner (2001) is that non-allied carriers set interline fares through the non-cooperative choice of "subfares" in the behind-the-gateway markets. As shown in Figure 2-5, the international markets *AD*, *AE*, *BD*, and *BE* are denoted "behind-the-gateway" markets when the Airline *1* uses city *H* as its hub and operates the routes shown as solid lines; Airline *2* uses city *K* as its hub and operates the routes shown as dotted lines. Both airlines serve the (transatlantic) city-pair market *HK* (gateway-to-gateway market). Additionally Airline *1* (Airline *2*) serves three domestic city-pair markets, *AH*, *BH*, and *AB* (*DK*, *EK*, and *DE*). When the collusion occurs between Airline *1* and Airline *2*, it is expected that the cooperation internalizes the negative externalities from the subfare choices and the result is downward pressure on the interline fares. Furthermore, it is expected that an alliance lead to higher fare in the gateway-to-gateway market.

To check the theoretical model, Brueckner and Whalen (2000) use data that are drawn from the U.S. Department of Transportation's Origin and Destination Survey for the third quarter of 1997. As the data involves the tickets with at least one segment flown on a U.S. carrier, foreign carriers offering on-line service in a market, or foreign carrier pairs offering interline service, are unobserved. Thus, they restrict the raw data. As a result, "behind-the-gateway" data set contains 11,694 observations, representing 6,917 city-pair markets. To determine which carriers operate alliances, code-sharing agreements during the sample period are listed. In the restricted data set of Brueckner and Whalen (2000), 50 alliance pairs are observed while four pairs dominate: Northwest-KLM carried 23.0 percent of the sampled alliance passengers; American-Canadian Airlines 14.9 percent; United-Lufthansa 12.5 percent; and United-Air Canada 9.4 percent.

As shown in Table 2-5, the results of interline data set indicate that alliance partners charge interline fares that are approximately 25 percent below those charged by non-allied carriers. However, it is found that passengers traveling to and from Australia and the Caribbean see little or no price benefits from alliances. Additionally, empirical evidence on the effect of alliances in gateway-to-gateway markets is looked for. The gateway-to-gateway data set contains 1,313 observations, representing 663 city-pair markets. As the raw data involves the tickets with at least one segment flown on U.S. carrier, this data set also involves round trips two-segment itineraries that are operated by a U.S. carrier. Although it is found that an alliance between two previously competitive carriers would raise fares by about 5 percent in the gateway-to-gateway markets, this effect is not statistically significant.

Table 2-5 International alliance effect on fares (Brueckner and Whalen, 2000, p.528)

	INTERLINE		BEHIND THE GATEWAY	
	U.S. Origin	*U.S. Destination*	*U.S. Origin*	*U.S. Destination*
Europe	-18.4	-29.8	-17.1	-29.9
Central America	-15.9	-26.7	-10.6	-23.4
Caribbean	1.1	-10.3	-6.2	-19.0
South America	-0.9	-12.3	22.0	9.1
Africa	-15.2	-26.6	-19.1	-31.9
Middle East	-4.0	-15.4	-11.4	-24.3
Far East	2.2	-9.2	-0.9	-13.7
Australian	8.5	-2.9	5.5	-7.3
Canada	-51.5	-62.9	-33.5	-46.3

Brueckner (2003a) summarizes and extends the empirical findings in the analysis of the airline cooperation effect on the interline fares by focusing on three measures of cooperation: alliance membership, code sharing and antitrust immunity. In this study, the 1999 data that indicate both the operating carrier and the ticketed carrier for each route segment of an itinerary is used to capture the effect of code sharing on fares at the city-pair level. The three airline cooperation measures are

i. whether the carriers belonged to one of the four major alliances in existence in the third of 1999: four major alliances are; the WINGS alliance (not officially adopted) consisted of Northwest, KLM, Alitalia and Continental; the STAR alliance consisted of United, Lufthansa, SAS, Air Canada, Varig, Thai Airways, Ansett Australia, and Air New Zealand; the ONE-WORLD alliance consisted of American, British Airways, Canadian, Qantas, and Cathay Pacific; the ATLANTIC EXCELLENCE alliance consisted of Delta, Swissair, Sabena, and Austrian Airlines.

ii. whether the itinerary involved code sharing between the two carriers,

iii. whether itinerary's two carriers enjoyed antitrust immunity: in the third quarter of 1999, Northwest-KLM, United-Lufthansa, United-SAS, United-Air Canada, American-Canadian, Delta-Swissair, Delta-Sabena, and Delta-Austrian had immunity (Brueckner, 2003a).

The results show that alliance membership reduces the fare by 4 percent and code sharing by 7 percent while antitrust immunity leads to a much larger reduction of 16 percent. These individual effects can be summed to arrive at particular total effects so three forms of cooperation lead to a 27 percent reduction in interline fares. Furthermore, Brueckner (2003a) computes the aggregate benefits from antitrust immunity and code sharing for the Star Alliance's interline passengers and finds that the immunity enjoyed by the Star partners generated an aggregate benefit of around $80 million per year for the interline passengers in 1999 while code sharing among Star partners yielded a benefit of $ 20 million.

2.3 Low Cost Carriers

After the deregulation of air services, with this laissez-faire policy, firstly the operational changes in networks from pre-deregulation linear systems to hub-spoke networks, secondly market power and hub premiums of carriers, offering high prices in the markets of network hub cities, thirdly airline mergers and finally international alliances are tried to be formalized with a huge empirical as well as theoretical studies. After analyzing the early studies about these four main changes above, we conclude that hub-and-spoke systems provide economies of density in network economies; and deregulation in air services cause market power, high prices and exclusion of competitors in direct routes from hubs and the routes that both airlines had served prior to the merger and the routes under parallel alliances while lower prices and higher traffic volumes in the routes under vertical mergers and complementary alliances. As there are many common characteristics and incentives of mergers and alliances with hub-and-spoke systems, the other most important operational development out of the formation of hub-and-spoke networks after the deregulation, is the new entrant activity, particularly new airlines with low cost operating strategies.

The success and the development of new low cost and low fare carriers are emphasized by the Secretary of Transportation in 1996 with these following worlds;

"In the past year, American consumers have saved an estimated $6.3 billion in airline fares because of the competition brought about by new low cost, low fare airlines- up from only $1 billion in savings eight years ago……….. Indeed, there has been a revolution going on in American airline travel (US DOT, 1996)".

The US DOT (1996) defines "low-cost carriers" on the basis of

i. estimated passenger expenses per seat mile for passenger service,

ii. average prices in all markets served.

Adapting low-cost strategy, new entrants afford very low fares. In markets that do not involve a dominated network hub, low cost service results in average fare savings of $46 per passenger while in markets that do involve dominated network hubs, fare savings of $70 per passenger (US DOT, 1996). Additionally, low fare stimulates demand. Thus, consumer savings are very large.

Southwest Airlines, which was an interstate carrier in the state of Texas before the Deregulation Act of 1978, altered the environment of domestic airline travel in U.S. Since 1978, while major, large airlines have been offering services with their hub-spoke network systems, Southwest Airlines has expanded his markets with a direct connection, frequent service and short-haul market strategy. Southwest began to expand his markets from Southwest States of US and then add California and the Midwest markets in 1991, the East

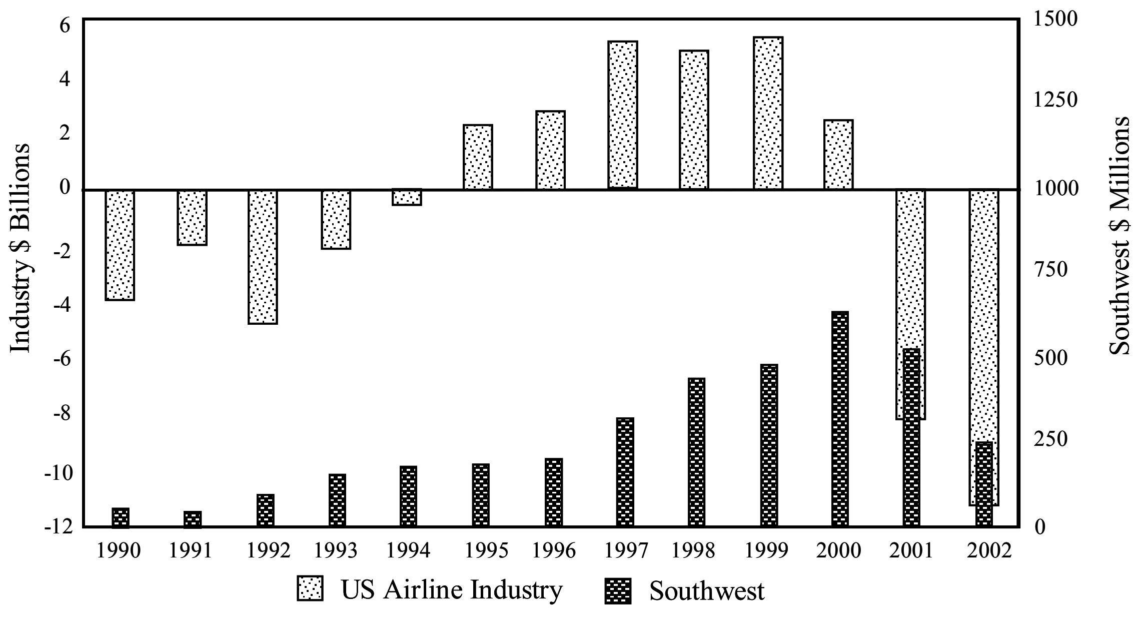


Figure 2-6 Net income of US airline industry and Southwest (Gillen and Lall, 2004, p.43)

Coast markets in 1993, the Northwest in 1994 and Florida in 1996 (Dresner et al, 1996). Figure 2-6 shows net income for the US airline industry and for Southwest. Even though the fluctuations are same in both, Southwest shows positive net income for the entire period.

Although Southwest Airlines was the only low cost carrier in 1992, it is no longer the only low cost carrier and new low cost airlines such as ValuJet, Reno Air, Air South, American Trans Air, Frontier in US and RyanAir, EasyJet and Buzz in UK (Gillen and Morrison, 2003) entered the industry. In Canada, WestJet has grown rapidly and most recently JetsGo has entered the market while Australia has Virgin Blue (Gillen and Morrison, 2003). For example, WestJet began in 1996 and UK-based carriers grew in the mid- to late-1990s as did Virgin Blue in Australia.

2.3.1 Competitive Advantages of Low-Cost Carriers

Although the origins and operating costs of new entrants are diverse, for the most part they all have lower operating costs. Their lower costs are partly explained by the simplicity of their operations, partly by their lower input costs, especially wages, and partly by their no-frills service policies. Table 2-6 presents the cost heterogeneity between airline firms in terms of average cost per passenger-mile and per seat-mile and average flight distance of 12 largest U.S. carriers during 1990. The USAir, with the highest cost airline, exhibits unit costs 64 percent above Southwest Airline's.

One reason of the lower costs in Southwest model is the rapid turnaround time when operating the system, which improves utilization of production such as aircraft, gates, ground equipment and labor. The other reason is simplicity in product design, service delivery and organization that is explained by Gillen and Morrison (2003) as followings: Southwest model and its variants have provided markets with unbundling of some services in exchange for a lower fare while full service airlines, operating hub and spoke systems, provide the bundled service that includes broad distribution through travel agents and other media, airport check-in facilities, airport lounges, priority boarding and pre-airport arrival seat assignment, in-flight service, baggage interlining, flight scheduling, multiple destination.

Table 2-6 Costs of major US Airlines, 1990 (Borenstein, 1992, p.61)

Airline	*Average Cost Per Passenger-Mile*	*Average Cost Per Seat-Mile*	*Average Flight Distance*
Southwest	0.111	0.067	376
America West	0.122	0.075	544
Eastern	0.128	0.078	606
Midway	0.144	0.084	636
American	0.144	0.088	776
United	0.145	0.093	809
Continental	0.150	0.087	743
Northwest	0.150	0.094	665
TWA	0.151	0.089	719
Delta	0.155	0.90	626
Pan Am	0.168	0.101	693
USAir	0.189	0.112	463

In addition, Southwest uses uncongested secondary airports to pay less for the services of airports and minimize congestion delays and service with the same type of aircraft and equipment to minimize maintenance costs and training costs. To avoid travel agency commissions and computer reservation fees, Southwest has its own system in serving high volume travel agents. Furthermore, it has a frequent flyer program, administrated in a very simple manner. Offering direct services on short haul routes, Southwest provides no meals in flights. Briefly, Table 2-7 illustrates the operational and design differences between major, large airlines and low-cost airlines.

Table 2-7 Airline characteristics (Gillen and Morrison, 2003, p.18)

Descriptor	*Full Service Carriers*	*Low Cost Carriers*
Fleet	Mixed	Uniform
Product design	Long/short haul Code sharing Network alliances	Short haul
Process design	Full service Business and coach	No frills Economy
Costs	High operating and maintenance costs	Low operating and maintenance costs
Airport affiliation	Hub and periphery Capital investment Control pax throughput	Periphery and non-hub airports

Developing an airport market share model based on the dynamics of airline pricing and frequency decisions in a multi-airport region, Cohas et al. (1995) illustrate the competition between a low-cost airline and full service airlines. The competition between the three San Francisco Bay Area airports- San Francisco (SFO), Oakland (OAK) and San Jose (SJC) and more specifically, the competition between San Francisco Bay Area- San Diego (SAN) are illustrated. For example, SAN-SFO airport-pair market involves competition between USAir, Southwest and United. In late 1988, USAir was the market leader with more than 50% of the traffic while United and Southwest captured less than 30 percent and 20 percent of the market respectively. Starting in the late 1989, Southwest increases its frequency from about 20 flights per a week in 1989 to nearly 70 flights per a week in 1992 when serving with an average fare of about \$40 against about \$50 for the other two carriers. As a result, at the second quarter of 1992 Southwest became the market leader with an approximately 50% market share.

Cohas et al. (1995) derive their multiplicative model about airport market share for traffic in a given origin-destination market:

$$MS_i = K_i \times FS_i^{\alpha} \times Fare_i^{\beta} \times OtherFare_i^{\gamma}\ , \tag{2-1}$$

where MS_i is airport i's market share; K_i is a parameter for airport i; FS_i is airport i's equivalent frequency share; $Fare_i$ is average fare, weighted by traffic at airport i; $OtherFare_i$ is the average fare in the same market at airports j. In this study, for three multi-airport systems, three origin-destination markets are chosen and then if i denotes one airport in the system, j and k denote the other two competing airports.

The model is estimated with a data of nine origin-destination markets out of three multi-airport systems: New York/New Jersey, San Francisco Bay Area, and Washington/Baltimore. Their statistical estimation for nine origin-destination markets results in positive elasticity of market share with respect to frequency of service (α) and negative direct elasticity to price (β) and positive cross-elasticity with respect to other fares

(γ). Additionally, the findings of Cohas et al. (1995) show that using smaller secondary airports in a metropolitan area is another way to avoid direct competition with larger carriers which operate at larger airports because in a smaller airport, there are some advantages: absence of congestion and delays; convenience and a time-gain advantage for travelers; shorter walks from the parking lot to the ticket counter and the gate.

When discussing the success of Ryanair in Europe, Barrett (1999) points at the very high productivity of its staff with a performance of 48 staff per aircraft and 4800 passengers per staff member in 1998, while in 1997 Aer Lingus Airlines has 159 staff per aircraft and 819 passengers per staff per year and Southwest Airlines has 91 staff and 1893 passengers per staff. Furthermore, Ryanair has reduced travel agents margins from 9 to 7.5% and developed its own telemarketing arm, Ryanair Direct. All other cost reduction policies of Ryanair such as servicing at lesser used airports, operating a single aircraft type, a standard 25 minutes turnaround time on international services and low cost no frills product are the same as the other low cost carriers in US. The only extra advantage of Ryanair is the attractiveness of Ireland's island location in Europe, where some 80 percent of all airline journeys are international, with most flights being under two hours in duration.

At last, low-cost carriers serve in point-to-point networks while incumbent carriers operate at hub-and-spoke networks because point-to-point networks provide easiness in adapting low-cost strategy. Reynolds-Feighan (2001) manifests the network characteristics and traffic distributions for low-cost and full-service carriers at airports by using "Gini index". Traffic distribution for 5 of major carriers (American, Continental, Delta, Trans World and USAir) and Southwest Airlines are compared over the period 1969-99. The Gini index shows that for the "full–service" major carriers, concentration of traffic distribution at a limited number of hubs has increased especially after deregulation in the US in 1978 but for Southwest Airlines the concentration is lower degree.

2.3.2 The Impact of Low-Cost Carriers on Competition

The impacts of low-cost carrier entry not only on carriers operating on the same routes but also on carriers operating on other routes at the same airport and operating at competitive airports in close proximity to the airport where entry occurred are analyzed by Dresner et al (1996). To determine the competitive effects of Southwest's entry onto two routes, to Cleveland and Chicago from BWI (Baltimore Airport International) in the Washington DC in 1993, they used firstly, the data of all origin and destination prices and traffic on all routes from each of three Washington area airports (BWI, National, Dulles) for the period of 1990 (first quarter) and 1994 (third quarter). Then to generalize the results, they added other low-cost carriers in addition to Southwest and used data from the top 200 US domestic origin and destination city-pairs for the same period.

The results of Dresner et al (1996) indicate that after the entry of Southwest Airlines into BWI, prices fell and traffic increase on those routes, additionally, prices fell and traffic increase on competitive routes from nearby airports and on other non-Southwest routes out of BWI. The fare reduction effect on competitive routes depends on the route distance. On short and medium haul routes (within a 500-mile radius or <1,000-mile radius of the Washington-Baltimore region), the fare reductions were approximately half the impact of actual entry and on long haul routes (>1,000 miles) much smaller impact. The general results show that the presence of only Southwest Airlines on the route reduces fares by 53 percent and the presence another low cost carrier reduces 38 percent. On competitive routes, fare reductions depend on the number of competitive routes, operated by Southwest or another low cost carrier. If Southwest operates on one competitive route, fares drop by 8 percent and this fare reduction increases at 45 percent when the number of routes, operated by Southwest, increases. If another low carrier serves the competitive route, then fare reduction is from 0 to 41 percent.

Volwes (2001) examines the Southwest Effect at airports in multi-airport region: Chicago- Washington, DC- Houston- and south Florida, collecting the data for the quarter prior to Southwest entry in a market as well as a year later. For Washington, DC multi-airport region, second Southwest Effect is found that average prices between Cleveland and Washington National fell by 45 percent and Cleveland- Washington Dulles' average fare dropped by 28 percent in that year after the entry of Southwest in the Cleveland-Baltimore route in the third quarter of 1993. In addition, The Southwest's ability to bleed traffic from other airports in a region by lowering fares is observed by the decrease by 15 percent in travelers of the other two markets. Like in the Washington, DC multi-airport region, the airport that Southwest enters is the lowest average fare and most popular in terms of passenger volume in the Chicago and south Florida regions. Two general trends are found in multi-airport region after Southwest began service at one of the airports in the region. One is the decrease in fares in a majority of airports and the other is that although fares are lowered after Southwest enters, enplanements do not increase at non-Southwest-served airports.

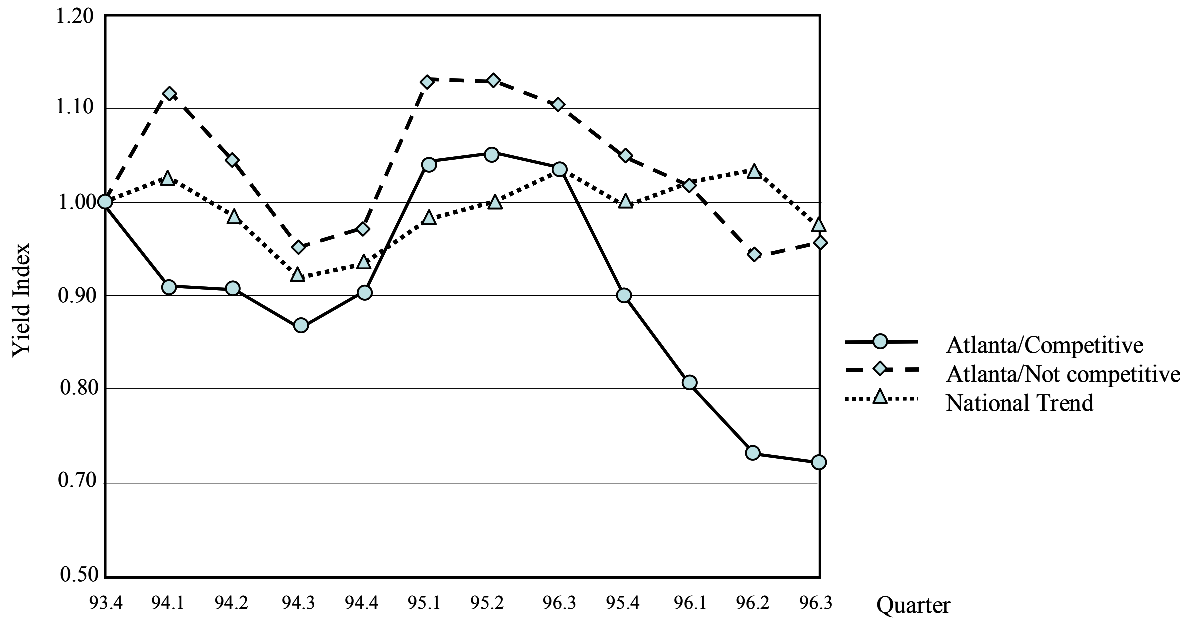


Figure 2-7 Trend Indexes on Delta's Atlanta yields (Windle and Dresner, 1999, p.72)

US DOT (1996) study, a larger analysis of low cost carriers, illustrates the impact of low cost entry on routes from two hubs of Delta Airlines, Atlanta and Salt Lake City and the reaction of Delta Airlines. Delta's hub at Salt Lake City was affected from the entry of low cost carrier, Morris Air in early 1993 at first and then Southwest Airlines after it acquired Morris Air. Delta's fares fell 33 percent on the routes where it competed with low cost competitor Morris Air, but did not either rise or fall, on average, on routes where Morris did not compete. At Atlanta, on the other hand, Delta's average fares have changed more modestly relative to the fares charged in its other Atlanta markets and has not has much effect on its traffic. Delta's different reactions is explained that ValuJet's entry at Atlanta has not yet reached the level of Southwest's at Salt Lake City and its market share is much less than at Salt Lake City.

Gathering data from the fourth quarter of 1993 to the third quarter of 1996, Windle and Dresner (1999) extends the study of US DOT (1996) about ValuJet's entry into Delta's hub, Atlanta while the most recent data of US DOT (1996) is the third quarter of 1995. It is found that yields on the competitive routes fell about 25%, while yields on the non-competitive routes continued to track the national trend. This result does not support that Delta raised rates and got a markup on the non-competitive routes to compensate the decrease in fares on competitive routes.

One of the recent studies about Southwest Airlines is the paper of Morrison (2001) that uses the set of competition variables in 1998 to estimate aggregate impact due to actual, adjacent and potential competition markets. Three ways that an airline may affect fares on a particular route are shown. First, the airline may serve the route in question. Second, the airline may serve an adjacent route in question. Third, although the airline may not serve the route in question or an adjacent route, it may affect fares on the route if airlines lower fares to make entry by potential competitors less attractive. According to the results, when Southwest serves a route, fares are 46 percent lower than on comparable routes that it does not serve. If it serves an adjacent route, fares are from 15 to 26 percent below otherwise comparable routes. Potential competition from Southwest lowers fares by 33 percent when Southwest serves at both airports but not that route and when Southwest only serves one airport that is near one of the airports of a route, fares are reduced by 6 percent.

Additionally, Morrison (2001) finds that the total estimated savings in 1998 were $12.9 billion and Southwest's low fares were directly responsible for $3.4 billion of these savings. The remaining part was a consequence of competitive impacts of Southwest on actual, adjacent and potential routes. Also these savings are comparable with the estimated savings of the US Department of Transportation (1996) during the year ending in the third quarter of 1995. US DOT (1996) estimated that consumer savings were $6.3 billion in that year.

Considering the downward pressures that the growth in low-cost carriers has had on prices in the comparison markets, US DOT (1996) analyses the overall premium for the concentrated hubs with data for

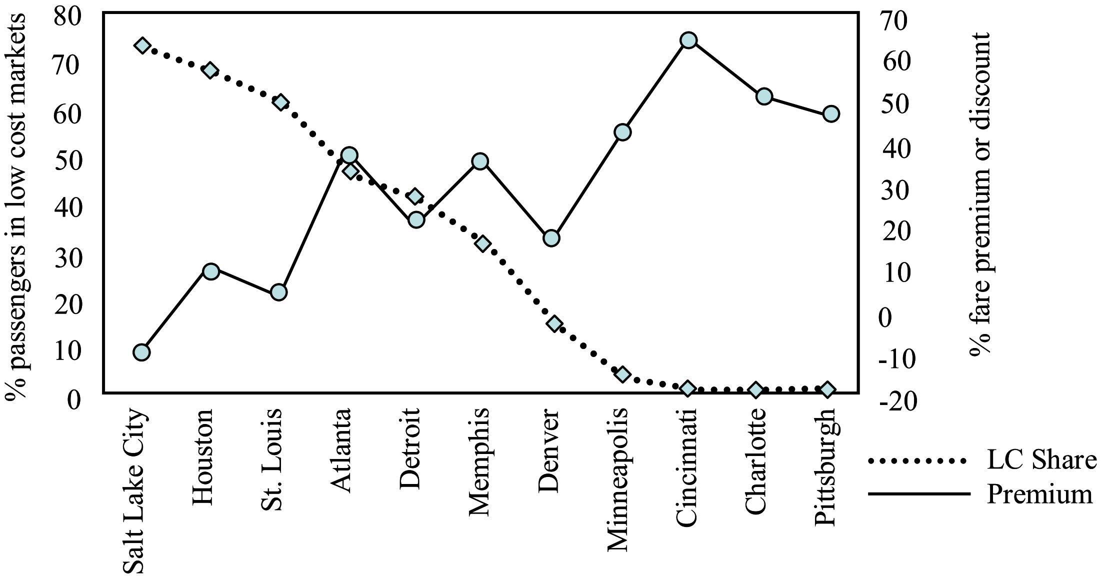


Figure 2-8 Relation of fare premium to participation of low cost carriers (US DOT, 1996, p.29)

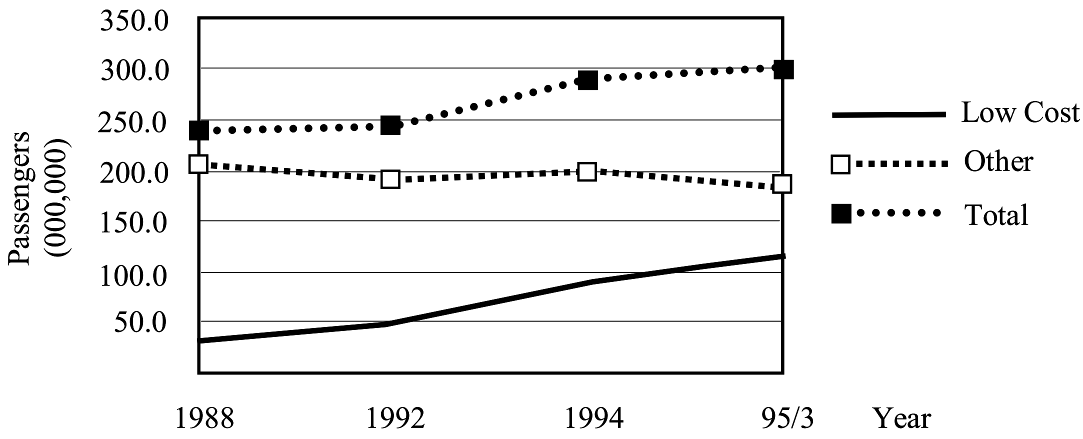


Figure 2-9 US domestic passengers (US DOT, 1996, p.6)

1994 and finds that premiums vary substantially, depending upon the degree of penetration of carriers operating low cost service. As shown in Figure 2-8, hub cities without substantial low cost entry tend to be subjected to very high fare premiums compared with other hub cities.

Barrett (1999) examines the success of Ryanair which is a Southwest for Europe. In 1991, Ryanair was restructured as a "No Frills" Airline by eliminating business class and complimentary in-flight services and abolishing the airline's frequent flyer program. From 1993 to 1999, it introduced services between Ireland and Britain, and then added new routes from Ireland to Mainland Europe. According to Barrett (1999), the point in the success of Ryanair is to expand the market rather than diverting a static market from other airlines. This strategy is to fill the gaps in the market left by incumbent airlines because it is found that Ryanair develops its market share by leisure visitors and business passengers who pay their own ticket. A similar result is also pointed by US DOT (1996) and shown with Figure 2-9. Finding that both low-cost airlines and incumbent firms have made profits, it concludes that low fare 100 services attract new passengers to the industry rather than diverting traffic from the incumbent carriers.

2.4 Airline Deregulation in Japan

2.4.1 Deregulation Policies

Deregulation of the Japanese airline industry, started in 1986, led to full liberalization in principle with the enforcement of the revised Aviation Law in February 2000 (Ida and Tamura, 2005). Even though the implementation of deregulatory measures has been less strident than in either North America or Europe, Japan has raised competition on domestic routes as well as international routes after deregulation. One of the significant impacts of policy change is the entrance of Skymark Airlines and Hokkaido International Airlines into the market in 1998.

The airline industry was controlled by Ministry of Transport with the adoption and implementation of 1970- 72 Scheme that creates a monopoly industry structure around three major companies: JAL were operating international routes and major domestic routes –that is, routes Tokyo, Osaka, Sapporo and Fukuoka- while ANA were operating major domestic routes and some short-haul international charter flights. Toa Domestic Airlines, which merged with several other small carriers to form Japan Air System in the 1980s, were serving local routes (Alexander, 2000).

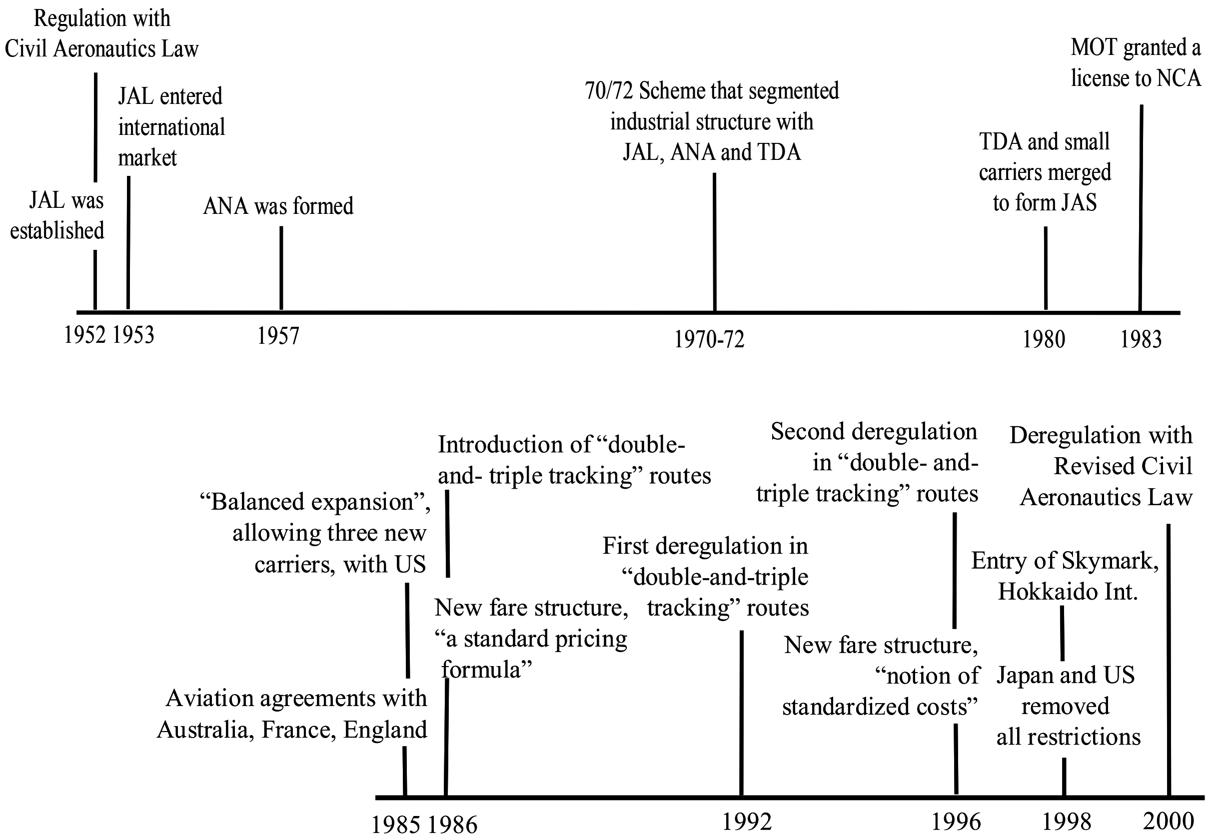


Figure 2-10 Deregulation policies in Japan

Competition between the three carriers was almost nonexistent till the establishment of Nippon Cargo Airways (NCA) and its entry into the market. The introduction of wide-body aircraft, which causes a decrease in freight cost, forced Ministry of Transport to grant NCA a license in 1983. The collapse of the single-company system continued with a provisional agreement between US and Japan in 1985. The contents of the agreement allowed both countries to commence operation of three new airline companies each on trans-Pacific routes based on "balanced expansion" of the air transport of both countries. To open international market to new entrants and keep the domestic market regulated coerced the government to change policy. In 1986 the council for transport policy submitted a report that indicates new aviation policy:

i. international routes will be served by multiple carriers,

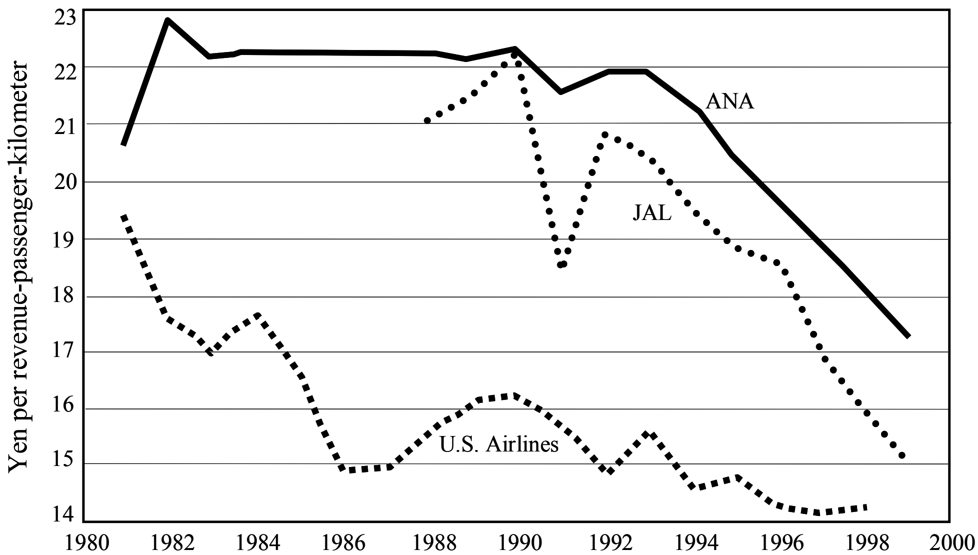
ii. competition on domestic routes will be promoted by new entry to a particular city-pair market,

iii. Japan Airlines will be 100% privatized (Yamauchi and Murakami, 1995).

Then, '70/'72 Scheme was abolished in 1986 and the implementation of double and triple-track standard system, the practice of two or three carriers servicing a particular route was began. Ministry authorities declared that two airlines would be allowed on routes with at least 700,000 passengers a year and three carriers would service routes with more than 1 million passengers annually and then lowered the barriers to 400,000 and 700,000 in 1992 and to 200,000 and 350,000 in 1996. Among the 179 domestic routes in 1991, the number of triple track ones are 10 (5.6%), double track 24 (13.4%), and monopoly 145 (81.0%).

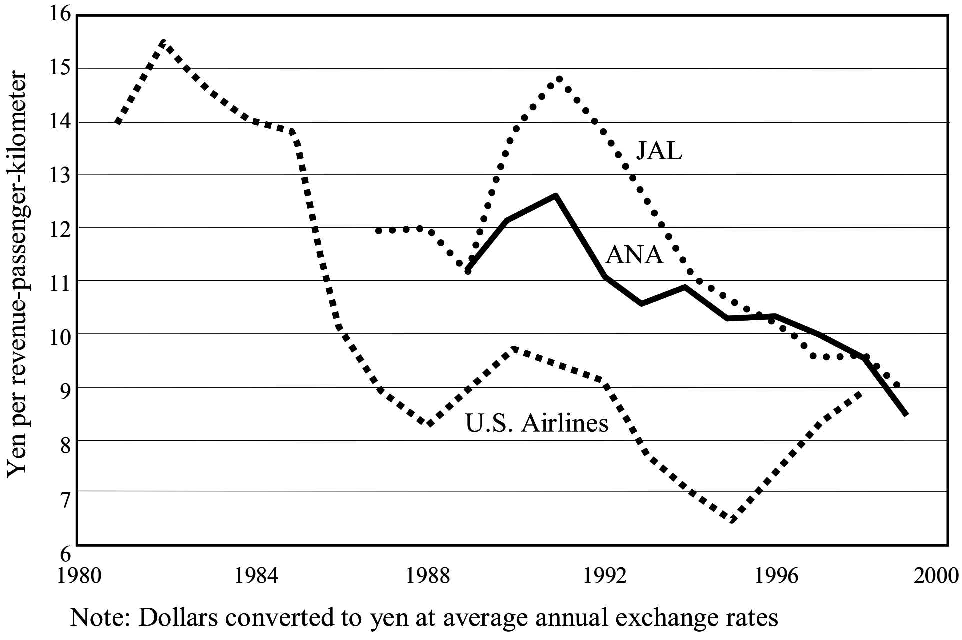
However, the number of passengers carried in triple track was 29,484,000 (42.9%), double track 15,530,000 (22.6%), and monopoly 23,673,000 (34.4%).

In 1986, Ministry of Transport introduced a standard fare formula that was determined by average costs and a “reasonable” profit. The reason for this system was that politicians from smaller towns and from Hokkaido did not want to pay more than ones from populated areas. However, lower international fares forced the authorities to allow discounts of up to 50 percent on domestic fares in 1994. In addition to decrease in fares, total cost began to increase after 1986 due to sales, administration costs and travel agent commissions. As a result, the revenues per passenger-kilometer that ANA and JAL took on domestic routes began to fall in the early 1990s, which can be observed from Figure 2-11, For international yields, competitive pressures confronting JAL and ANA can be observed from Figure 2-12.



Note: Dollars converted to yen at average at annual purchasing power parities

Figure 2-11 Domestic passenger yields; Japan-US (Alexander, 2000, p.6)



Note: Dollars converted to yen at average annual exchange rates

Figure 2-12 International passenger yields; Japan-US (Alexander, 2000, p.7)

Compared with the unit fares between US and Japan from Table 2-8, though normal fares in Japan tended to be lower than the US, discount fares were several times higher. In the US, 90% of passengers use discount tickets (Yamauchi and Murakami, 1995). In 1996, Ministry of Transport introduced a new fare structure based on the notion of standardized costs in which published fares could be as much as 25 percent below the standard. This discount ratio was set for the fares of one year so discounts were carried on a much broader and deeper scale, including time-of-day and time-of-year.

New pricing pressures emerged in 1998 when the United States and Japan signed bilateral agreement that removed all restrictions on transpacific flights by two passenger airlines. Then two new entrants appeared and fares between Sapporo and Fukuoka dropped by 35% and 50%. In 2000, a revised Civil Aeronautics Law went into effect, which eliminated regulations on domestic airfares and gave airlines a free hand in determining their routes and flight frequencies. Furthermore, slot allocation adjustment is being conducted by the Ministry for slot shortage at Japan's two busiest airports –Tokyo, Haneda and Osaka, Itami Airports to achieve "open skies" in the domestic market.

Table 2-8 Comparison of unit fares; US-Japan (Yamauchi and Murakami, 1995, p.126)

Routes	Tokyo – Osaka	Tokyo - Sapporo	Sapporo - Osaka	Sapporo - Fukuoka	Sapporo - Okinawa	
Distance	530	897	1,167	1,602	2,426	
Jun-89 Normal	28	27	30	27	23	
Jun-89 Discount	22	22	25	23	21	
Mar-91 Normal	28	27	27	25	22	
Mar-91 Discount	22	22	23	21	18	
Routes	San Francisco – Los Angeles	San Francisco – San Diego	New York – Chicago	Minneapolis – Boston	San Francisco – Minneapolis	San Francisco – Boston
Distance	539	715	1,154	1,798	2,542	4,326
Jun-89 Normal	38	30	40	31	25	18
Jun-89 Discount	10	6	14	10	8	6
Mar-91 Normal	41	26	47	37	29	16
Mar-91 Discount	5	5	10	8	8	7

2.4.2 Japanese Airlines as Alliance Partners

Oum et al (2000) classified airline alliances into three categories: Type I (simple route-by-route alliances); Type II (broad commercial alliance); and Type III (equity alliance). Type I involve a lower level of commitment such as code sharing or shared (joint) operations involving a few routes only. Joint use of airport ground facilities such as gates and lounges, coordination of ground handling, block space sales, and shared frequent flyer programs are involved in Type I alliances. Type II alliance involves linking the two partners' networks to a substantial degree and feeding traffic to each other's hub airports. Type II alliance partners cooperate via the following activities: coordination of flight schedule and ground handling, joint use of ground facilities, shared frequent flyer programs, flight code sharing, block seat sale, and joint advertising and promotion. In Type III, the partners cooperate in almost all areas of joint activities including such areas as exchange of flight crews, joint development of systems and system software, joint advertising and promotion, and joint purchase of fuel, other supplies and possibly aircraft. Japanese Airlines are the partners of Type I alliances. Case description of Japanese airlines as alliance partners is

i. **Air Canada (AC) – All Nippon Airways (NA) (September 1994):** AC currently acts as the general sales agent for NA in Canada. The two airlines cooperate in the joint use of ground facilities, coordination of flight schedules, code sharing and block space sales, and the joint development of system,

ii. **Air France (AF) – Japan Airlines (JL) (May 1994):** The airlines operate three joint non-stop weekly services between Paris/CDG and Tokyo/Narita. Furthermore, they operate seven joint non-stop weekly services between Paris/CDG and Osaka/Kansai. Reciprocal passenger handling in Paris and Kansai. This joint services help mitigate the high costs associated with flying into Kansai airport. AF and JL already cooperate on the cargo front and are building, with LH, a joint terminal at NY/JFK,

iii. **Canadian Airlines International (CAI) – Japan Airlines (JL) (April 1996):** Code sharing on CAI flights on the Nagoya-Vancouver route. Block space agreement on certain CAI domestic routes,

iv. **Delta (DL) – All Nippon Airways (NA) (June 1994):** They currently have a marketing alliance wherein reciprocal ground handling occurs in Japan, Los Angeles, and New York. They plan to have code sharing and block space agreements on 13 weekly flights between Los Angeles and Tokyo that is subject to government approval. They also plan caducei on the New York/JFK-Osaka/Kansai, Honolulu-Kansai and Portland-Nagoya routes,

v. **Japan Airlines (JL) – Air New Zealand (NZ) (December 1989):** JL used to own about 5% of NZ's shares, but has already sold them. The carriers still caducei flights from Osaka/Kansai, Tokyo/Narita and Fukuoka to Auckland and Christchurch. The two partners also have FFP participation,

vi. **Japan Airlines (JL) – KLM (KL) (1985):** Code sharing on the Tokyo-Amsterdam-Madrid and Tokyo-Amsterdam-Zurich routes wherein JL operates the Tokyo-Amsterdam leg of the routes and KL operates Amsterdam-Madrid and Amsterdam-Zurich legs of the routes. These caducei flights replace JL's non-stop flights from Tokyo to Madrid and Zurich,

vii. **Japan Airlines (JL) – Thai Airways (TG) (1985):** Joint operations from Bangkok to Nagoya, Fukuoka and Osaka/Kansai,

viii. **All Nippon Airways (NA) – USAir (US) (December 1990):** Block space agreement and connecting service to Orlando for NA's services to Washington/Dulles and New York/JFK. Reciprocal FFP participation (Oum et al, 2000).

2.4.3 Comparison of Deregulation among Japan, USA and Europe

Table 2-9 Comparison of deregulation among Japan, USA and Europe

ITEMS	JAPAN	USA	EUROPE
Policies	* Civil Aeronautics Law of 1952 gave MOT to set fares, routes and operators. * Heavy regulation with 1970/72 Scheme began. * In 1985, Japan-US signed "balanced expansion", allowing three new carriers. * In 1986, 1970/72 Scheme was abolished and "double and triple tracking" routes were introduced to promote competition. * Japan-US removed all restrictions in 1998. * In 2000, Revised Civil Aeronautics Law was passed.	* Civil Aeronautics Act of 1938 remained until 1978 unchanged. * Deregulation Act for domestic markets was passed in 1978 and enlarged for international markets in 1979. * Authority over routes was to end in 1981 and over fares in 1983.	* Domestic routes were monopolies or duopolies operated by the publicly owned national carriers. UK became gradually more liberalized from 1980s. * From mid-1980s, UK signed a number of liberal bilateral agreements. * With European Union, three packages, issued in 1987, 1990 and 1993, has been implemented. * From 1993, member states committed "full liberalization". * Starting in 1997, full cabotage was permitted.

ITEMS	JAPAN	USA	EUROPE
Airfares	* Compared with the unit fares between the US and Japan, though normal fares in Japan tended to be lower than the US but discount fares were higher. Furthermore in US, 90% of passengers use discount tickets.	* There are stable fare reductions of roughly 27 percent since 1994 and during 1998, 80 percent of passengers, accounting for 85 percent of passenger miles, paid fares that were lower than the estimate of regulated fares. * The annual net benefits to travelers from airline deregulation are measured at $20 billion when fare and service quality are accounted	* Looking at 34 inter-city markets between 1988 and 1992, it is found that on fully liberalized routes, the standard economy fare had fallen by 34%. * However, there had been little change on routes that remain monopolies or duopolies. * The study for four markets (Amsterdam /London, Brussels /Rome, Madrid /Rome and Madrid /Milan) found that fares had not fallen dramatically during 1992-1997.
No. of carriers	* Till the entry of Skymark and Hokkaido International Airways, three major carriers: JAL, ANA and JAS dominate the domestic and international markets in Japan.	* More operated at the end of 1993 (seventy-six) than at the end of 1978 (forty-three). * However, there is a sharp reduce that makes the number of competitors slightly fewer than had existed before deregulation as a result of mergers. * At route level, it is found that airlines are more competitive than they were under regulation. * The rapid expansion of low cost carriers affects competition.	* Domestic routes that operated by two or more carriers rose from 65 in 1963 to 114 in 1996 with the largest expansions in France, Spain and Germany. * UK CAA (1998) found that the dominance of major carriers has declined with regional carriers enjoying a larger market share. * However, where the national carrier does not still control more than 70% of the market is Ireland where Ryanair has 60%.
New Entry	* Entry of Skymark Airlines and Hokkaido International Airlines in 1998 ends up the dominance of three major airlines; JAL, ANA and JAS. * After the entry of Skymark Airlines, airfares between New Chitose and Osaka became 40% cheaper while 30% cheaper between New Chitose and Haneda after the entry of Hokkaido International Airlines.	* New entrant activity has been a significant component in US air transport. Southwest Airlines has a unique position because there was a rapid growth in the number of low cost carriers, each taking the Southwest strategy plan. * The estimated savings from Southwest in 1998 were $12.9 billion where low fares were directly responsible for $3.4 billion. The remaining represents the effect of competition.	* The first new entrant airline in the EU is Ryanair as a result of 1991 restructuring and relaunch as a “No Frills” airline. * Average yield was reduced by 50% between 1991 and 1994. * During 1993–1997, Rynair expanded its program on UK routes and on Mainland Europe during 1997–1998. * Easyjet (which recently purchased GO), Buzz and Bimybaby emerged in UK.
Cost	* Japan Airlines and All Nippon Airways were over 50% less cost competitive than American Airlines because of their input prices (Oum and Yu, 1998)	* Among US carriers, American Airlines, United Airlines and Delta were similar in cost competitiveness, while Northwest and Continental enjoyed, respectively, 5 and 12% cost competitiveness over American Airlines (Oum and Yu, 1998).	* Major European carriers were 7% (British Airways) - 42% (Scandinavian Airlines System) less competitive than American Airlines because of higher input prices and lower efficiency (Oum and Yu, 1998).
Alliances	* Initially, most of US and Canadian trunk carriers used alliances. A similar pattern occurred in European carriers. * The first international alliance was formed in 1986 between Air Florida and British Island. Since then, many international alliances were formed between European and North American carriers. * Since about 1990, Asia Pacific carriers have joined the alliances, linking Asia with North America and Western Europe. * More recently, alliances extended to new regions, including Latin America, the Caribbean, and Africa. * There are three types of alliances. Japanese Airlines take part in Type I alliances (simple route-by-route alliance).		

2.5 Conclusion

This chapter is organized to enlighten the profile of the airline industry after the deregulation. The past 25 years has seen an increased liberalization of air transport markets. A trend that began with the U.S. domestic market in the mid-1970s has spread to many other national, regional and international markets.

Besides, there has been extensive reform of airports. In several cases, airports have been fully or partly privatized, and in other cases, they have been restructured as corporations. The aviation industry has been treated as a special case in international business, subject to different rules and held to different standards. Briefly, the liberalization period has seen major changes in the airline industry, bundling of services, the growth of hub-and spoke networks, waves of mergers among major carriers, economic regulation of airports, increase in competition, and variability of fares and services, entry of low-cost carriers as observed in Figure 2.13.

Focusing on the operational changes in air transport markets and categorizing these changes into two main groups: the operational change in network systems to hub-spoke networks; entrant activity, we review the empirical literature that investigates the development of hub-spoke networks and the competitive effects and comparative advantages of new entrants.

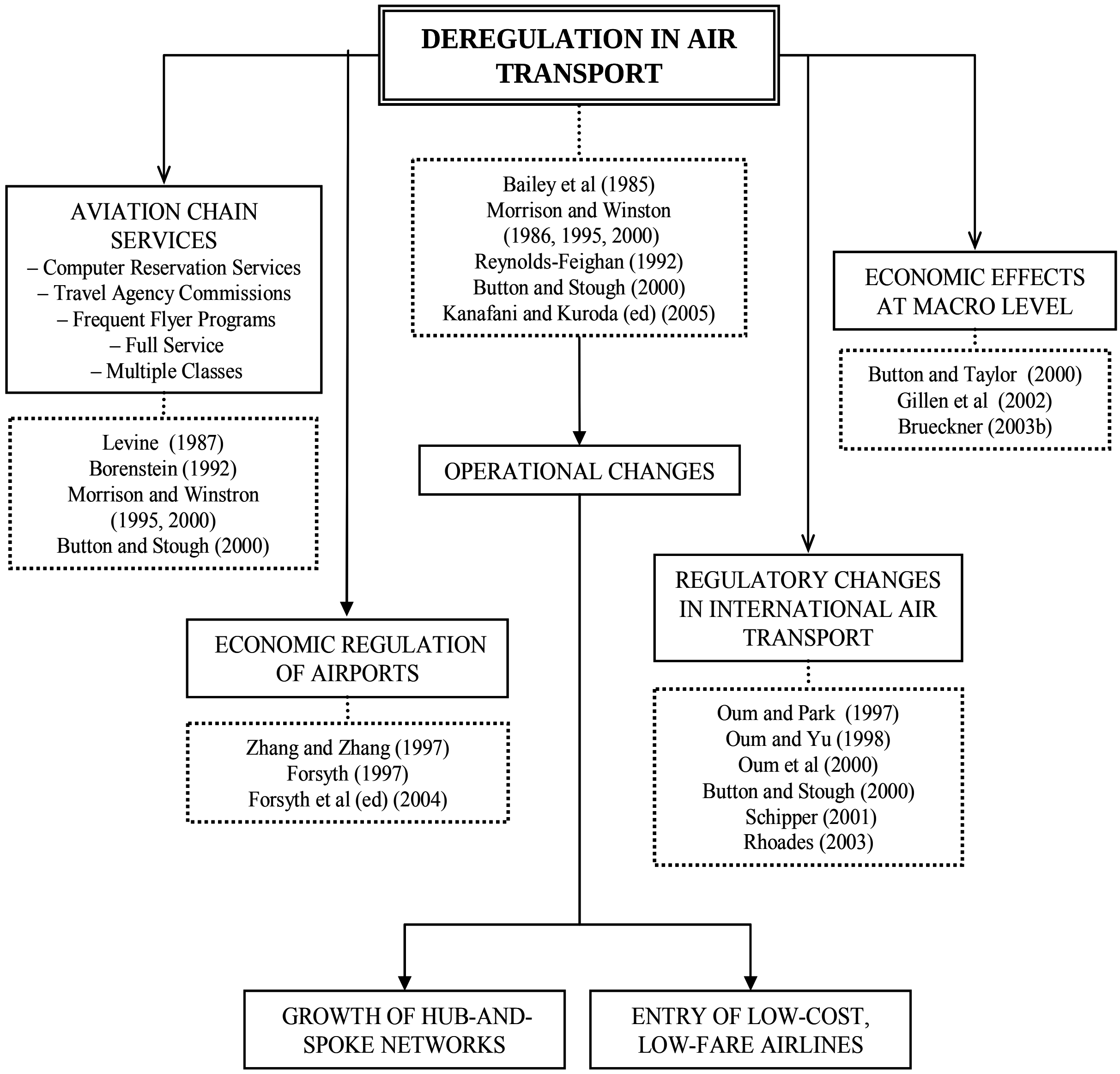


Figure 2-13 Empirical studies about air transport deregulation

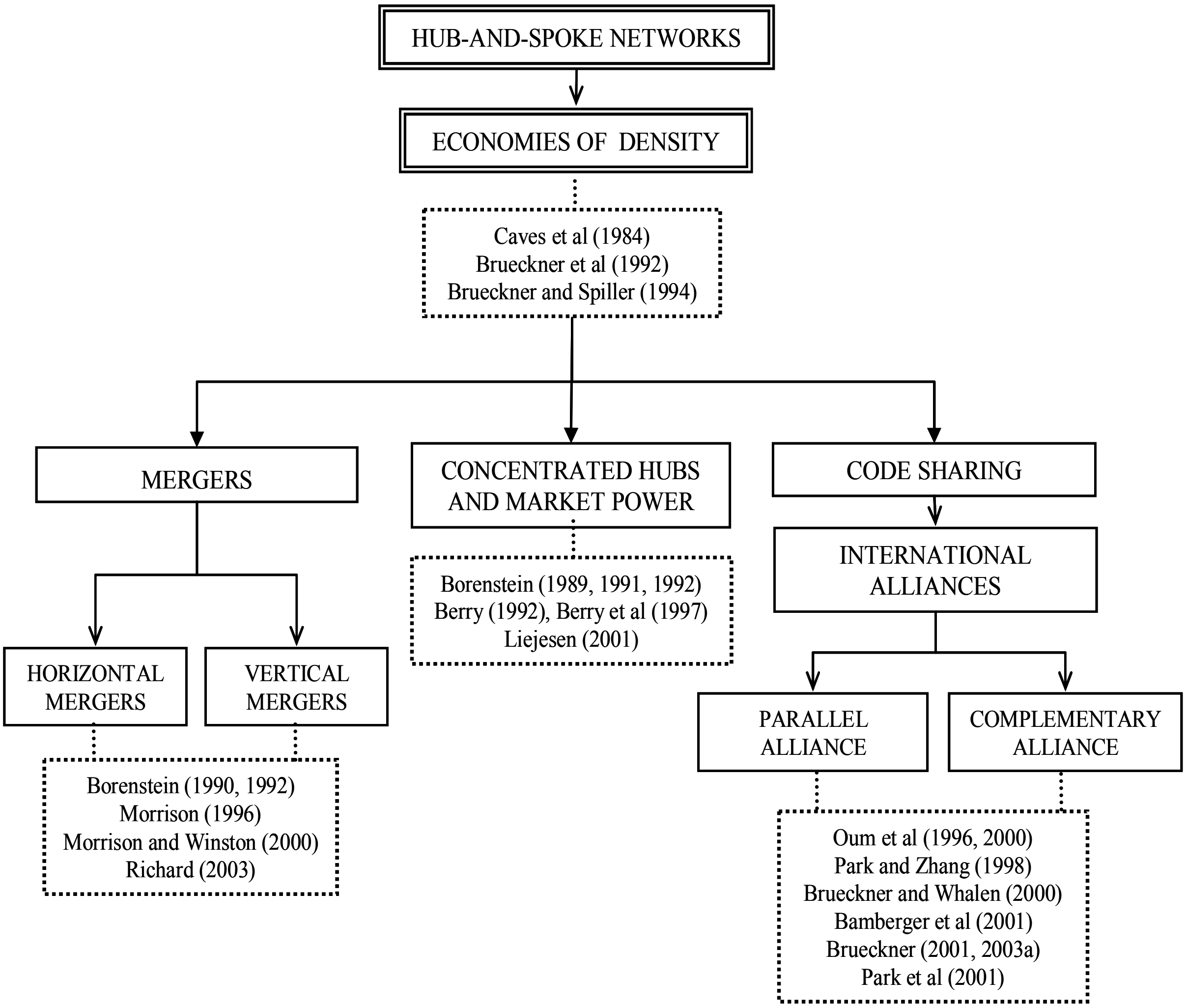


Figure 2-14 The economics of hub-and-spoke networks

The general observations and empirical studies about hub-and-spoke networks can be followed from Figure 2-14. The key point of all articles, reported in Section 2.2, is “economies of density”, all of them discuss the optimality and competition power of hub-spoke networks with respect to the relation between higher traffic levels and lower fixed costs in airline industry. However, the papers, reported in Section 2.3, show that despite the benefits of hub operators, a number of regional airlines such as Southwest Airlines, Ryanair and Morris Air have invaded the markets of HS networks by entering on the edge and become consistently profitable carriers since deregulation. To identify the concepts and the discussions in airline network literature, we draw Figures 2.13 and 2.14. As shown in these figures, the network choices of airlines with marketing choices result in different strategies. While hub-and-spoke system allows high load factors and market power, point-to-point networks provide easiness in adapting lower-cost strategy and therefore defining new aviation market. This is attracting new passengers as a result of increase in frequency and charge inexpensive fares.

Even though the studies, discussed in this chapter provides enough evidence about the evolution of airline industry, that the source of the data generally depends on the same survey, the US Department of Transportation’s Ticket Origin-Destination Survey (Data Bank 1A), a 10 percent sample of airline tickets of each year, makes a bias in generalizing the conclusion because the US DOT data involves the tickets with at least one segment flown on a U.S. carrier. Although we try to involve the studies, investigating the air transport markets in Europe and international markets in all over the world, the profile of airline industry in geographically small countries and foreign carriers offering services in a domestic market are still unobserved.

The studies, reviewed in this chapter, investigate the effects of deregulation at industry level, not measure the effects of liberalized air transportation on economic development at a macro-level. In the literature, it is possible to find such kind of papers. For example, the study of Button and Taylor (2000) examines the gains (largely in terms of employment) from liberalization and the introduction of international services. Gillen et al (2002) develops a model to assess the effects of the changes in a bilateral air transport agreement, governing the supply of air transport services, on the distribution of benefits and costs. While the former concerns North Atlantic market where there are two major trading blocs, the European Union and the North American Free Trade Area, the latter illustrates four country North Pacific air transport network and Canada-Japan liberalization. Additionally, Brueckner (2003b) shows that a 10 percent increase in passenger enplanements in a metro area leads approximately to a 1 percent increase in employment in service-related industries.

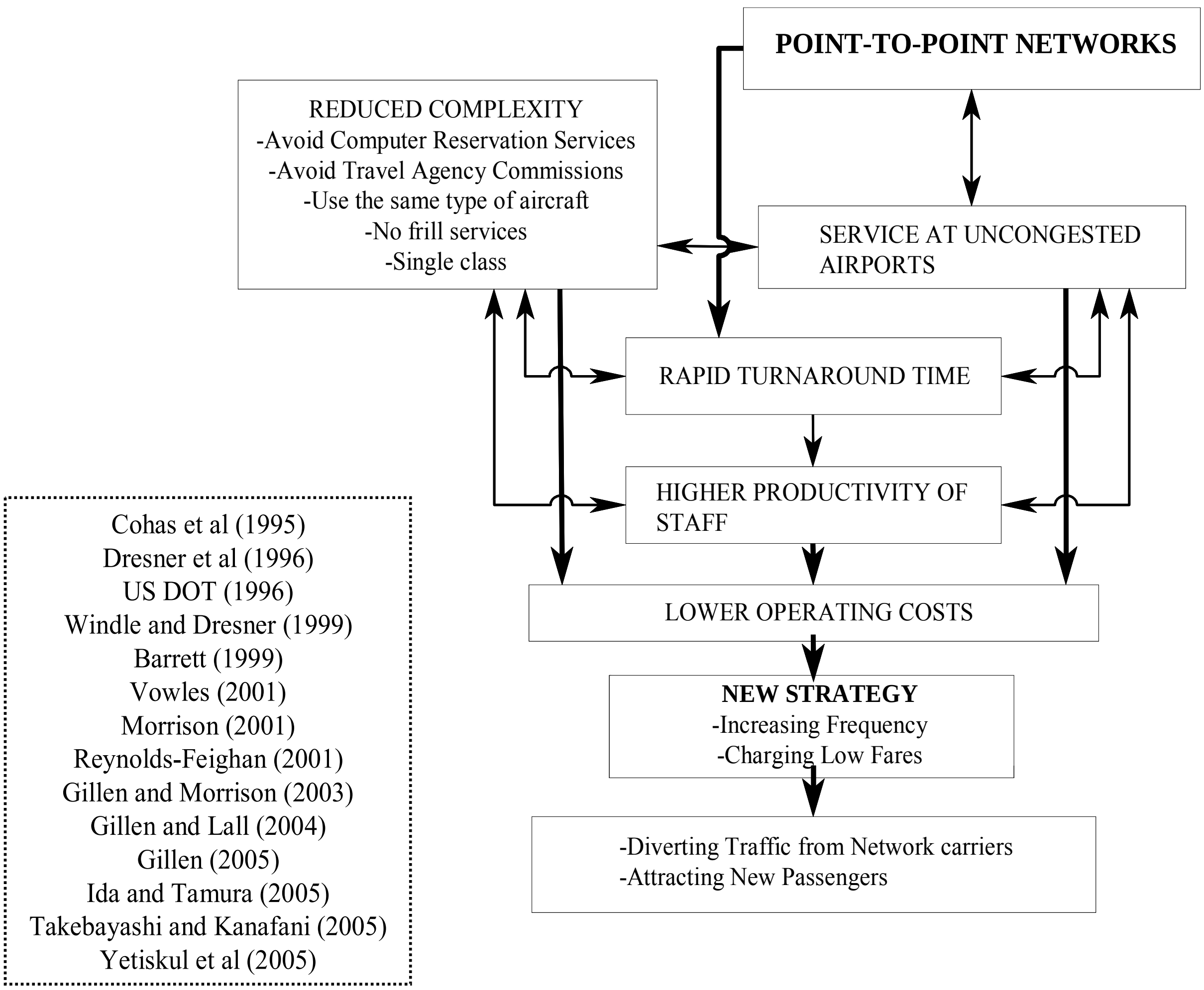


Figure 2-15 Market strategy of low-cost airline

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3 THEORY AND FIRM STRATEGY IN DEREGULATED AIRLINE MARKETS

3.1 Introduction

The main body of this chapter is designed to summarize theoretical models that enlighten the changes raised after Airline Deregulation, allowing air carriers to do what they want in offering their services, charging their fares and choosing their networks and routes. Many economists supported airline deregulation, calling contestability theory because it is believed that contestable- market structure has a disciplining effect on potential competition. Under this market structure, it is assumed that entry doesn't require any sunk cost so potential entrants in airline industry can make costless enter or exit a city-pair market if they already serve one or both of the cities when connecting other cities (Bailey and Panzar, 1981). However, it is impossible to find an industry where firms do not have to sink any investment prior to entry. Additionally, Stiglitz (1987) show that if entrants face even tiny sunk costs, then the only subgame percent equilibrium is the case that an incumbent charges a monopoly price and makes a monopoly profit. Thus, contestability theory to explain the situation in airline industry is failed (Borenstein, 1992 and Shy, 1995).

Levine (1987) reviews the changes in the airline industry after deregulation and points out that even though the deregulation was acted to create an actual competition, there are many ways in which the incumbents can deter market entry such as: hub airport dominance, predatory pricing, grand handling monopolies, computer reservation systems, anti-competitive mergers, frequent flyer programs. He concludes that neither perfect competition theory nor contestability theory is able to explain these unpredicted consequences. This Chapter comprehends the studies that deal with the reasons of these consequences and the impacts of them on airline market structure.

After the failure of the contestable- market structure, theoretical research about airline industry follows imperfect competition models because aviation industry is highly oligopolistic in general and duopolistic on routes. Thus, we choose an analytic approach, shown in Figure 3-1, and review the models that scrutinize the impacts of airline deregulation on the behavior of airline firms, the competition and social welfare and conclude that even though deregulation results in welfare gains generally, market failures in some airline markets are present because airline firms develop strategies to deter new entrants and get the market power after deregulation. One of them is the intensified use of hub-and-spoke networks.

"Economies of density" is found as the major reason why the carriers choose hub-and-spoke networks. Furthermore, there are enough empirical results that emphasize a substantial decline in the number of major carriers in airline industry so theoretical models that show the relation between this decline and the increase in the use of hub-and-spoke networks as an offensive or a defensive strategy in airline network competition are developed. Furthermore, to benefit from higher traffic densities, airline companies develop the same policies for international markets and form strategic alliances. Then the theoretical studies that examine the complementary effects of cost and demand factors among the traffic levels in each alliance partner and the differences in fares before and after an alliance are expanded. Although, the new entrant activity, particularly new airlines with low cost operating strategies, is the other most important operational development after the deregulation out of the formation of hub-and-spoke networks, in the literature there is no theoretical model that explains the success of these carriers or their behavior patterns in an oligopolistic environment.

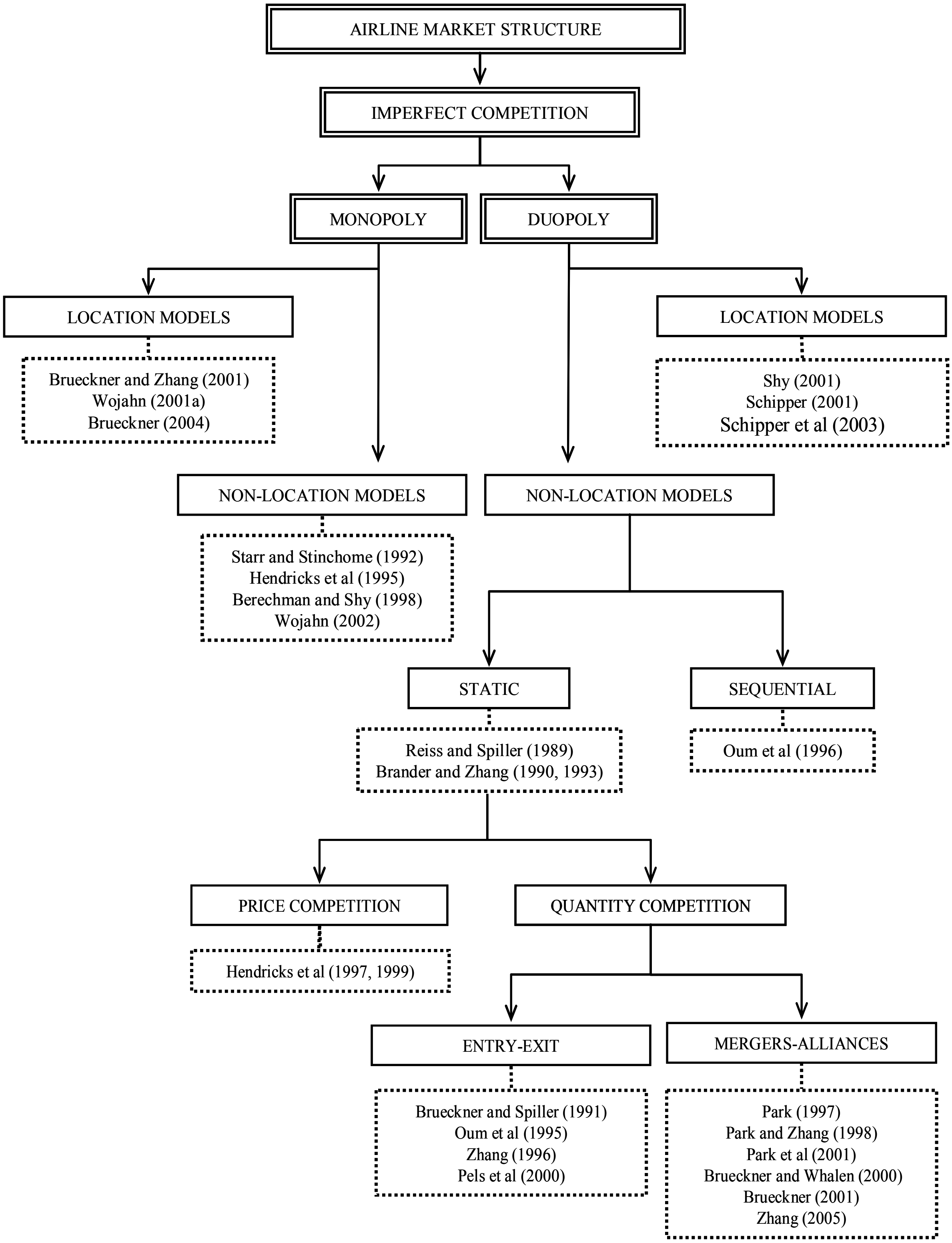

Figure 3-1 Theoretical studies about airline market structure

As shown in Figure 3-1, firstly the monopoly models that explain economies of hubs are investigated and then oligopoly models in the airline competition are reviewed. Price and quantity competition form the analysis of the oligopolistic strategies. The quantity competition models, Cournot equilibrium is discussed in two subsections. One is the analysis of the determination of market structure by reviewing the role of concentration (hub and spoke networks) in deterring entries while the other includes the causes and consequences of mergers and alliances. The location approach is analyzed in Section 3.2.2 and 3.3.4. Even though there are a few studies, depending on location approach in airline market solutions, it provides an alternative method by introducing location into consumers' preferences. This chapter also draws the connection between theoretical models and the empirical findings, examined in Chapter 2.

3.2 Network Choice under Monopoly

3.2.1 Non-Location Models

Starr and Stinchcombe (1992) examine network economics in finding optimal network for a monopolist and solve optimization problems under different constraints in cost functions, assuming that prices are exogenous and the quantity flows are fixed. The demand for flights, chosen by the passengers in response to the route structure and the cost of running the route structure with the benefit, gotten from running the airline to service the demand, describe the efficient route structure. Demand and cost in a transport network are assumed as symmetric and the timing issues of business vs. weekend travelers are ignored. Route structures are also symmetric(m), (there are direct flights from i to j if and only if there are direct flights from j to i) where m denotes the number of steps in a route structure when traveling from i to j. The cost function forms

$$C(R, M; \tilde{\alpha}, \tilde{\beta}) = \sum_{ij} c_{ij}(R, M; \tilde{\alpha}, \tilde{\beta}), \tag{3-1}$$

where $C(R, M; \tilde{\alpha}, \tilde{\beta}) = \alpha_{ij} + \beta_{ij} m_{ij}(R, M)$.

α_{ij} and β_{ij} are cost parameters and $m_{ij}(R,M)$ denotes passenger miles moved from i to j when passengers choose their favorite routes in response to route structure, R, to serve the demand M. $\tilde{\alpha}$ or $\tilde{\beta}$ are the vectors that show the conditions for cost in city set. Passengers plan their routes in a fashion that depends on R but not on $\tilde{\alpha}$ or $\tilde{\beta}$ *;* passengers choose some one of the possible ways of going from i to j. $C(R,M)$, the measure of cost, is linear in $\tilde{\alpha}$ and $\tilde{\beta}$, for $(\tilde{\alpha}, \tilde{\beta}) \geq (0,0)$. The different conditions of $\tilde{\alpha}$ and $\tilde{\beta}$;

i. if $\tilde{\alpha} \cong 0$ and $\tilde{\beta} \cong \beta.\tilde{1}, \beta > 0$, when $\tilde{1}$ denotes the vector of 1's in the set of cities (costs are nearly linear in passenger miles) then the cost minimizing schedules are direct, point-to-point systems,

ii. if $\tilde{\alpha} \cong \alpha.\tilde{1}, \alpha > 0$ and $\tilde{\beta} \cong 0$, (all transportation costs are fixed costs (small variable costs) per vehicle trips), then the size of optimal network is $n-1$, where n indicates the number of connected points or cities. If fixed costs are also independent of the pairs of destination, the optimum networks are cyclical route structures which provide minimum cost with the minimum number of vehicle trips,

iii. if more than one change of vehicle per trip isn't allowed and $\tilde{\beta} \cong 0, \tilde{\alpha} \cong \alpha.\tilde{1}, \alpha > 0$, then the only solution is two-step hub-spoke system with the requirement that number of connected points is equal to or more than *4*, otherwise if $n=3$, a cycle has strictly lower cost than a hub-spoke system,

iv. if $\tilde{\beta} \cong 0$ and $\tilde{\alpha} > 0$, (but not necessary $\cong \alpha.\tilde{1}$) and route structures are also symmetric then the graph associated with any solution is a tree with many hubs and no cycles.

It is concluded that in the presence of high fixed costs and low marginal costs on each line, optimal airline networks display a system-wide scale economy because the network of size *n-1* provides linear costs, *2(n-1)*, but quadratic benefits, *n(n-1)*. Table 3-1 shows the greater impact of adding more links through a hub. With the expectation that each single route achieves efficient passenger loads on each flight, scale economy causes declining average cost in each airline route. Consistently decreasing average cost characterizes a natural monopoly. The analysis suggests that monopoly is the natural and predictable outcome of an unregulated route structure, in as much as a hub-spoke system is characterized by unlimited economies of scale.

Table 3-1 Impact of hub-and-spoke networks on the number of city pairs served

No. of cities *n*	No. of direct connections *n-1*	No. of city pairs served via the hub *(n-1)(n-2)/2*	Total city pairs served *n(n-1)/2*
3	2	1	3
7	6	15	21
10	9	36	45
25	24	276	300
50	49	1176	1225

Starr and Stinchcombe (1992) restrict their analysis to linear cost functions in which either fixed costs (α_{ij}) or variable costs (β_{ij}) are small and omit the option of non-linearity but Hendricks et al. (1995) take the variable costs non-linear and the fixed costs in a different kind of linearity, depending on the number of direct connections in a network. Additionally, the former endogenize both network structure and prices. When fixed costs are positive and variable costs are small or zero, both show that the optimal network is a hub of size *n-1* because of network economics. However, the former claim that "economies of density" arises not only from spreading fixed costs over a larger volume of passengers but also declining marginal costs so they conclude that the optimal network for the monopolist is either a hub of size *n-1* or completely and directly connected one when variable costs also exhibit economies of density.

Hendricks et al. (1995) defined "fixed costs", *F,* as station and ground site costs, ticketing, promotion and administration costs and "variable costs", *V*, as aircraft leasing and operating costs while fixed costs represent approximately 40-50% of air carrier's total costs. Total costs of a direct connection in the city *g-h* market are denoted as the sum of fixed costs and variable costs,

$$C(Q_{gh}, Q_{hg}) = F + V(Q_{gh}, Q_{hg}), \tag{3-2}$$

where Q_{hg} denotes the total flow from city *g* to city *h* and it is assumed that *V(.,.)* is symmetric. With symmetric demands and costs, the monopolist optimization problem is to maximize

$$\sum_{g=1}^{n} \sum_{h \neq g} R(D(p_{gh})) - \sum_{g=1}^{n} \sum_{h>g} V(Q_{gh}(P,\Delta), Q_{hg}(P,\Delta)) - Fm(X). \tag{3-3}$$

The first term denotes sums up the total revenues which the monopolist can collect from each market (*N={1,2,….,n}* set of distinct cities).The second and the third terms represent the variable costs and fixed costs of connecting up city pairs when *m* denotes the number of direct connections in a network. $D(p_{gh})$ is the demand in the city *g-h* market, where p_{gh} is the price of a ticket to travel from city *g* to city *h*. $Q_{gh}(P,\Delta)$ is the total flow from city *g* to *h* with a price configuration, *P,* and a flow configuration, *Δ*.

Claming that economies of density arise from two sources, Hendricks et al (1995) characterize the solution with two main theorems. Theorem 1 says that the monopolist wants to serve all *n(n-1)* markets with a smallest network if fixed costs are positive and variable costs are zero and this objective is achieved with *n-1* direct connections. In Theorem 2, variable costs are supposed as $V(Q, Q') = \phi(Q + Q')$, where ϕ is concave and that any network of size *m* where *m* is an integer out of *n-1* or *n(n-1)/2*, is not optimal, is proved. Then asking whether network of size *n-1* or *n(n-1)/*2 is optimal, they focus on the level of fixed costs in each type.

The gross profits (revenue minus variable costs) of networks with size *m* that is in the ranges, *n(n-1)/2>m>n-1* or *n-1>m>1,* are compared with the gross profits of *n-1* and *n(n-1)/2* networks. For the concavity of ϕ, piece-wise linear cost function, $\phi_L(Q) = \min\{c_i Q + f_i\}$, is used and for any network *X*, define

$$\Pi_\phi(X) = \max_{P,\Delta} \sum_{g=1}^{n} \sum_{h \neq g} R(D(p_{gh})) - \sum_{g=1}^{n} \sum_{h>g} \phi\big(Q_{hg}(P,\Delta) + Q_{gh}(P,\Delta)\big). \qquad (3\text{-}4)$$

$\pi(kc) = \max_q \left[R(q) - kcq\right]$ where k and q represent the number of connections and the number of passengers in each city pair markets respectively. *k* equals to 1 in markets served by direct connections and 2 in hub-spoke networks. The monopolist gains *π(c)* profits from directly connected *2m* markets, *π(2c)* profits from indirectly connected *n(n-1)-2m* markets. Hence, for $\phi_L(Q) = \min\{c_i Q + f_i\}$, the profits of a hub-spoke network (H) and point-to-point network (T) are defined as

$$\Pi_i^H = (n-1)\big(2\pi(c_i) - f_i + (n-2)\pi(2c_i)\big), \qquad (3\text{-}5)$$

$$\Pi_i^T = n(n-1)\big(2\pi(c_i) - f_i\big)/2. \qquad (3\text{-}6)$$

$\pi(c_i)$ is convex in c_i. Then it is clear that $\Pi_\phi(H) \geq \max_{i \in I} \Pi_i^H$ and $\Pi_\phi(T) \geq \max_{i \in I} \Pi_i^T$. Finally, a linear combination of $\Pi_\phi(H)$ and $\Pi_\phi(T)$ for any *m* between *n-1* and *n(n-1)/2* is written as

$$\overline{\Pi}_m = \Pi_\phi(H) + 2(m - n + 1)(n-1)^{-1}(n-2)^{-1}\big(\Pi_\phi(T) - \Pi_\phi(H)\big) \qquad (3\text{-}7)$$

and $\Pi_\phi(X) \leq \overline{\Pi}_m$ is shown if *m* is between *n-1* and *n(n-1)/2*. If *m* is between *1* and *n-1,* adding a connection to the network of size *m*, *(m<n-1)*, is profitable because additional *2(m+1)* markets can be served and average costs per every traveler can be decreased in the network. For that reason, it is optimal to connect the network up to *m=n-1*.

These results imply that the optimal network is either a hub of size *n-1* or a network of size *n(n-1)/*2. However, which of two is optimal depends on the fixed costs. The level of fixed costs at which the net profits of both networks are equal, is defined as $A = 2(n-1)^{-1}(n-2)^{-1}\big(\Pi_\phi(T) - \Pi_\phi(H)\big)$. If $F < A$, the optimum network is a point-to-point network but if $F > A$, the optimum one is a hub with size n-1. Furthermore, if demand is same in every city, *A* will be same for all city-pairs. Consequently, it exceeds *F* for either every city-pair or none. For the former case, a point-to-point network is optimal while for the latter, a hub-spoke network is. Even though Hendricks et al (1995) claim that "economies of density" arises not only from spreading fixed costs over a larger volume of passengers but also declining marginal costs, their optimal network solution depends on the fixed cost level so they suggest one stop traveling from hub city when the sizes of cities are small and direct connections when city sizes are quite large.

3.2.2 Location Models

In this Section, we continue to scrutinize the models under monopoly but in these models consumers are heterogeneous. Having different tastes or location, each consumer has a different preference for the brands sold in the market. Since deregulation, airline carriers began to compete for customers not only by prices but also the level of brands. Hence, the airline's network choice depends on not only "economies of density" but also the service quality, provided by network type. In airline industry, one of the elements related with service quality is flight frequency. However, there are a few models that analyze flight frequency in the literature. Brueckner and Zhang (2001) analyze how a hub-and-spoke network affects flight frequency, fares and welfare. In the model, instead of consumers being physically located, their "most preferred arrival times" as termed by Douglas and Miller (1974) are located over time. Consumption expenditure equals income y minus the airfare p, while trip benefits are equal to a gross benefit δ minus the time costs of the trip. Time costs depend on travel time and schedule delay that measures the deviation between the desired and actual arrival times. A passenger's utility is written as

$$u = y - p + \delta - \alpha\left|t_a - t^*\right| - \beta h, \tag{3-8}$$

where h is the travel time, t^* is the desired arrival time, t_a is the actual arrival time. The parameter β gives the disutility per hour of travel time, while α gives disutility per hour of schedule delay. For a given arrival time t_a, the smallest value of t^* for which a passenger finds a trip worthwhile indicates that the utility from the trip is equal to the utility from not traveling. To analyze the characteristics of the two types of networks, the airline's profit maximization problem under the fully connected network and hub-and-spoke network are solved. Under fully connected one, the airline serves three city-pair markets AH, BH, and AB with separate flights and total profit is

$$\pi_{FC} = 3(fpq - fc), \tag{3-9}$$

where f and q denote the number of flights and passengers per flight respectively. c is the airline fixed cost per flight. The solution under fully connected network yields the flight frequency that all passengers are served and the optimal fare that equals trip benefit net of travel-time cost minus the airline's cost per passenger. When the airline operates a hub-and-spoke network, it offers flights on two rather than three routes so passengers in the AB city-pair market must make a connecting trip through the hub H. Hence, the time duration of the trip is assumed to equal $2h$ and the profit of airline is equal to

$$\pi_{HS} = 2fpq + fPQ - 2fc, \tag{3-10}$$

where P and Q denote the price and the traffic level in the connecting market AB. After solving the profit maximization problem under hub-and-spoke network and comparing the results under two cases, Brueckner and Zhang (2001) conclude that flight frequency is higher in the hub-and-spoke network than in the fully connected network and local passengers pay a higher fare under the hub-and-spoke network, but the fare paid by connecting passengers could be higher or lower than in fully connected network. According to them, this finding suggests the downward pressure on fares due to economies of density may be partly or fully offset by the effect of higher flight frequency in a hub-and-spoke network.

To deepen the understanding of scheduling in networks, Brueckner (2004) offers a model that improves upon the previous work. In addition to comparing flight frequencies and fares, this analysis compares aircraft sizes and passenger volumes between the two network structures. Consumer utility is given by *u=C+B-time cost*, where *C* is consumption and *B* is travel benefit. In the model, travel benefit varies across consumers so average schedule delay cost is supposed. Letting *f* denote the number of flights, the time between flights is *T/f* and average time to the nearest flight is a quarter of this value, *T/4f*. When schedule delay cost is denoted as δ, utility for each passenger is equal to $C+B-G-\delta T/4f$, in which *G* is the cost for nonstop travel between any pair of cities.

It is supposed that *B* has a uniform distribution with support $\left[\underline{B},\overline{B}\right]$ and density $\eta = 1/(\underline{B} - \overline{B})$, implying that the total mass of consumers is unity. The number of consumers traveling then equals

$$q = \int_{-(Y-p-G-\delta T/4f}^{\overline{B}} \eta dB = (\overline{B} + Y - p - G - \delta T / 4f)\eta. \tag{3-11}$$

The inverse demand curve for *p*, is given by

$$p = \alpha - \beta q - \gamma / f, \tag{3-12}$$

where $\alpha = \overline{B} + Y - G$, $\beta = 1/\eta$, and $\gamma = \delta T/4$. The key feature is that, reducing average schedule delay, an increase in flight frequency induces more consumers to travel, leading to an upward shift in the inverse demand function. The operating cost per flight is given $c(s) \equiv \theta + \tau s$, with θ equal to fixed cost and τ equal to marginal cost per seat when *s* denotes the number of seats per flight. Finally, it is assumed that all aircraft seats are filled. With this assumption, $s = q / f$ is written. After analyzing the fully connected and hub-and-spoke networks, Brueckner (2004) concludes that switching to a hub-and-spoke network leads to increases in both flight frequency and aircraft size, while stimulating local traffic in and out of the hub. However, the comparison of traffic levels and fares in connecting market between the network types is ambiguous. When fixed cost is large, when travel demand is low, hub-and-spoke network is favored. Additionally, when the travel cost parameter is low, when the disutility of schedule delay is large, again hub-and-spoke network is suggested but if customers have low travel cost, they have also low schedule delay cost and vice versa. Then this is a contradiction.

3.3 Network Choice under Oligopoly

In this Section, the oligopolistic models that focus on strategic market interactions between carriers in choosing networks to connect cities and competing with each other for customers are investigated to discuss the role of network economics in airline competition. If the firms' strategies depend on quantity competition and each firm believes that the other firm's choice is independent from its own, this is Cournot-like behavior and if firms take prices as the relevant strategic variables, then Bertrand-like behavior is observed. When the quantity leadership or price leadership model occurs, this means that one firm sets his quantity or price which the other firm then takes as given.

Before scrutinizing the models one by one, we show the results of the studies that draw inferences about whether Bertrand, Cournot or cartel models are supported by the data. Brander and Zhang (1990, 1993) calculate conduct parameters (or "conjectural variations") for a set of duopoly airline routes and find that airline conduct is close to Cournot behavior. Denoting the "conjectural variation" as v_i for firm *i*, *i=1,2* and outputs of firms as x_1 and x_2, respectively, the appropriate first order condition is written as

$$\pi^{i}{}_{i} = p + x_i p'(X)\left[1 + v^i\right] - c^i = 0 \ , \tag{3-13}$$

where total output, denoted X, is the sum of x_1 and x_2, and inverse demand is $p(X)$. π and c^i represent derivative of firm profit and marginal cost of firm i, respectively. If two firms have the same costs, which can be described as the Bertrand model, both should have conduct parameters of -1, since the first-order condition reduces to price equals marginal cost. Cournot case arises if $v=0$, in which each firm believes that the other firm's choice is independent from its own. The cartel solution arises, under identical costs, if the conduct parameter equals 1.

3.3.1 Price Competition

Hendricks, Piccione and Tan (1997) study the extent of economies of networks to show the competition between a national carrier with a choice of hub-spoke network and a regional carrier that offers flights only on one spoke market and conclude that the complementarities associated with a hub-and-spoke network can deter new entry. In the model, competition is formulized using a stylized game with three stages. Firstly, national carrier chooses hub-spoke network and regional carrier enters on a spoke market, in the second stage, both carriers make exit decisions and finally, they choose their prices. The fixed cost of providing a nonstop service, F, between a pair of cities is same for both carriers while c^N and c^R denote the national and regional carriers' marginal cost per traveler of a round trip on a direct flight and it is assumed that c^R cannot exceed c^N. A proportion γ of F is assumed to be sunk upon establishing nonstop service (entry cost), $(1-\gamma)F$ is the fixed production costs, and exit costs are zero.

Considering three possible outcomes and identifying inter-market pricing constraints, equilibrium prices of both carriers are discussed. The first outcome is that national carrier operates the hub-spoke network as a monopolist and charges monopolist prices, $p_M(c^N)$ from direct markets, $p_M(2c^N)$ from connected markets. Assuming that the price elasticity of demand, $\in(p) = -pD'(p)/D(p)$, is non-decreasing in price, p, $p_M(2c^N) \leq 2p_M(c^N)$ is found.

In the second outcome, national carrier withdraws its nonstop service between hub city 1 and non-hub city 2 and only regional carrier offers services. The two carriers service the interlining markets according to demand, $D(s^N_{g2}+p^R_{g2})$. Price charged by national carrier for its segment of the trip (from city g to hub city 1) is denoted by s^N_{g2} and p^R_{g2} is the price charged by regional carrier to transfer passengers from hub city 1 to city 2. The following constraints are given to force the interlining passengers to purchase one ticket when traveling between connected markets.

(C2) $\quad p^N_{g1} \geq s^N_{g2}, \qquad \text{if } g = 3,....,n,$

(C3) $\quad p^R_{12} \geq p^R_{g2}, \qquad \text{if } g = 3,....,n.$

These mean that carriers cannot charge the interlining travelers higher prices than hub travelers. Price equilibria is featured in two cases; in one case, best-reply functions of the carriers are decreasing, and flights are strategic substitutes with $\pi(c^N + c^R)/2 < \pi(2c^N)$ while in other case, both best replies are increasing and flights are strategic complements with $p_M(c^R) > c^N$ (monopoly price of regional carrier is more than marginal cost of national carrier). Nash equilibrium of the second outcome is $p^R_{g2} > c^N, g \neq 2$ because in the former case, best replies are downward sloping so the prices at their intersections are less than monopoly prices, $p_M(c^N)$ and $p_M(c^R)$. Thus the constraints (C2) and (C3) are not binding and $p^R_{g2} > c^N, g \neq 2$. In the latter case, the constraints, (C2) and (C3) are binding so the price equilibrium is unique, this is possible when the best-reply functions intersect only once. Hence, national carrier cannot discriminate between (*g-2*) and (*g-1*) travelers and charge different prices. Also regional carrier must charge each interlining passenger the same price.

In the third outcome that the national and regional carriers offer nonstop services between cities *1* and *2*, the carriers are prefect substitutes in the 1-2 market and the one offers the lower price wins the entire market like in Bertrand case. In non-hub (*g-2*) markets, the national carrier decision to share the markets with the regional carrier, depends on whether it sets p^N_{g2} lower or higher than $p^R_{g2} + s^N_{g2}$. These imply that the regional carrier's price in every (*g-2*) market cannot exceed c^N and there is an accommodating equilibrium point by $z \in [c^R, c^N]$ in which the regional carrier charges *z* for its flights. However, when the national carrier doesn't share the connecting (*g-2*) markets, there may be some deterrence equilibria.

Briefly, the entry and exit decisions of firms depend on the number of cities in the system because if the national carrier withdraws its services from the market *1-2*, he begins to lose markets with a (*n-2*) proportion so *n* does not have to be very large for the loss to exceed $(1-\gamma)F$. Thus, when *n* is large, the national carrier never withdraws nonstop. If the regional carrier does not have a marginal cost advantage, $c = c^R = c^N$, it is difficult to enter the market. Lastly, if $c^R < c^N$, the regional carrier enters on a spoke and neither carrier exits.

Hendricks et al (1999) modelize the competition between two large carriers, *i=A,B* with different network choices in two cases. One is the case that when carriers behave like Bertrand competitors and the other one is the non-Bertrand competition case. Their consequence is similar to previous ones, that competition between carriers with hub-spoke networks is not equilibrium. The model is a reduced-form game in which carriers choose networks simultaneously. The lengths of the paths chosen by the carriers to transport travelers in the market are the characteristics of each carrier's operating profits (revenue minus variable costs). $\pi(z^i, z^j)$ denote the operating profits that carrier *i* obtains from a city-pair market in which it offers a path of length z^i and carrier *j* offers a path of length z^j and $\pi_M(z) \equiv \pi(z, \infty)$ defines the profit that a monopoly carrier earns when it services a city-pair market with a path of length z.

Some assumptions are defined

$$\begin{array}{ll}
\text{(A1)} & \pi(z,y) \geq \pi(z+1,y), \\
\text{(A2}-\text{i)} & F(n(n-1)/2) > n(n-1)\pi_M(1), \\
\text{(A2}-\text{ii)} & (n-1)2\pi_M(1) + (n-1)(n-2) > F(n-1), \\
\text{(BC)} & \pi(z,y) = 0 \quad \text{if} \quad z \geq y.
\end{array}$$

While (A1) implies that a carrier can not gain by using a longer path, (A2-i) and (A2-iii) state that a point-to-point network is not profitable even if the carrier is monopolist and a complete hub-spoke network is profitable. This is a contradiction. With these assumptions, they directly eliminate the option that a carrier is operating a point-to-point network. Additionally, the carriers are not allowed to choose paths longer than two segment ones with a condition (BC). Hence, the case that carriers behave like Bertrand competitors concludes monopoly outcome in which only one carrier operates a complete hub-spoke network. Non-hub duopoly equilibrium exists if both carriers don't offer services for the same markets with the same lengths, which means that every city-pair market is serviced by only one carrier, the one with length advantage. However, this solution is another kind of monopoly power.

In the second case that carriers do not compete aggressively and avoid marginal cost pricing in city-pair markets where neither has an advantage, condition (A2-ii) is replaced by

$$\text{(A4)} \qquad (n-2)(n-3)\pi(2,2) > F(n-2) .$$

(A4) requires profits to be positive in city-pair markets where both carriers offer a one-stop connection. With this assumption, airlines can differentiate their product and build consumer loyalty. In characterizing the equilibria sets, the modularity properties are defined. If carrier *i* gains more profit when he chooses a direct connection against carrier *j*'s one-stop connection and a one-stop connection against carrier *j*'s direct connection; the operating profit of carrier *i*, π, is quasi-submodular. The converse is in the quasi-supermodular case. π is quasi-submodular if for any pair of positive integers (z, y)

$$\pi(z,y) + \pi(y,z) \geq \pi(z,z) + \pi(y,y) , \tag{3-13}$$

and quasi-supermodular if the opposite inequality holds.

Hendricks et al (1999) exhibits the existence of duopoly hub-spoke equilibria by laying down the properties of the profit function. The proof about the carriers' best responses consists of two steps; in the first step, they show that carrier *i*'s best response to a hub-spoke network of size *n-1* is a hub-spoke network, in the second one, that the best reply to a hub-spoke network of size *n-1* is a hub-spoke network of size *n-1*, is shown. To require the second solution, it is supposed that the profit, obtained by adding one more connection in the network, exceeds the fixed cost of the connection and is defined as

$$F(n-1) - F(n-2) < 2\pi(1,1) + 2(n-2)\pi(2,1) . \tag{3-14}$$

In sub-modular case, carriers should transfer the passengers from different hub cities while in super-modular case; both carriers use the same paths and the same hub city as its rival does. If the condition (3-14) is satisfied, the carriers want to operate a hub-spoke network of size *n-1* because in the sub-modular case, each carrier will want to establish a direct connection between the two hub cities while in the other case, using the same complete hub-spoke network is more profitable than any network of size *n-2*.

Under these conditions, duopoly equilibria in hub-spoke networks can exist. However, it is possible that the gains from hubbing are less profitable than the gains, obtained in non-hub equilibria. In the context of the airline network choices, the assumptions point at some restrictions. One of them is that even though travelers prefer direct flights to one-stop connections, carriers are not allowed to operate a point-to-point network. In addition, there may be some city-pair markets in which the volume of traffic is large enough to offer a direct connection. The other uncertainty is about non-hub equilibria because it is difficult to stop a carrier from offering new services to the other markets which are not connected by him, if he is able to earn positive profits in his city-pair markets. If the conditions on π and F (3-14) is assumed, it automatically concludes completeness in hub-spoke network. Thus, it is needed to loosen these assumptions in searching duoply network equilibria.

3.3.2 Quantity competition

In this Section, we continue to review duopoly airline models, developed to search network competition. After scrutinizing the models of Hendricks et al (1997, 1999) that characterize the equilibrium prices in searching the network externalities of a hub-and-spoke network, Brueckner and Spiller (1991), Zhang (1996) and Park (1997) examine the effects of hub-and-spoke networks or alliances in Cournot equilibrium with special cases, in which linear demand curve and marginal cost function are assumed. Cournot equilibrium and the comparative static effects of the network variable (hub-and-spoke network or any kind of alliance) on the equilibrium outputs are discussed in Oum et al (1995), Park and Zhang (1998), Park et al (2001) and Zhang (2005). Brueckner (2001) in analyzing the effect of alliances on traffic levels, fares and welfare, takes price-based approach in interline markets while assuming Cournot behavior in the inter-hub market.

3.3.2.1 Concentration, Entry and Exit

In quantity setting models, known as Cournot, airline firms are choosing their quantities and letting the market determine the price. Brueckner and Spiller (1991), Zhang (1996) and Park (1997) set their models like Cournot model and analyze the effects of hub-and-spoke networks or alliances on firms' output and air fare, assuming that both marginal revenue and cost functions are linear.

$$R'(Q) \equiv \alpha - Q, \qquad \alpha > 0; \tag{3-15}$$

$$c'(Q) \equiv 1 - \theta Q, \qquad \theta > 0. \tag{3-16}$$

The scale of demand relative to costs is represented by α and the extent of increasing returns (relative to the demand slope) is measured by θ (constant returns corresponds to $\theta=0$). The common cost function (denoted as $c(Q)$), used to represent a carrier's trip cost of carrying Q passengers, reflects increasing returns to traffic density, with satisfying $c'(Q) > 0, c''(Q) < 0$ because of cost complementarities in a hub-and-spoke network. Pels et al (2000), check the optimality of airline networks that is formulated using linear marginal and demand functions and claim that these functions guarantee the optimality of the hub-and-spoke networks as a result of zero fixed cost assumption. We also believe that distinguishing the costs in the investigation of network optimality is more reliable setup. However, these models also feed some explanatory conclusions about "economies of density", network competition and alliances in airline industry.

Brueckner and Spiller (1991) develop a simple model of hub-and-spoke network to focus on the cost complementarities and the welfare effects of competition within a hub system, using linear marginal and demand functions. Firstly, the monopoly solution as a benchmark case is developed. As shown in Figure 3-2, a monopoly airline that serves four cities: *A*, *B*, *C* and *H* (hub city) is supposed.

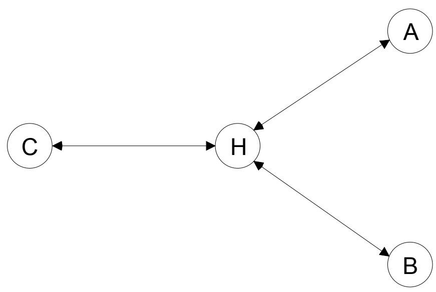

Figure 3-2 A simple hub-spoke network (Brueckner and Spiller, 1991, p.327)

Assumed that demand is symmetric across city-pairs, the inverse demand function for round-trip travel in any given city-pair market ij is given by $D(Q_{ij})$ while Q_{ij} is representing the number of round-trip passengers in the market. In the AB case, for example, revenue is $R(Q_{AB})= Q_{AB}D(Q_{AB})$ and marginal revenue is $R'(Q_{AB})$. The monopolist's profit maximization (revenue minus cost) problem is written:

$$\begin{aligned} \max\ & R(Q_{AH})+R(Q_{BH})+R(Q_{CH})+R(Q_{AB})+R(Q_{AC})+R(Q_{BC}) \\ & -c(Q_{AH}+Q_{AB}+Q_{AC})-c(Q_{BH}+Q_{AB}+Q_{BC})-c(Q_{CH}+Q_{AC}+Q_{BC}). \end{aligned} \tag{3-17}$$

The first order condition of a city-pair market, such as AH for the monopolist's problem is:

$$R'(Q_{AH}) = c'(Q_{AH}+Q_{AB}+Q_{AC}). \tag{3-18}$$

Referring to (3-18) and recalling $c''<0$, the marginal cost of serving a passenger in the AH market falls when either Q_{AB} or Q_{AC} increases, which results in "economies of density" (Brueckner and Spiller, 1991). Given (3-15) and (3-16), the first order conditions of the maximization problem (3-17) can be solved:

$$Q_{AB} = Q_{AC} = Q_{BC} = \frac{2-\alpha(1+\theta)}{5\theta-1}, \tag{3-19a}$$

$$Q_{AH} = \frac{\alpha-1+\theta(Q_{AB}+Q_{AC})}{1-\theta}. \tag{3-19b}$$

In addition, it is necessary to define both quantities and marginal revenues positive in the maximization problem, then the second-order condition for the monopolist's problem reduces to $\theta<1/5$ and the inequalities $2/(1+\theta)<\alpha<1/3\theta$ must be hold.

After revealing the monopoly case, "inter-hub competition" in the AB market is considered in the case that a different, competing airline firm which serves cities A and B through a different hub, K, is entered into the market. The two firms play a Cournot game in AB market while charging their prices. The original firm is firm 1 and the other is firm 2, there are symmetric solutions for both firms. For example, the revenue of firm 1 from city pair AB is

$$R(Q^1_{AB}) = Q^1_{AB}\left[\alpha-(Q^1_{AB}+Q^2_{AB})/2\right] \tag{3-20}$$

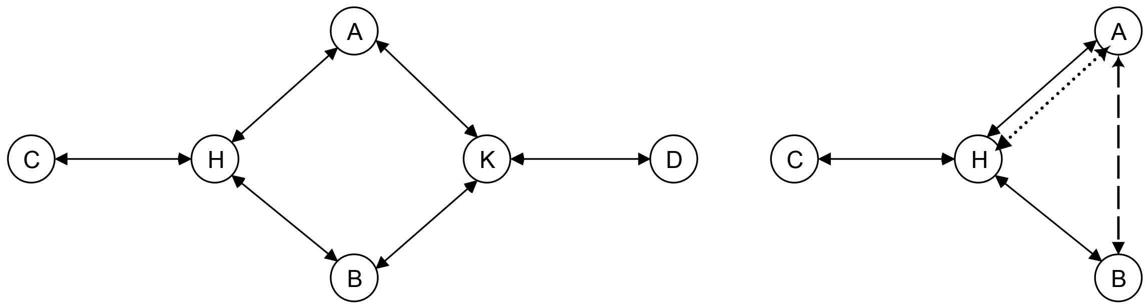

Figure 3-3 Competition in hub-spoke network (Brueckner and Spiller, 1991, p.330, 332, 333)

Q_{AB}, Q_{AC} and Q_{BC} of firm 1 under the requirement that $Q^1_{AB}=Q^2_{AB}$ is solved

$$Q_{AB}^{1} = [2-\alpha(1+\theta)]\frac{4\theta/3-2/3}{8\theta^2-19\theta/3+1}, \quad \text{(3-21a)}$$

$$Q_{AC}^{1} = Q_{BC}^{1} = [2-\alpha(1+\theta)]\frac{5\theta/3-1}{8\theta^2-19\theta/3+1} \quad \text{(3-21b)}$$

When the traffic level of *AB* city-pair market under inter-hub competition, Q^{1}_{AB}, is compared with that under the monopoly, Q^{m}_{AB}, it follows that

$$Q_{AB}^{m} > (<) Q_{AB}^{1} \text{ as } \frac{1}{5\theta-1} < (>) \frac{4\theta/3-2/3}{8\theta^2-19\theta/3+1} \quad \text{(3-22)}$$

Rearranging, (3-22) reduces to $(1-4\theta)(1-\theta)<(>)0$. Since $\theta<1/5$, $Q^{m}_{AB}>Q^{1}_{AB}$ is obtained, which means *AB* traffic through hub *H* is lower under inter-hub competition than under monopoly. However, whether passengers in the *AB* markets are better off (worse off) depends on the level of increasing returns because when increasing returns are relatively weak (stronger), inter-hub competition raises (lowers) total *AB* traffic and lowers (raises) prices. When traffic levels in *AC*, *BC*, *AH*, *BH* and *C*H city-pair markets under both regimes are compared; the results lead to higher fares and lower traffic under inter-hub competition than under monopoly.

In addition, Brueckner and Spiller (1991) examine the effects of competition in the cases that hub airline faces small non-hub competitors in the some of its markets. In the case of "direct competition", a small airline firm serves one of the non-hub city-pair markets of the original network (*AB*). In the case of "leg competition", one of the hub-inclusive city-pair markets of the original network (*AH*) is served. Both cases are shown in the right-hand side of Figure 3-3. The results are summarized as follows: under direct competition in *AB* market (under leg competition in *AH* market), total traffic is higher in *AB* (*AH*) and the fare is lower than under monopoly when increasing returns are weak and demand is strong.

Following the model of Brueckner and Spiller (1991), Zhang (1996) develops a similar network model to explain the lack of local competition between similar hub-and-spoke carriers because these carriers get market power in the spoke segments (*A, B*) from their respective hubs (*H, K*), which is referred to as "fortress hubs" phenomenon (Levine, 1987). However, they compete for the traffic between non-hub cities via trans-hub (*AB*). While the former case in airline competition is scrutinized above. Zhang (1996) also assumes that demand and marginal cost functions are linear and finds that "Under a local invasion, where firm *1* enters its opponent's local markets (departing from or arriving to the opponent's hub city, *AK* and *BK*), the invading firm produces less (greater) output, and earns less (greater) profit, in its own hub-and-spoke network than under fortress hubs as increasing returns are relatively strong (weak)". After identifying the negative effect of local competition, Zhang (1996) shows that for some values of α and θ where local retaliation raises the retaliating firm's total profit or for relatively weak increasing returns, local entry is each firm's dominant strategy, though both are worse off under reciprocal local entry than under fortress hubbing. For these values (α,θ), competition in local entry results in Prisoners' Dilemma.

These two studies conclude that whether the competition in airline hub-and-spoke networks depends on the degree of increasing returns to traffic density. When increasing returns are relatively strong, in the markets where competition takes place passengers benefit while outside those markets, competition imposes negative network externalities. When increasing returns are weak, the result is vice versa.

Oum, Zhang and Zhang (1995) examine the strategic interaction between airlines when their network choice are either a linear system or a HS network and show the comparative advantages of HS networks due to the reduction in marginal costs or improvement in service quality (increase in flight frequency). The developed model is a three-city model with three city-pair markets.

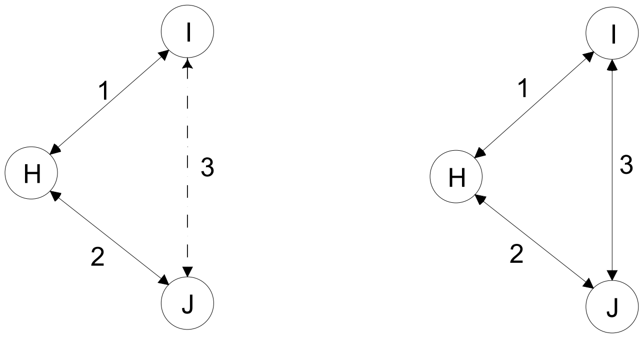

Figure 3-4 A simple air transport system (Oum et al, 1995, p.840)

Cost function of a carrier is detailed as conveyance cost, $c^i_k(x^i_k)$ and schedule delay cost, $g^i_k(x^i_k)$, caused by a passenger's delay time between his desired departure and actual departure time. As long as the schedule delay cost depends on the flight frequency of airlines, it is argued that hubbing which causes an increase in the traffic volume, also causes an increase in flight frequency and an increase in service quality. x^i_k denotes firm i's output on the kth route and the cost of carrying passengers in a point-to-point airline is $\sum_{k=1}^{3} c^i_k(x^k_i)$ while hub-spoke airline incurs $\sum_{k=1}^{2} c^i_k(X^k_i) + c^i_h$ in two routes with $X^i_k \equiv x^i_k + x^i_3$. X^i_k refers to the total passengers carried by airline on the spoke routes and $c^i_h \equiv c^i_d + c^i_a$ is the cost of hubbing networks out of linear networks when c^i_d and c^i_a assign the sunk investment costs of hub development and other extra costs for routing flights between two spoke cities through the hub, respectively.

Thus, different network strategies give different outputs in a firm's profit function. $x^i \equiv (x^i_1, x^i_2, x^i_3)$ is carrier i's output vector and d^i_k denotes the inverse demand functions of carrier i. The profit of carrier i with a choice of linear network and hub-and-spoke network are expressed as

$$\pi^{iL}(x^A, x^B) = \sum_{k=1}^{3} d^i_k(x^A, x^B)x^i_k - \sum_{k=1}^{3} c^i_k(x^i_k) - \sum_{k=1}^{3} g^i_k(x^i_k)x^i_k, \quad (3\text{-}23)$$

$$\pi^{iH}(x^A, x^B) = \sum_{k=1}^{3} d^i_k(x^A, x^B)x^i_k - \sum_{k=1}^{2} c^i_k(X^i_k) - c^i_h - \sum_{k=1}^{2} g^i_k(X^i_k)X^i_k - \gamma^i x_3, \quad (3\text{-}24)$$

where γ^J denotes the extra cost of a connecting passengers of route *3*, flying through hub city.

To indicate the complementarities between local and connecting services in a hub-and-spoke network, π^{iH} is differentiated with respect to x^i_k and x^i_3 and the following relation is found

$$\frac{\partial^2 \pi^{iH}}{\partial x^i_k \partial x^i_3} = -c^{i''}_k(X^i_k) + \left[-2g^{i'}_k(X^i_k) - X^i_k g^{i''}_k(X^i_k)\right] \qquad k=1,2. \qquad (3\text{-}25)$$

Either returns to scale on the production side, $c''<0$, or network service externalities on the demand side make equation (3-25) positive. These network externalities affect the decision of a monopolist in choosing network type because the monopolist will form a hub-and-spoke network if switching from a linear to a hub-and-spoke network reduces it total cost. The cost differential between networks results that the more significant economies of density are, the more likely the hubbing strategy is. Then the network decision will hinge on which network provides travelers with better service.

To solve for duopoly equilibrium, firms compete in two stage-competition with Cournot behavior, in the first stage, they choose their network types (θ^A, θ^B) and in the second stage, choose their outputs to maximize profits. Assuming that the outputs of the two firms are substitutes in each city-pair markets, the comparative static effects of the network variable θ^i on the equilibrium outputs, $x^i(\theta^A, \theta^B)$ and $x^j(\theta^A, \theta^B)$ are found as

$$\frac{\partial x^i(\theta^A, \theta^B)}{\partial \theta^i} > 0, \quad \frac{\partial x^j(\theta^A, \theta^B)}{\partial \theta^i} < 0 \quad , \tag{3-26}$$

which gives that switching from linear to a hub-spoke network will increase firm *i*'s own output, while simultaneously decreasing its rival's output, in each market by assuming that switching from a linear network to a hub-spoke network does not increase firm *i*'s marginal cost. Furthermore, it is shown that even if switching network increases total cost, hubbing remains the firm's dominant strategy. At that time, the use of hub-and-spoke networks is for strategic purposes because it is not guaranteed that firms are better off if both choose a hub-spoke network than if they both choose a linear network. The situation is a Prisoners' Dilemma. Finally, Oum et al (1995) examine hubbing as entry deterrence and indicate that if switching does not increase the firm's marginal cost in the connecting market, switching will reduce its rival's profit because of entry cost. As a result, an incumbent firm can choose a hub-spoke network as a device to deter potential entry.

3.3.2.2 Mergers and Alliances

Park (1997) explains the effects of alliances on the firms' outputs and profits, airfare and economic welfare. Pre-alliance, complementary alliance and parallel alliance conditions are scrutinized as benchmark cases. In the network, it is assumed that three carriers are offering services and firm *1* is serving all three markets (*AH*, *BH* and *AB*) via hub city, *H* while firm *2* and firm *3* are serving *AH* and *BH* city-pair markets respectively.

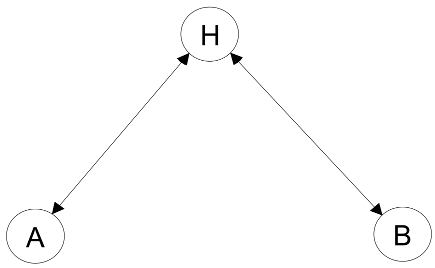

Figure 3-5 A simple air transport network (Park, 1997, p.183)

In the pre-alliance case, the formation of alliances between none of the firms has not been allowed yet. It is assumed that the three firms behave like Cournot competitors in each market of the network. Then, the pre-alliance profit function of firm *1* is expressed as

$$\begin{aligned}\Pi^{1b} &= Q^1_{AH}D(Q^1_{AH}+Q^2_{AH})+Q^1_{BH}D(Q^1_{BH}+Q^3_{BH})+Q^1_{AB}D(Q^1_{AB})\\ &\quad -C(Q^1_{AH}+Q^1_{AB})-C(Q^1_{BH}+Q^1_{AB})\end{aligned}. \tag{3-27}$$

With the linear demand and marginal cost assumptions, firm *1*'s first-order conditions of the profit function are

$$\begin{aligned}&\alpha-2Q^1_{AH}-Q^2_{AH}=1-\theta(Q^1_{AH}+Q^1_{AB}),\\ &\alpha-2Q^1_{BH}-Q^3_{BH}=1-\theta(Q^1_{BH}+Q^1_{AB}),\\ &\alpha-2Q^1_{AB}=\left[1-\theta(Q^1_{AH}+Q^1_{AB})\right]+\left[1-\theta(Q^1_{BH}+Q^1_{AB})\right]\end{aligned} \tag{3-28}$$

From the equations (3-28), cost complementarities inherent to hub-and-spoke networks can be observed. Writing the other firms' pre-alliance profit functions and the first order conditions like firm *1*'s and equating $Q^1_{AH}=Q^2_{BH}$ and $Q^2_{AH}=Q^3_{BH}$ yield firm *1, 2* and *3*'s equilibrium outputs in pre-alliance case.

If firms *2* and *3* connect their services between city *A* and city *B* by making a complementary alliance, the complementary-alliance profit functions of firms become as

$$\begin{aligned}\Pi^{1c} &= Q^1_{AH}D(Q^1_{AH}+Q^2_{AH})+Q^1_{BH}D(Q^1_{BH}+Q^3_{BH})+Q^1_{AB}D(Q^1_{AB}+Q^{2+3}_{AB})\\ &\quad -C(Q^1_{AH}+Q^1_{AB})-C(Q^1_{BH}+Q^1_{AB}),\end{aligned} \tag{3-29}$$

$$\begin{aligned}\Pi^{(2+3)c} &= Q^2_{AH}D(Q^1_{AH}+Q^2_{AH})+Q^3_{BH}D(Q^1_{BH}+Q^3_{BH})+Q^{2+3}_{AB}D(Q^1_{AB}+Q^{2+3}_{AB})\\ &\quad -C(Q^2_{AH}+Q^{2+3}_{AB})-C(Q^3_{BH}+Q^{2+3}_{AB}).\end{aligned} \tag{3-30}$$

In parallel alliance case, firms *1* and *2* become partners in the *AH* segment of the network instead of being competitors. In the model it is assumed that the partners of an alliance agree to share revenues equally and cost in the joint service segment. Then the parallel-alliance profit functions are written

$$\begin{aligned}\Pi^{(1+2)p} &= Q^{1+2}_{AH}D(Q^{1+2}_{AH})+Q^1_{BH}D(Q^1_{BH}+Q^3_{BH})+Q^1_{AB}D(Q^1_{AB})\\ &\quad -C(Q^{1+2}_{AH}+Q^1_{AB})-C(Q^1_{BH}+Q^1_{AB}),\end{aligned} \tag{3-31}$$

$$\Pi^{3p}=Q^3_{BH}D(Q^1_{BH}+Q^3_{BH})-C(Q^3_{BH}). \tag{3-32}$$

After solving the complementary and parallel alliance equilibrium quantities, Park (1997) compares the firms' outputs and profits in the pre-alliance case with in the two alliance cases. Under complementary alliance, it is found that firm *1* produces less output in all his markets and earns less profit while the partners produce more output in both their local markets and their joint market and earn more profit. The reason of this solution is the competition in *AB* market and the cost complementarities between the markets. Under parallel alliance, it is observed that the alliance partners produce less output in market *AH*, but produce more output in markets *BH* and *AB*, and firm *3* produces less output in its local market *BH*. Finally, Park (1997) discusses economic welfare of alliances, depending on the levels of α and θ and the results can be summarized as:

i. The complementary alliance (the parallel alliance) makes society better off (worse off) when the size of the markets is sufficiently large,

ii. The complementary alliance (the parallel alliance) may make society worse off (better off) when the size of the markets is sufficiently small and economies of density are sufficiently high.

Assuming that passengers prefer on-line connecting services, offered by only one firm to interline services, Park (1997) ignores the interline connecting services between firms 2 and 3 in the pre-alliance model. For that reason, Brueckner (2001) defines the strategies of airlines in interline fare determination in the case of non-alliance and analyze the downward pressure on fares in the interline city-pair markets as a result of cooperative pricing of trips after alliance because he claims that in the case of non-alliance, each airline chooses a "subfare" for its portion of the trip and this non-cooperative behavior causes a negative impact on the other airline's profit.

In the model of Brueckner (2001), there are two international firms, operating in a network structure like in Figure 3-6. Airline Firm *1* offers services to the domestic endpoints *A* and *B* as well as to an overseas city *K* while using city *H* as a hub city. Firm *2* operates an overseas route from his hub city *K* to city *H*, as well as serves domestic cities *D* and *E*. Together, both airlines also provide interline service in the international markets *AD*, *AE*, *BD* and *BE*.

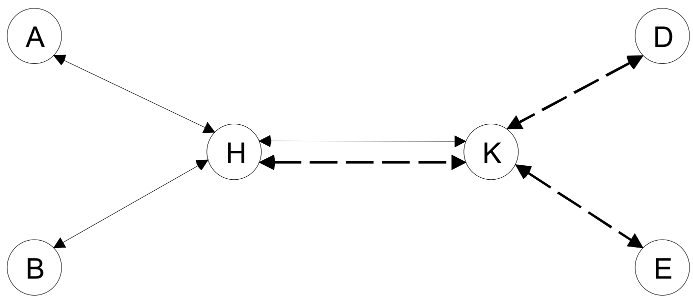

Figure 3-6 Network structure (Brueckner, 2001, p.1479)

With an alliance between firm *1* and firm *2*, the airlines collude in the inter-hub market, where each carriers half the total traffic. Since the profit-maximization problems of the two firms are symmetric, only firm 1's profit-maximization problem is considered. The total revenue of firm *1* is given by

$$\begin{aligned}&R(Q_{AB})+R(Q_{AH})+R(Q_{AK})+R(Q_{BH})+R(Q_{BK})\\&+1/2\left[R(Q_{HK})+R(Q_{AD})+R(Q_{AE})+R(Q_{BD})+R(Q_{BE})\right]\end{aligned} \tag{3-33}$$

Traffic densities of each connection depend on the traffic levels in the individual city-pair markets that the firm serves and half of the traffic in *HK* market and interline markets. Then the total cost of operating airline 1's network is equal to

$$\begin{aligned}&C(Q_{AB}+Q_{AH}+Q_{AK}+Q_{AD}+Q_{AE})+C(Q_{AB}+Q_{BH}+Q_{BK}+Q_{BD}+Q_{BE})\\&+C(Q_{AK}+Q_{BK}+1/2\left[Q_{HK}+Q_{AD}+Q_{AE}+Q_{BD}+Q_{BE}\right].\end{aligned} \tag{3-34}$$

With the symmetry of *A* and *B* endpoints and the networks of firm *1* and firm *2* in passenger volumes ($Q_{AH}=Q_{BH}\equiv Q_{XH}$, $Q_{AK}=Q_{BK}\equiv Q_{XK}$ and $Q_{AD}=Q_{AE}=Q_{BD}=Q_{BE}\equiv Q_{XY}$, where *X* and *Y* denote the domestic endpoints of firm *1* and firm *2* respectively), the profit function of firm *1* is differentiated with respect to the various traffic levels, then the first-order conditions in the alliance case give that marginal revenue in a city-pair market equals the marginal cost of carrying an additional passenger in that market.

In the absence of an alliance, not only quantity-based approach between airlines but also price-setting approach is considered because while in the inter-hub market *HK*, the firms choose their own traffic levels according to Cournot behavior instead of cooperatively choosing total traffic Q_{HK}, in the interline market, each airline chooses a "subfare" for its portion. With this approach, the traffic levels in the inter-hub market *HK* and in one of the interline markets satisfy

$$\begin{aligned} &R'(Q_{HK}) - Q_{HK}D'(Q_{HK})/2 = C'(2Q_{XK} + 1/2Q_{HK} + 2Q_{XY}) \\ &R'(Q_{XY}) + Q_{XY}D'(Q_{XY}) = 2C'(Q_{AB} + Q_{XK} + Q_{XH} + 2Q_{XY}) + C'(2Q_{XK} + 1/2Q_{HK} + 2Q_{XY}) \end{aligned} \tag{3-35}$$

However, in an alliance equilibrium,

$$\begin{aligned} &R'(Q_{HK}) = C'(2Q_{XK} + 1/2Q_{HK} + 2Q_{XY}) \\ &R'(Q_{XY}) = 2C'(Q_{AB} + Q_{XK} + Q_{XH} + 2Q_{XY}) + C'(2Q_{XK} + 1/2Q_{HK} + 2Q_{XY}) \end{aligned} \tag{3-36}$$

are found. The comparison of the equations show that Q_{HK} is lower (and the fare higher) and Q_{XY} is higher (the fare lower) under an alliance when the airline technology exhibits constant returns to scale (C' is a constant).

Brueckner (2001) illustrates these results with constant returns in a case of linear demand and then in a case where economies of traffic density are present by replacing the constant marginal cost expression by linear marginal cost function, $C'(Q) = 1 - \theta Q,\ \theta > 0$. The aim of this second analysis is to compare solutions for all feasible combinations of the two parameters, α and θ. The findings of this analysis show that the presence of economies of density does not affect the general results about traffic levels and fares. Thus, he concludes that even though a negative effect of alliance is found on traffic levels and fares in the interhub market, in the welfare analysis, an alliance is likely to a positive effect in total. The reason is that a typical alliance affects many interline markets but only one or two inter-hub markets.

Brueckner and Whalen (2000) set up another model which has four firms (carrier *1*, *2*, *3* and *4*) instead of two. Two competing carriers, carriers *1* and *2* operate in the domestic city-pair markets, *AH*, *BH* and *AB* while carriers *3* and *4* compete in the markets, *DH*, *EH* and *DE*. In the international markets, *AD*, *AE*, *BD* and *BE*, competing carrier pairs, either allied or non-allied serve in. It is assumed that carriers *1* and *3* always form an interline pair and carriers *2* and *4* are forming the other interline pair in both cases: allied or non-allied.

To set up a four-firm model provides Brueckner and Whalen (2000) to capture some issues:

i. in an empirical study of airline alliances, there maybe many international passengers, making interline trips with different choices between several carrier pairs, either allied or non-allied,

ii. there maybe some effects of alliances on the traffic levels and fares in airlines' domestic city-pair markets.

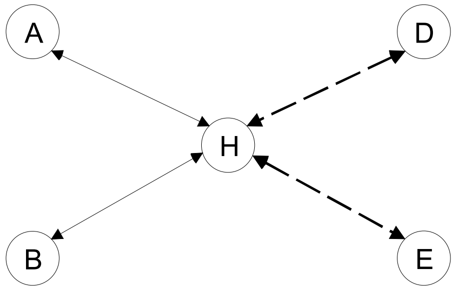

Figure 3-7 Network structure (Brueckner and Whalen, 2000, p. 508)

The competition between carrier pairs, *1-3* and *2-4*, is discussed in two cases: symmetric and asymmetric cases. In the analysis of symmetric equilibrium, carriers 2 and *4* follow the behaviors of carriers *1* and *3* in forming an alliance or not. In the asymmetric case, one pair of carriers is allied and the other is non-allied.

Following Brueckner and Spiller (1991), Zhang (1996) and Brueckner (2001), linearity on the marginal cost function, $C'(Q) = 1 - \theta Q,\ \theta > 0$, is assumed. In addition in this model brand loyalty of passengers is also assumed. Because of brand loyalty, a carrier or a carrier pair can increase its fare above the fare of its competitor without losing its traffic. A passenger will fly on carrier *i* instead of its competitor *k*, if the fares satisfy $\mathrm{p}^{\mathrm{i}} < p^k + a$, or $a > p^i - p^k$, where *a* is the individual's dollar dominated preference for carrier *i* and uniformly distributed over the interval $\left[-\alpha/2, \alpha/2\right]$. Carrier *i*'s traffic and *k*'s traffic are;

$$\begin{aligned} \mathrm{q}^i &= \int_{p^i - p^k}^{\alpha/2} \frac{1}{\alpha} da = \frac{1}{2} - \frac{p^i - p^k}{\alpha}, \\ \mathrm{q}^k &= \int_{-\alpha/2}^{p^i - p^k} \frac{1}{\alpha} da = \frac{1}{2} + \frac{p^i - p^k}{\alpha}. \end{aligned} \tag{3-37}$$

Solving the equilibrium fares in the domestic markets and in the international markets for the symmetric alliance and non-alliance cases, it is found that the equilibrium fares in the domestic markets (*AH* or *BH*, *DH* or *EH*) and *A*B (*DE*) are same in the alliance and non-alliance cases and the interline fare under an alliance is lower than under non-alliance. In the asymmetric equilibria, carriers *1* and *3* form an alliance and charge interline fare under an alliance while carriers *2* and *4* offer interline services without an alliance, charge the subfares. Finding the equilibrium prices in asymmetric case, Brueckner and Whalen (2000) compare all prices and conclude that in asymmetric case, the domestic fares of carrier *1* (the alliance partner) are lower than those of carrier *2* and its own fares in the symmetric case. The other result of the asymmetric case is that the alliance partners charge a lower interline fare than the non-allied carriers and both interline fares are cheaper than those charged in the symmetric cases. Brueckner and Whalen (2000) strengthen their theoretical results with empirical model. The details of data and the findings are discussed in Section 2.2.4.

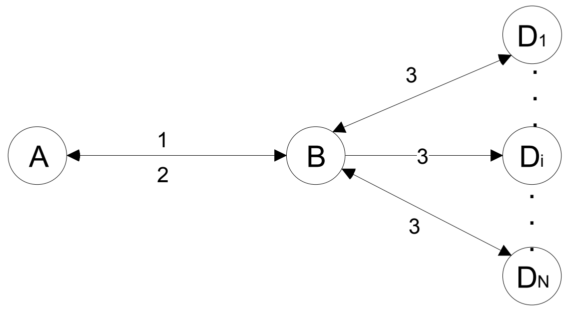

Figure 3-4 Linkage between airlines 1 and 3 (Park and Zhang, 1998, p.248)

Park and Zhang (1998) examine the effects of alliances with a comparative-statics analysis for the traffic changes in partners' outputs. In the network structure, shown in Figure 3-8, there are two gateway cities *A* and *B*, where airlines *1* and *2* provide homogenous services and *N* cities that are linked to city *B* by airline *3*. The symmetry of *N* cities in the connection to city *B* is assumed. When airline *1* and *3* form an alliance to feed each other's traffic and the profits of airlines *1* and *2*, offering services on the *AB* market is written

$$\begin{aligned}\Pi^1 &= P_{AB}(Q^1_{AB} + Q^2_{AB}).Q^1_{AB} + s.\sum_{k=1}^{N} P_{Ak}(Q^1_{Ak}).Q^1_{Ak} - C^1_{AB}(Q^1_{AB} + \sum_{AB}^{1} Q^1_{Ak}) \\ \Pi^2 &= P_{AB}(Q^1_{AB} + Q^2_{AB}).Q^2_{AB} - C^2_{AB}(Q^2_{AB})\end{aligned} \qquad (3\text{-}38)$$

where $P(Q)$ is inverse demand function and s denotes the ratio that splits the connecting services revenue between firms *1* and *3* ($0<s<1$). It is assumed that in each market an airline's marginal revenue declines when the output of its rival rises (for market k).

$$\frac{\partial \Pi^i}{\partial Q^i_k \partial Q^j_k} < 0 \qquad (3\text{-}39)$$

Firms *1* and *2* are maximizing their profits with $Q^1 \equiv (Q^1_{AB}, Q^1_{An})$ and $Q^2 \equiv Q^2_{AB}$, the first order conditions and the second order conditions of profit functions of firms *1* and *2* are expressed

$$\begin{aligned} &\Pi^1_1(Q^1, Q^2; N) = 0 \qquad && \Pi^1_{11} \equiv \begin{bmatrix} \Pi^1_{AB_1AB_1} & \Pi^1_{AB_1An_1} \\ \Pi^1_{An_1An_1} & \Pi^1_{An_1An_1} \end{bmatrix} < 0 \\ &\Pi^2_2(Q^1, Q^2) = 0 && \Pi^2_{22} \equiv \left[\Pi^2_{AB_2AB_2}\right] < 0 \end{aligned} \qquad (3\text{-}40)$$

when the subscripts denote partial vector derivatives. To get the reaction functions of firms, the first-order conditions of the firm *1*'s profit function (firm *2*'s function) with respect to Q^2 (Q^1) are differentiated.

$$\begin{aligned} R^1_2 &\equiv \partial R^1(Q^2)/\partial Q^2 \equiv -(\Pi^1_{11})^{-1}\Pi^1_{12} \\ R^2_1 &\equiv \partial R^2(Q^1)/\partial Q^1 \equiv -(\Pi^2_{22})^{-1}\Pi^2_{21} \end{aligned} \qquad (3\text{-}41)$$

The matrix of the reaction function is negative because both $(\Pi^i_{ii})^{-1}$ and Π^i_{ij} are negative.

To examine the output changes in relation to the changes in the number of linked cities, *N* after an alliance, the comparative-statics analysis is used. Differentiating the first order-condition functions of firms with respect to *N* yields

$$\Pi^1_{11}\frac{dQ^1}{dN}+\Pi^1_{12}\frac{dQ^2}{dN}+\Pi^1_{1N}=0$$
$$\Pi^1_{21}\frac{dQ^1}{dN}+\Pi^2_{22}\frac{dQ^2}{dN}=0 \tag{3-42}$$

where $\Pi^1_{1N} \equiv \left[\Pi^1_{AB_1N}\,\Pi^1_{An_1N}\right]^t$. When these equations are solved for $(dQ^1/dN, dQ^2/dN)$ with the reaction functions of firms $(R^1_2$ and $R^2_1)$, it follows

$$\frac{dQ^1}{dN}=-\left[I-R^1_2R^2_1\right]^{-1}(\Pi^1_{11})^{-1}\Pi^1_{1N}$$
$$\frac{dQ^2}{dN}=-R^2_1\left[I-R^1_2R^2_1\right]^{-1}(\Pi^1_{11})^{-1}\Pi^1_{1N} \tag{3-43}$$

Since $R^i_jR^j_i$ is a positive matrix, it gives that $(I-R^i_jR^j_i)^{-1}$ is also a positive matrix according to the Neumann lemma. Therefore, $dQ^1/dN>0$ and $dQ^2/dN<0$ and firm *1*'s traffic on the *AB* route rises as its partner increases the number of cities connected onto the *AB* route when firm *2*'s traffic decreases on that route. Hence, Park and Zhang (1998) concludes that alliance partner's traffic on alliance routes is likely to increase more than will traffic on non-alliance routes and check the results with a panel data from four major alliances in North Atlantic markets during 1992-1994 period, which is discussed in Section 2.2.4.

Park et al (2001) investigate the effects of complementary and parallel alliances with more general demand and cost specifications, assuming strategic substitutability between the outputs of the rival airlines and network complementarities between the alliance partners. Comparative static effects of alliance variable on the equilibrium outputs are found. The structure of the model and the firms is similar to that in Park (1997), scrutinized in Section 3.3.2.1. Three gateway cities located in different countries are *a*, *b* and *h*. Three firms are offering services on two route segments, *ah* and *bh*. One of which, firm *H* is serving both segments using its hub city, *h* and the other firms, A and *B*, serving the *ah* and *bh* segments, respectively.

$$Q^i=D^i(\rho^1,\rho^2,\rho^3,\rho^4)\quad \text{for } i=1,2,3,4 \tag{3-44}$$

is the demand function where ρ^1 and ρ^2 are the "full" price of traveling with firm *H* on segment *ah* and *bh*, ρ^3 and ρ^4 are the "full" price of traveling with firm *A* and firm *B* on segment *ah* and *bh*. In this model, the demand function (Q^i) depends not only on the prices of the same route (ρ_1 and ρ_3), but also on the prices of the connecting traffic (ρ_2 and ρ_4) because the interline services between firm *A* and firm *B*, which is ignored in the model of Park (1997), is captured. Additionally, cost function of this model also involves non-ticket costs, the schedule delay cost of passengers that is discussed in Oum et al (1995). When p^i and $g^i(Q^i)$ denote the round-trip ticket price and the schedule delay cost for each local route, respectively, "full" price is expressed as

$$\rho^i=p^i+g^i(Q^i)\,. \tag{3-45}$$

It is assumed that the outputs between *ah* and *hb* satisfy the "network complementarities",

$\Pi^H_{12}>0,\ \ \Pi^A_{34}>0,\ \ \Pi^B_{43}>0$ and the outputs of the rival airlines satisfy strategic substitutes,

$\Pi_{13}^{H} < 0,\ \ \Pi_{31}^{A} < 0,\ \ \Pi_{24}^{H} < 0,\ \ \Pi_{42}^{B} < 0,$ on each segment, and

$\Pi_{14}^{H} < 0,\ \ \Pi_{41}^{B} < 0,\ \ \Pi_{23}^{H} < 0,\ \ \Pi_{32}^{A} < 0,$ on different route segments.

Firms' competition is modeled in the Cournot fashion and a "complementary" alliance between firms *A* and *B* and "parallel" alliance between firms *H* and *A*, are debated. The results of the model are the same as those in Brueckner (2001) and Park (1997). A complementary alliance (a parallel alliance) will likely increase (decrease) total output and decrease (increase) full price and as a result, consumer welfare and economic welfare will likely increase (decrease) on the market. The predictions of the model are tested by using the data of 17 trans-Atlantic alliance routes for the 1990- 1994 period, which is also found in Section 2.2.4.

3.3.3 Leadership Models

Oum et al (1996) modelize the profit-maximizing behavior of the leader and followers like in the Stackelberg model to investigate the effects of complementary code sharing between non-market small carriers on the market leader's price and passenger volume. The market leader has the largest share of total passengers traveling on the non-stop route while the others are non-leaders. The demand functions for the market leader and the non-leaders are written as

$$Q = Q(P, P^*, \Gamma; \alpha)\ ; \qquad\qquad Q^* = Q^*(P, P^*, \Gamma^*; \alpha^*) \tag{3-46}$$

where *Q(Q*)* and *P(P*)* denote passenger volumes and the prices of the leader firm and non-leaders respectively. $\Gamma(\Gamma^*)$ and $\alpha(\alpha^*)$ are the exogenous variables and the parameter vectors. More general supply relations, equations in (3-47), for the oligopoly behavior of firms are defined because firms describe their optimum values according to the conjectural variations of the firms. Although the supply relations of the firms are the forms of the equality between marginal revenue and marginal cost, the ratios of price-cost markup to quantity (variables, *t* and *t**) are defined as *(P-MC)/Q and (P*-MC*)/Q** for the leader and the non-leaders. These variables indicate the competitiveness of the firm conduct and the supply relations are

$$P - tQ = MC(Q, W; \beta)\ ; \qquad\qquad P^* - t^*Q = MC^*(Q^*, W^*; \beta^*) \tag{3-47}$$

where *Q(Q*)* and *W(W*)* denote its own output and input prices of the leader (non-leaders) respectively with parameters $\beta(\beta^*)$. The solution of the equilibrium price and the quantity of the leader firm can be determined from the residual demand curve and the supply relation (3-47) while the residual demand function is derived from equations (3-47) and (3-48) by solving *P** as a function of *P*. *P* affects the leader's demand through directly and indirectly. The direct effect is its own price effect on the structural demand and the indirect effect is the effect of *P* on the non-leaders' price responses *P**, which affect the leader's demand. The residual demand function is

$$Q = R(P, \Gamma, \Gamma^*, W^*; \alpha, \alpha^*, \beta^*)\ . \tag{3-48}$$

It is observed that the system does not require any data about non-leaders' prices and passenger volumes. In econometric model, the residual demand function is specified as

$$Q = a_0 + a_1 P + a_2 F + a_3 NF + a_4 NW + a_5 FEED + a_6 CS + \varepsilon_d \tag{3-49}$$

where F and NF are the flight frequencies of the market leader and the others respectively, NW is the input-price index of the non-leaders and the presence of connecting services between a carrier and its subsidiary and the presence of codesharing are the dummy variables, *FEED* and *CS*. To operatinalize the supply relation, the conduct term (t) and the marginal cost (MC) are defined separately. The marginal cost follows

$$MC = b_0 + b_1 Q + b_2 W + b_3 D + \sum_{i=1}^{10} d_i YR_i + \sum_{i=1}^{2} e_i RG_i + \varepsilon_1 \tag{3-50}$$

where W is an input cost index of the leader, D is distance between two cities, YR_is are year dummy variables, (1982-1992 period), RG_is are route group dummy variables and except for the error term, ε_1, the others are the coefficients. In the specification of the conduct term, t, the number of competing airlines in the non-stop market (*COM*), the leader's market share in the non-stop market (*MS*), the presence of connecting services between a carrier and its subsidiary (*FEED*) and the presence of codesharing (*CS*) are formed as

$$t = c_0 + c_1 COM + c_2 MS + c_3 FEED + c_4 CS + \varepsilon_2 \tag{3-51}$$

Rearranging equations (3-50) and (3-51) in the equation (3-47), the market leader's supply relation is obtained and the empirical model is estimated by using Non-linear Three-Stage Least Squares (N3SLS). The results of the model and the effects of variables in the equations are found in Section 2.2.4.

3.3.4 Location Models

The location models, discussed in Section 3.2.2, capture the general key elements of an airline optimization problem: economies of density, flight frequency and aircraft sizes, however, competition with other carriers are missing. Thus, in this section, we provide the review of location models that analyze the schedule competition between carriers. Shy (2001) explores the effect of flight frequency on airline carriers' network choices. Assuming that in every city; there are two types of passengers who have high or low value of time, he investigates the change of networks to hub-spoke networks. η passengers who have high value of time, are assumed to lose a utility of δ, if they transfer their flight in the hub city. The other type η passengers who have low value of time are indifferent between flying directly or indirectly. The profit of monopoly airline under fully connected network with three cities is

$$\pi = 3\pi_i = 6\eta\gamma - 3\mu, \tag{3-52}$$

where γ and μ denote the utility value a passenger attaches from traveling and airline's cost per flight respectively and p_i is airfare on route i. The monopolist can get the maximum surplus by setting $p_i=\gamma$ where all passengers are served. Under hub-spoke network it sets $p_i=\gamma$ for the passengers of direct flights while $p_i=\gamma-\delta$ for the passengers of connected flights not to lose any passengers and the profit equals to

$$\pi = 3\pi_i = 6\eta\gamma - 2\eta\delta - 2\mu. \tag{3-53}$$

After finding that the point-to-point network is more profitable than the hub-spoke network for monopoly airline when aircraft movement cost, μ, is small, Shy (2001) checks entry deterrence and entry accommodation equilibrium when entry is allowed in only one market (connected market). Entry deterrence via a point-to-point network is more profitable than via hub-and-spoke network because the incumbent firm lowers the price to per-passenger cost for connecting passengers, $p_3^I = \mu / 2\eta$ when operating a fully connected network but $p_3 = \mu / 2\eta - \delta$ when operating a hub-and-spoke network to compensate high time value passengers of connected market. Entry accommodation equilibrium does not exist when the incumbent operates a point-to-point network. However, when the incumbent operates a hub-spoke network, he can abandon connected market and earn a profit from the other two routes as a monopolist but if he serves low time value passengers of connecting market, equilibrium airfares is found in Undercut-Proof equilibrium.

In an Undercut-proof equilibrium, the entrant sets maximal price of connecting market subject to

$$\pi^I = 4\eta\beta + \eta p_3^I - 2\mu \geq 4\eta\beta + 2\eta(p_3^E - \delta) - 2\mu. \tag{3-54}$$

while the incumbent airline maximizes the price subject to

$$\pi^E = \eta p_3^E - \mu \geq 2\eta\beta + 2\eta p_3^I - \mu. \tag{3-55}$$

Solving the two constraints with equality yields entry accommodation equilibrium prices and substituting them into (3-54) and (3-55), comparable profit functions are found

$$\pi^I = 4\eta\beta + \frac{2\eta\delta}{3} - 2\mu \quad \text{and} \quad \pi^E = \frac{4\eta\delta}{3} - \mu. \tag{3-56}$$

When the results are compared, it is found that the incumbent finds entry accommodation with a hub-spoke network to be more profitable than entry deterrence with a fully connected network.

Additionally, Shy (2001) introduces the frequency of flights to analyze market consequences of code-sharing agreements among airline companies and assumes that there are two passenger types; airline α oriented and airline β oriented when flight frequency of airline α and airline β are different. Under no code-sharing, it is found that the airline which provides a higher frequency of flights, $f_\alpha \geq f_\beta$, charges a higher airfare, $p_\alpha \geq p_\beta$. In order to investigate the effect of code sharing on the profits, he differentiates the costs for airlines: cost of operating a high frequency, μ^H, and cost of operating a low frequency, μ^L and shows that a code sharing agreement is profit enhancing to contracting firms because under an agreement, both airline firms prefer to supply low frequency of flights to cut their costs.

To analyze the increase in the use of hub-and-spoke networks and code sharing agreements in airline industry, Shy (2001) introduces the effect of flight frequency and develops a location model in which two types of passengers are assumed. Schipper (2001) models competition in frequency and prices between airlines. The preferred departure time of the consumer is a natural application of the address concept. A potential traveler faces schedule delay cost in addition to price p and derives gross utility $\bar{v}$ from taking the trip. The utility loss is θx when flight i leaves at a time distance $x=|t_i-t_{pref}|$ from his or her preferred departure time, t_{pref}. It is assumed that potential travelers are distributed uniformly with respect to desired departure time on a circular market of length 1 and density D; the departure times of flights i and $i+1$, t_i and t_{i+1} respectively, separated by a headway H. Then the utility of the traveler from the two flights is written as

$$\begin{aligned} v_i &= \bar{v} - p_i - \theta x \\ v_{i+1} &= \bar{v} - p_{i+1} - \theta(H - x) \end{aligned} \tag{3-57}$$

A consumer will choose the flight belonging to the larger of the above expressions and buy a ticket if the net utility is positive. Air transport services are offered by $n \geq 1$ airline firms. Costs of airlines consist of a fixed costs F and costs per flight c^f and marginal costs per passenger c^p. Denoting f_l as the number of flights and q_l as the total number of passengers carried by airline l, profit of the firm is

$$\pi_1 = p_l q_l - C_l \tag{3-58}$$

where $C_l = F + f_l c^f + q_l c^p$.

After monopoly solution, symmetric zero-profit equilibrium (SZPE), in which each firm represents one product in the circular market, is analyzed. The mono-product or mono-departure assumption in the SZPE model, led no advantages associated with the provision of multiple products so two alternative ways: simultaneous frequency-price competition, dynamic frequency-price competition, are discussed. In the latter one, decisions about prices and frequencies are taken simultaneously while in the former one; frequency decisions are less flexible than price decisions.

Assuming interlaced configuration in which the two neighboring flights are operated by competitors and equal spacing, the headway H is calculated as the length of the market $L=1$ divided by the total number of flights offered.

$$H = \frac{1}{\sum_{l=1}^{n} f_l} . \tag{3-59}$$

The general problem to be solved by the airlines is

$$\max_{p_l, f_l} \pi_l = f_l D\left(p_l - c^p\right)\frac{p_{\_l} - p_l + \theta H}{\theta} - f_l c^f - F . \tag{3-60}$$

The equilibrium frequency and price are derived as the best responses in a symmetric multi-departure equilibrium (SSME).

$$f^{SSME} = \sqrt{\frac{(n-1)}{n}\frac{D\theta}{c^f}}; \qquad p^{SSME} = c^p + \sqrt{\frac{n}{(n-1)}\frac{\theta c^f}{D}}, \qquad \text{n} \geq 2 . \tag{3-61}$$

At a given n, it should be checked that the symmetric equilibrium profit is non-negative. Alternatively, one can assume that the number of firms is determined endogenously by a zero-profit condition.

Under dynamic frequency-price competition (DSME), after entry, airlines simultaneously choose frequencies first, and then, having observed the chosen schedules, they simultaneously choose prices. With the symmetry of the price solution, the profit-maximizing price of carrier l is a function of all flights offered.

$$p_l^*\left(f_l, f_{\_l}\right) = c^p + \frac{\theta}{\sum_{l=1}^{n} f_l} . \tag{3-62}$$

Substituting the profit-maximizing price p_l* and using symmetry of the frequency equilibrium ($f_l = f_{\_l}$, all l), aggregate frequency and price are

$$f^{DSME} = \sqrt{\frac{(n-2)}{n}\frac{D\theta}{c^f}}; \qquad p^{DSME} = c^p + \sqrt{\frac{n}{(n-2)}\frac{\theta c^f}{D}}, \qquad n \geq 3 . \tag{3-63}$$

An increase in frequency has a number of effects on profit: apart from a cost effect, there is an effect on demand, and in dynamic game, an effect on price. The addition of a departure in the present model increases firm demand on one hand, while at the same time; the extra flight has a "cannibalization effect" on the demand of existing flights. Comparing the equilibria SSME and DSME, it is found that the flight frequencies and prices under SSME are higher and lower respectively than under DSME. The main results in the symmetric oligopoly model are that departure frequencies per firm decrease and aggregate frequency increases in the number of (symmetric) firms.

3.4 Conclusion

This Chapter is organized to provide a theoretical linkage of the factors that affect the organization of airline industry after deregulation. Reviewing the models, developed in the literature, we scrutinize the impacts of airline deregulation on the behavior of airline firms, the competition and social welfare and conclude that even though deregulation results in welfare gains generally, market failures in some airline markets are present because airline firms develop strategies to deter new entrants and get the market power after deregulation. Switching from pre-deregulation linear system to hub-and-spoke system in airline networks is found as one of the factors that affect concentration and the failure of the competitive market structure because benefiting from "economies of density", hub operators creates monopoly and hub premium in direct routes from hubs. Furthermore, airline firms extent this strategy to domestic and international routes that they had compete before and form horizontal mergers and parallel alliances, which causes high prices and exclusion of competitors. However, in the routes under vertical mergers and complementary alliances, welfare gains increase as a result of lower prices and higher traffic volumes. Briefly, the models, reported in this Chapter, investigate the effect of network economies on airline market structure, competition and social welfare.

In the models, it is assumed that firms can affect the market outcome consisting of prices, quantities, and the number of brands so the strategic approach and strategic international trade analysis with the tools of game theory are applied to analyze the impacts of airline deregulation. After the failure of contestability theory in airline industry, the firms' behavior is searched under imperfectly competitive market structures. The monopoly market structure in which the monopolist chooses a price or a quantity according to the market demand curve is analyzed in two sections: Section 3.2.1 where network structure and price/quantity are endogenized; Section 3.2.2 where frequency of flights is also solved by introducing location or addresses into consumers' preferences. The duopoly market structure of airline firms is generally modeled in non-cooperative behavior which is classified as one-shot games and sequential games. In the latter one, the firms choose their strategic variables once and simultaneously, believing that the competitor's variable level remains unchanged. If the strategic variable is price (quantity), the market structure is Bertrand (Cournot). In the former one, firms move in sequence and this type of market structure is referred to as Leader-Follower on the basis of von Stackelberg's work. Finally, the address (location) models are analyzed in investigating the duopoly market structure of airlines.

In the literature, there are many Cournot-type models that analyze competition in airline markets. However, there are only a few analyses which discuss the market structure with respect to location or addresses in consumers' preferences. This can be observed from Figure 3.9. Thus, there are enough proofs that explain "economies of density" in hub-and-spoke networks and their competition power in duopoly market in terms of airline costs while economic analyses of service quality that affects consumers' preferences as much as price in airline networks are rare. In fact, consumers' choices depend on not only pecuniary costs but also brands so the approach that only investigates the airline market with price and cost relations is biased, especially, if the network type in which large numbers of passengers are transferred via hubs, which causes an increase in time costs and inconvenience of passengers, is found as optimum network. Hence, the value of time and the cost of inconvenience have to be included into the models. Additionally, the passengers are heterogonous enough with respect to their income and brand levels so it is needed to discriminate the market such as business/economic class or high/low time value passengers.

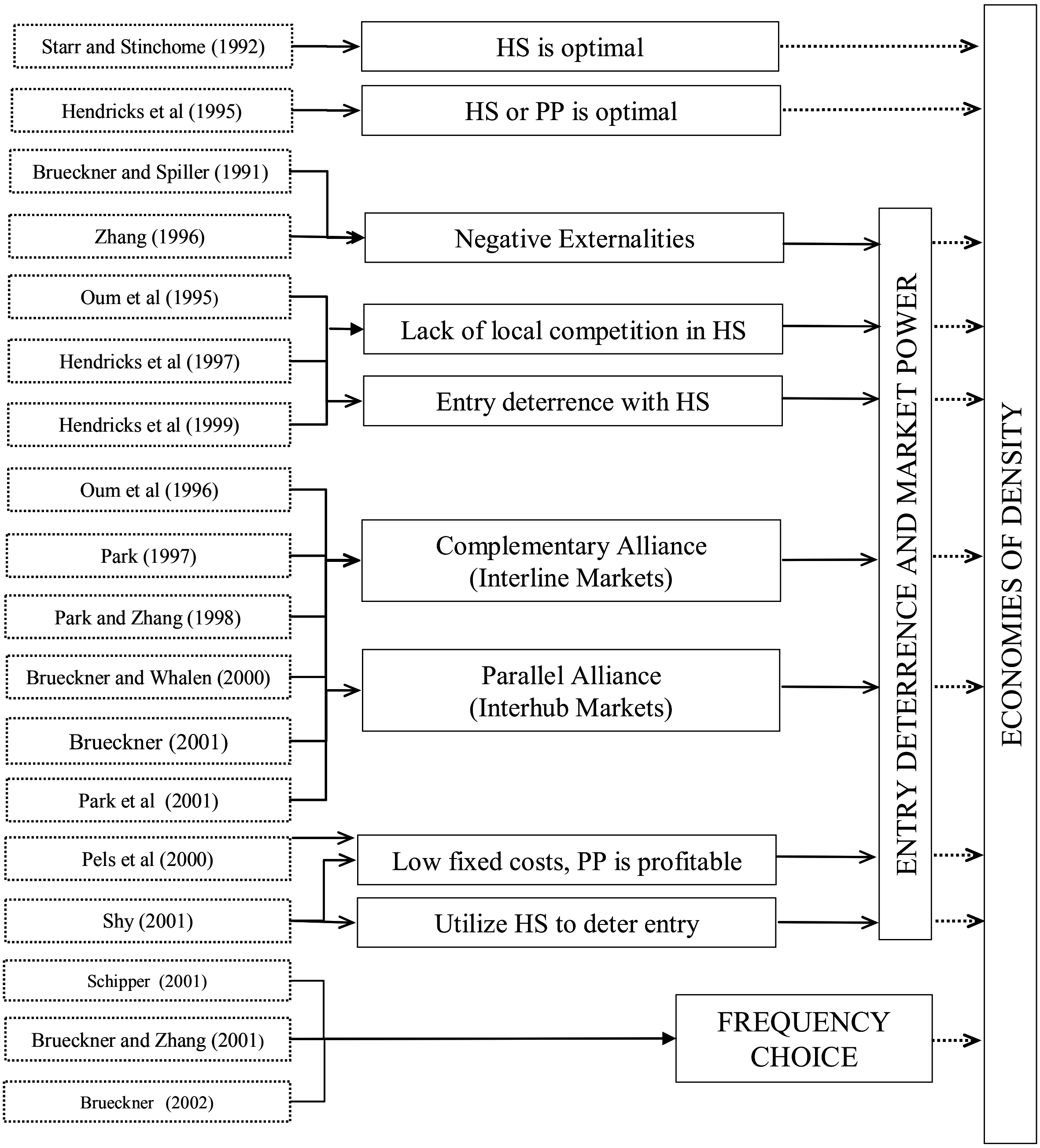

Figure 3-5 Analysis of theoretical studies

In the models, discussed in this Chapter, there are common flaws, which yield them well fitted to conclude that a hub-spoke network is an optimal network configuration under monopoly or duopoly cases. One of them is the assumption of linear marginal cost and symmetric demand functions. Claiming that using these functions guarantee the optimality of HS networks, Pels et al (2000) check the recent literature (Brueckner and Spiller (1991), Zhang (1996), Park (1997) and Brueckner (2001)) which are formulated with these functions. Alleging that fixed costs are assumed to be zero in these studies, they solve the network choice problem where the fixed costs depend on the number of the links in the network and marginal variable cost function, $MC=1-\theta Q$, is linear and show that HS networks are not profitable when the fixed costs are low, market size is large and density economies are low.

Additionally, the profitability of a hub-spoke connection is not valid for every city-pair. For that reason, although Hendricks et al. (1995) show economies of hubs, they append the case that point-to-point connections may be more profitable and suggest direct connections between cities whose sizes are quite large. Besides, Brueckner and Spiller (1991), Zhang (1996) and Park (1997) conclude their propositions, depending on the conditions that demand is strong (weak) and increasing returns are weak (strong).

Secondly, all models, analyzed in this Chapter, assume that costs and demand are symmetric across city pairs. Assumptions of the identical costs and demand between city-pairs are quite strong because the identical costs mean that the distance between the cities is same whereas the identical demand means that the population of cities is same. However, in the literature, there are some models in which asymmetric demand is considered. For example, Wojahn (2001b) tries to find cost-minimizing network, which is a mixture of a point-to-point and a single hub network, with asymmetric demand, proportional to the city sizes. Additionally, in the models, it is assumed that each carrier has the same cost and capacity structure as the other firms. This assumption excludes any kind of asymmetry (cost and capacity advantage) between incumbent firms and new entrants.

Thirdly, in real life, airline carriers operate more complicated networks that contain more than one hub city and sub-networks, which may be any kind of networks (point-to-point one or cyclical route). However, generally, in the papers a network with a few cities is modeled in finding the optimal network choice of airline companies and the effects of airline alliances so it is difficult to generalize the results of models, illustrated in a few city environments to the real airline transport networks. In the case that the scale of market increases, whether the same results are valid is a question.

In summary, all of the studies enlighten the understanding of hub-spoke networks under deregulation and strategic alliances but in the literature, on one hand, the benefits of hub operators from “economies of density” and their market power in the airline competition have been discussing, on the other hand, in the last decade the success and development of new low cost and low fare carriers, offering point-to-point connections and the advantages of fully connected network structures have been examined because it is seen that a number of regional airlines such as Southwest Airlines, Reno Air and Morris Air have invaded the markets of HS networks by entering on the edge and become consistently profitable carriers since deregulation. Then the literature about low cost carriers has been developed. Some of them are the analysis of Dresner, Lin and Windle (1996), Windle and Dresner (1999), Volwes (2001), Cohas, Belobaba and Robert (1995) in which it is possible to find enough econometric evidence that indicates that low cost carriers decrease fares and increase traffic on routes they operate. However, none of them explain the success of these low cost carriers and their behavior patterns in a theoretical model.

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4 AIRLINE NETWORK STRUCTURE WITH THICK MARKET EXTERNALITY

4.1 Introduction

The purpose of this Chapter is to define and model the strategies of low-cost carriers in explaining their success and expansion, which is significantly analyzed in Section 2.3 with the review of some empirical studies (Cohas et al, 1995, Dresner et al, 1996, Volwes, 2001, Windle and Dresner, 1999). The chapter is the same as the study (Yetiskul et al, 2005). To discuss the competitive advantages of low-cost carriers over against major network carriers, we highlight the comparative advantages of a point-to-point network over against a hub-and-spoke one and scheduling decisions of airlines according to networks. While hub-and-spokes (hereafter HS) are designed to decrease the costs of airlines by feeding traffic from spokes, which is called as "**economies of density**", what are the advantages of point-to-point (hereafter PP) ones?

The common strategy of low-cost airlines, which is the source of the increase in their competitiveness and market shares can be summarized as offering frequent services in a point-to-point (hereafter PP) network type and providing lower operating costs because

i. while major, large airlines have been offering services with their hub-spoke network systems, Southwest Airlines and new carriers, imitating Southwest have expanded their markets with a direct connection market strategy.

ii. USAir, the highest cost airline, exhibits unit costs 64 percent above Southwest Airline's (Borenstein, 1992). Gillen and Morrison (2003) also find that the low-cost airlines are substantially lower cost than the full service carriers. The Southwest and others' low cost strategies are partly explained by their simplicity of their operation, partly by their lower input costs, especially wages, and partly by their no-frills service policies.

For that reason, in this chapter, we distinguish a simple network model between two basic network types, a PP and a HS, and highlight the cost heterogeneity under two alternative networks.

Additionally, this chapter analyzes the relation between flight schedule and network choice. While there is a large theoretical literature about two alternative networks, only a few theoretical papers, Berechman and Shy (1998), Brueckner and Zhang (2001), Wojahn (2001) and Brueckner (2004) analyze scheduling decisions in a monopoly case. The frequency decision is very important for both airlines and passengers because flight frequency on one hand fixes an airline's cost with a large proportion; on the other hand, as frequency determines the quality of services for passengers, it also stimulates market demand. Demand for trips is derived by aggregating individual travelers' preferences. A traveler's demand is a function of actual fare and time cost. While the importance of the former on passengers' choices is continuing, the importance of the latter is rising as a result of the increase in the number of business activities as well as leisure ones. These two changes cause not only a shift in travel demand but also an increase in time pressure on consumers. Hence, our model incorporates time costs.

In this chapter, a potential passenger has a start time of the activity in the destination city which is the same as desired arrival time. Besides, each has also two inter-activity times. While one of the inter-activity times equals to the interval from the end of the activity in the origin city to the desired arrival time, the other one arises from the time beginning from the end of the activity in the destination city until the next activity in the origin city. A passenger's choice for travel depends whether his inter-activity time is large enough to cover the travel time and schedule delay, which is the difference between the actual and desired arrival times. While the former one is related with the network configuration, the latter depends on the frequency of flights. Hence, the increase in frequency causes a decrease in schedule delays, resulting in shifting the demand curve outwards. The increase in flexibility time for consumers, that is the interactivity time minus the travel time minus the schedule delay, increases the possibility that they make trips, which automatically causes an increase in market size. This phenomenon is called ‘thick market externality’ (Matsushima (2004), Matsushima and Kobayashi, 2004 and 2005). As a result, the increase in the number of passengers gives an additional payoff to the airline.

This chapter is organized as follows: After explaining the basic thoughts of this research in Section 4.2, we introduce the model for a monopoly airline in a point-to-point network choice in Section 4.3. Then we carry out the similar analysis in a hub-and-spoke one and the advantages of each network structure as compared to the other in terms of fare, flight frequency and profit are discussed and two numerical examples are illustrated in Section 4.4. After analyzing social welfare, the comparison between the solutions for the profit maximization and the social welfare problem are figured out in Section 4.5. Concluding remarks follow in Section 4.6. The proof of the proposition is included in the appendix.

4.2 Model Basics

4.2.1 Point-to-Point Network and Hub-and-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 illustrated in Figure 1. In our model, we assume that only one carrier offers services for these city-pair markets because of governmental restrictions. The single company formalizes its choice according to the network economies.

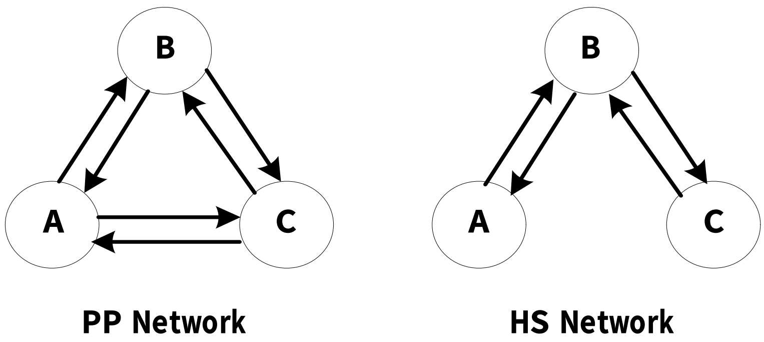

Figure 4-1 A point-to-point network and a hub-spoke network

In a “hub-and-spoke network”, the airline carries the passengers whose city of origin or destination is that hub city directly and the passengers of connecting trips indirectly by transferring at the hub city (city *B* in Figure 4-1) so gathering the passengers of different city-pair markets in one aircraft, the airline benefits from the economies of operating larger aircraft. However, changing planes on longer trips and waiting for hours at congested hub airports are the drawbacks of this network for passengers. Additionally, operating a larger aircraft and increasing the service quality to match the disutility that arises from extra travel time and layover time at hub, cause an increase in fixed and variable costs for companies.

On the other hand, if the airline offers services in a “point-to-point network” by connecting each pair cities, thick market externality is acquired. Direct services on all routes, providing shorter trips for passengers also provides strategic advantage to offer frequent flights. This motivates an increase in demand. Furthermore, the more passengers the airline carries the more frequent flight services it offers. A positive feedback affects so in PP network, economies of scale runs in a different way. Thus, the study of comparative advantages of one type of network contrary to the other type is difficult. In this research, economies of density that HS network type provides and the external expression that determines the market thickness and the comparison of the profit levels of the monopoly firm under two alternative networks are focused on.

4.2.2 Trip Scheduling

The monopoly airline offers direct services in three city-pair markets, *AB*, *BC,* and *AC* in which consumers reside in one city and want to take two-way trips. For example, in *AC* city-pair market, there are consumers who want to travel from city *A* to *C* and back and similarly, others who reside in city *C* want to take two-way trips, originating from city C and ending at city *C*. As it is assumed that the size and characteristics of the residents of each city in the network are identical, travel demand is symmetric on both directions in each city-pair market as well as in three of them. Thus, in the model, we firstly formulate the behavior of potential passengers who are taking two-way trips, originating from city *A* and terminating in city *C* and back then extend the model to the other direction and city-pair markets because in a PP network, airline offers identical services for each market.

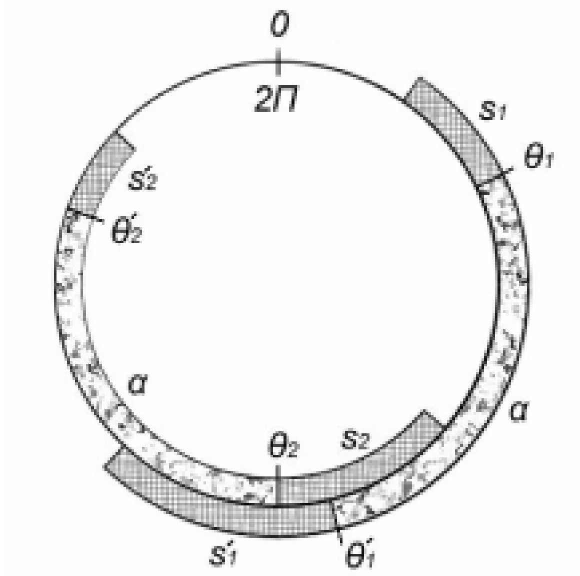

Figure 4-2 Example of inter-activity times of two passengers

It is assumed that each potential passenger has a scheduled activity in the destination city *C* in a time segment $(-\infty,+\infty)$ and for each consumer, there is a start time for her activity, denoted by θ. It can be also called as desired arrival time in the destination city for a consumer, which is similar to the "most preferred departure time", termed firstly by Douglas and Miller (1974). Assuming that the distribution of activity start times is continuous and uniform in infinitely long time, we focus on the potential passengers who are addressed in a circular time interval $[0,2\pi]$ where the end joins to the beginning. Besides, we assume that the number of this corresponding group is equal to *M*. On the other hand, these consumers have to return to city *A* after staying for a time in the destination city until the end of their activities. In Figure 4-2, α denotes time duration of the activity for a potential passenger. For simplicity, we normalize α to a fixed value, zero, for each consumer. Equalizing α to zero for each passenger results that the start time of the activity θ also denotes the end time of the activity in the destination city.

In addition to consumer heterogeneity in the start/end times of the activities, we assume that consumers differ in their gross utilities, derived from taking trips to the destination city *C*. w denotes the consumer-specific gross utility and has a uniform distribution with support $[0, \overline{w}]$. Due to the heterogeneity in the gross utilities, the fare policy of the airline affects the trip demand.

Furthermore, it is thought that the potential passengers who are located in a circular interval $[0,2\pi]$ have other activities in the origin city *A*, which are scheduled before taking the outbound trips to the destination city *C*. In the case that the start time of the activity in city *A* is so early that cannot be reached after the activity in city *C* is completed, it is supposed that the priority of a consumer is the activity in the origin city so the trip to city C is cancelled.

Ignoring any distance differences between cities in the network of three cities, we assume that the duration of a nonstop travel between any city pairs is identical and it is shown as f, ($0<f<\pi$). In a PP network, the actual flight time is same on each city-pair while in a HS network for the connecting market, the duration of the trip is equal to two actual flight times ($2f$). We suppose that there is no restriction in the capacity of aircrafts.

4.3 PP Network and Market Equilibrium

4.3.1 Passengers

The travel demand for the outbound trip is generated as follows. The potential passenger who has a specific activity start time in the destination city *C* has to complete another activity in the origin city *A* before taking the trip. Recalling the assumption in which the time duration of the activities is equalized to zero, we suppose that the potential passenger can not leave city *A* before the time $\theta_A=\theta-s$. Here, s denotes the time interval from the activity before leaving the origin city until after arriving in the destination city, for a consumer. Hereafter, s is called as “inter-activity time” which can be also defined as the possible time to take one-way trip. We assume that inter-activity times are consumer specific times and distributed uniformly and continuously in an interval $[0, \overline{s}]$. If there is a consumer whose inter-activity time is short enough to arrive in the destination city, it is supposed that his priority is to complete the activity in the origin city *A* so the outbound trip to the city *C* is cancelled.

On the other hand, the travel demand for the return trip is similar to that of the outbound trip. The potential passenger has to return to his origin city *A* before the time $\theta'_A=\theta'+ s'$ where θ' denotes the end time of the activity in the destination city *C* and s' denotes inter-activity time that arises from the interval, beginning from θ' and ending at the start time of next activity in the city *A*. The term s' is also consumer specific and has a uniform distribution with support $[0, \overline{s}]$. As noted above, in the case that there is no enough time to reach the activity in the origin city, we assume that the priority of the consumer is the activity in the origin city so the trip is cancelled. Throughout this chapter, it is supposed that consumers schedule activities sequentially along a time scale. One of the activities is in the origin city and the other in the destination city but the consumer puts more priority to those activities located in the origin city. Additionally, the inter-activity times of a consumer are independent. Thus, a two-way trip exists only if both inter-activity times are long enough to complete/reach the activities in the origin city, otherwise there is no trip.

The airline company offers n flights on each direction in each city-pair market and the intervals (i.e., the headways) between departure times of flights are the same. The flights, originating from city *A* to city *C* are indexed by i and $t(n)=(t_1, \ldots\ldots, t_n)$ denoting the set of arrival times of the flights i. The headway is equal to $2\pi/n$. Then, the arrival time of each flight that originates from city A and terminates in city C is

$$t_i = (i-1)\frac{2\pi}{n} \qquad (i = 1,\ldots,n) \ . \tag{4-1}$$

Recalling that the time duration of the travel between city A and C is f, we can find the departure times of the flights from $d_i=t_i$-f. Besides, we assume that the potential passenger who has to arrive in the city C before the start time of the activity θ chooses the flight belonging to the smaller value of time, spent in the destination city. Then the arrival and departure times of the specific outbound flight for our representative consumer is denoted as $t^*_C(\theta)$ and $d^*_A(\theta)$, respectively. Similarly, that consumer chooses the flight for his return trip that leaves the destination city as early as after the activity ends and $d^*_C(\theta)$ and $t^*_A(\theta)$ are the departure and arrival times of the specific return flight, originating from city C and terminating in city A.

In the model, the demand in the market is determined by solving two independent probability expressions in sequence. While first of them is dependent on the vertical differentiation, arises from the heterogeneity in the inter-activity times of potential passengers and is employed to define the condition, related with scheduling; the second is dependent on the heterogeneity in the gross valuations of potential passengers and is to characterize the impact of ticket price on the demand. In other words, if the first condition is satisfied for a potential passenger, whether he finds worthwhile to take the trip is checked in the second step. The role of the inter-activity times runs in defining the first probability so following condition can be written as

$$f + \theta \leq s \ . \tag{4-2}$$

Condition (4-2) implies that a potential passenger can take one of flights only if the flight originates at the city after the activity ends and terminates at the other city before next activity starts. Furthermore, in order to guarantee the demand for a flight, it follows that

$$s \geq f \tag{4-3}$$

To incorporate the effect of ticket price on the demand in the market, the indirect utility of a potential passenger is given by

$$U(\theta, w, p, n) = \begin{cases} Y + w - p & \text{if condition (4 - 2) is satisfied} \\ -\infty & \text{otherwise} \end{cases} \tag{4-4}$$

where Y is a fixed amount of income for him and p is the price of one-way ticket. Trip utility for each consumer can be found from the specific gross utility w minus the price. As the impact of time flexibility on the demand is captured externally in this research, the utility function doesn't contain the costs borne by actual flight time and layover time from the arrival of the flight until the scheduled activity in the destination city. Then, the utility condition is written as

$$U(\theta, w, p, n) \geq Y \ . \tag{4-5}$$

Equation (4-5) means that if the condition $w - p \geq 0$ is satisfied for a consumer, he finds worthwhile to take the trip.

To outline the role of actual flight times, flight frequency and inter-activity times of consumers and solve the effect of time flexibility on the market demand, we suppose a small group of potential passengers whose activity start time in the destination city is located in an infinitesimal interval $[\theta, \theta + d\theta]$. As the inter-activity times of consumers are distributed uniformly and continuously in $[0, \bar{s}]$, the number of the passengers for whom inter-activity time is sufficiently long to take the trip after the activity in the origin city ends and before the activity in the destination city starts, can be expressed as

$$R(\theta) d\theta = \frac{\bar{s} - f - \theta}{\bar{s}} d\theta \,. \tag{4-6}$$

Focusing on the small groups of potential passengers that are addressed in the interval $[0, 2\pi/n]$, the demand for one flight can be identified because the distribution of θ is uniform and continuous and the headway is equal to $2\pi/n$. Then (4-6) is the same for each infinitesimal group and the patronage of one flight in terms of scheduling can be calculated by the integral of small changes in $d\theta$ over the time scale from 0 to $2\pi/n$. Thus, it is

$$\frac{1}{2\pi} \int_0^{\frac{2\pi}{n}} R(\theta) d\theta = \frac{(\bar{s} - f)}{\bar{s}} \frac{1}{n} - \frac{\pi}{\bar{s} n^2} \,. \tag{4-7}$$

Letting each interval $[(i-1)2\pi/n, i2\pi/n]$, $(i=1, \ldots, n)$, that is located sequentially along the circular time scale from 0 to 2π, be defined as one headway, the patronage of all flights, scheduled between 0 to 2π can be found because the probability of the potential passengers whose activity start time in the destination city is located in one of the intervals and whose inter-activity time is long enough to take the trip is the same as the probability, given in (4-7). Then, aggregating the probabilities for all sequential intervals yields

$$P(n, f, \bar{s}) = \frac{\bar{s} - (f + \pi/n)}{\bar{s}} \,. \tag{4-8}$$

This is the key demand expression that gives the patronage of the flights for one-way trips in terms of the scheduling. Taking the square of (4-8), the probability of potential passengers whose both inter-activity times are large enough to travel on both legs is found. Additionally, writing the second demand expression from (4-5), the overall two-way demand for the flights on one direction can be expressed as

$$\begin{aligned} X(p, n) &= MP(n, f, \bar{s}) \int_0^{\bar{w}} \Pr(w - p \geq 0) \, dw ds d\theta \\ &= M \left\{ \frac{\bar{s} - (f + \pi/(n))}{\bar{s}} \right\}^2 \frac{\bar{w} - p}{\bar{w}} \end{aligned} \tag{4-9}$$

where Pr(.) defines the probability. While the first expression of the right-side of (4-9) shows the probability of passengers whose both inter-activity times are large enough to satisfy the condition (4-2), the second one is the share of passengers whose net utilities, derived from taking trips by purchasing a ticket are non-negative.

4.3.2 Firm Behavior and Market Equilibrium

The monopolist maximizes his profit according to two-way trip demand and optimizes the number of flights, n and a ticket fare, p. Before analyzing firm behavior in a PP network, firstly we note that airline's fixed cost, d_i, per flight on each connection between two cities differs belonging to network types, $i=p,h$ where the former one denotes the PP network, and the latter one is the HS. As the fixed flight cost consists of maintenance cost, landing fee and services provided to the aircraft while it is on the ground as well as salaries of the flight crew, the size of aircraft and from where the services are provided affect the cost. Then, the size of an aircraft, served under a PP/HS network, landing fees and the services of hub/secondary airport, etc can be different from the other. Therefore, we distinguish airline fixed cost between two alternative networks. Additionally, it is assumed that the passenger cost, c_i, associated with services such as providing food and drink on board and passenger baggage is different under each network type. c_p and c_h denote, respectively, the variable cost per passenger on a PP and HS network.

Assuming that the demands for two-way trips are symmetric in AC city-pair market (from city A to C and back, from city C to A and back), the profits, earned by the carrier from operating the flights on both directions in AC market can be written as

$$\pi(p,n) = 2(p - c_p)X(p,n) - 2nd_p. \tag{4-10}$$

Additionally, there is symmetry between the demands of each city-pair market in the three-city-model so the monopolist that offers n flights in each direction and sets the ticket fare, p, faces the following maximization problem

$$\max_{p,n}\{\Pi(p,n) = 3\pi(p,n)\}. \tag{4-11}$$

Substituting (4-9) and (4-10) into (4-11), we can write the profit as a function of p and n. Taking the first derivative with respect to p yields

$$6M\left\{\frac{\overline{s} - (f + \pi / n)}{\overline{s}}\right\}^2 \left(\frac{\overline{w} - 2p + c_p}{\overline{w}}\right) = 0. \tag{4-12}$$

From (4-12), the optimum price p^* for one-leg of the two-way trip is found as

$$p^* = \frac{1}{2}\left(\overline{w} + c_p\right). \tag{4-13}$$

Equation (4-13) shows that the monopolist sets a price that covers the marginal cost of a seat partially. After finding the optimum price, we can rewrite the total profit function, conditional on n, as

$$\Pi\left(n, p^*\right) = \frac{3M\left(\overline{w} - c_p\right)^2}{2\overline{s}^2\overline{w}}\left\{\overline{s} - f - \frac{\pi}{n}\right\}^2 - 6nd_p. \tag{4-14}$$

To find the optimal n^*, the first derivative of (4-14) is equalized into zero. Then, the first order gives the following condition

$$\frac{M\pi\left(\overline{w} - c_p\right)^2}{2\overline{s}^2\overline{w}}\left\{(\overline{s} - f)n - \pi\right\} = d_p n^3. \tag{4-15}$$

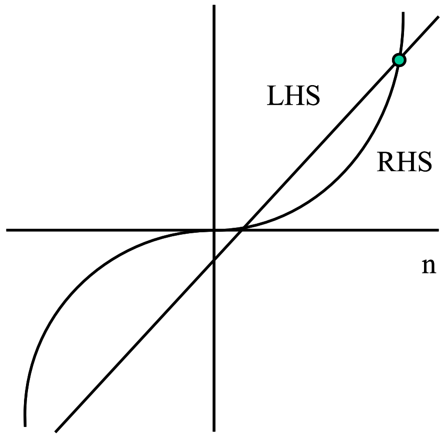

Figure 4-3 The frequency solution under PP network

The left-hand-side and the right-hand-side of the condition (4-15) are illustrated in Figure 4-3, where the S-shaped curve and the line represent the RHS and LHS of the expression, respectively. The curve and the line intersect at two positive points in which the second solution illustrates the optimum number of flights when the second-order condition is checked. The way outlined here is essentially the way presented in Brueckner (2004).

An observation of the equation (4-15) generates a number of comparative-static results. For example, an increase in one unit of variable cost, causing an increase in the ticket fare, results in a frequency decrease. However, when the gross valuation of consumers $\overline{w}$ increases, the slope of the line in Figure 4-3 increases, raising n. Additionally, the smaller value the fixed cost is, the higher the frequency is.

In addition to activity start times of potential passengers over time, given the inter-activity times of them over $[0, \overline{s}]$ and the gross utilities with support $[0, \overline{w}]$, the monopolist first sets the ticket price for one-leg of the trip and then schedules the flights. As under PP network, the airline serves each of the three city-pair markets *AB*, *BC* and *AC* directly, p^* and n^* are the same for all.

4.4 HS Network and Market Equilibrium

4.4.1 Passengers

In this section we consider that the monopolist chooses a “hub-and-spoke network” and offers services for the three city-pair markets of city *A, B,* and *C*. It transfers the passengers of *AC* market via city *B* as its hub so its aircrafts fly only on the *AB* and *BC* routes. The monopolist offers m flights on each of two connections in a circular time interval $[0,2\pi]$. The headways between the flights are same and equal to $2\pi/m$. As it is assumed that the size and characteristics of the residents of each city in the network are identical, the number of flights and the arrival times of them on both directions as well as in each connection are identical.

The passengers’ behavior in *AB* and *BC* city-pair markets of the HS network is the same as that in the markets of the PP network but the behavior of *AC* market passengers can be different because of traveling via hub. Hence, under HS network, we distinguish between two different types of price: $\overline{p}$ and $\overline{q}$, the price set for the direct and connecting market passengers, respectively.

Under HS case, taking one of the scheduled flights on one leg of the trip depends upon s, which is the same as that under PP case. However, under the HS case, a potential passenger of the connecting market involves additional time that arises from flying on both connections so his inter-activity time has to be large enough to cover the duration of the total travel time, $2f$. As the passenger takes the trip after the activity ends and before next activity starts, this condition can be written as

$$\theta + 2f \leq s \tag{4-16}$$

The indirect utility of a connecting market passenger that can actually take the trip is given by

$$\overline{U}(\theta, w, \overline{q}, m) = \begin{cases} Y + w - \overline{q} & \text{if condition (4-16) is satisfied} \\ -\infty & \text{otherwise} \end{cases} \tag{4-17}$$

Each potential passenger flies if only the utility of taking the trip exceeds his income, Y,

$$\overline{U}(\theta, w, \overline{q}, m) \geq Y \, . \tag{4-18}$$

Equation (4-18) shows that if the condition $w - \overline{q} \geq 0$ is satisfied, the consumer takes the flight.

Given symmetry between both legs of a two-way trip, the thickness of the connecting market is found from the multiplication of the probabilities for both legs so the overall demand for the connecting flights can be written as

$$\overline{X}(m, \overline{q}) = M \left\{ \frac{\overline{s} - (2f + \pi / m)}{\overline{s}} \right\}^2 \frac{\overline{w} - \overline{q}}{\overline{w}} \tag{4-19}$$

4.4.2 Firm Behavior and Market Equilibrium

The monopolist carries the passengers of the direct and connecting markets in the same aircraft under a HS network so he sets the flight frequency according to total passenger volume in one connection. The term m is the same on each of the two direct routes. Owing to the asymmetry in the ticket prices, the monopolist optimizes the fare of a ticket, $\overline{p}$ for direct passengers and $\overline{q}$ for connecting passengers. As we clarified in section 4.3.3, we separate airline's costs into fixed cost, d_i per flight and variable cost, c_i per passenger and assume cost heterogeneity under both types of networks. The revenue of the firm under a HS network comes from carrying the passengers of two direct markets and one connecting market. However, total fixed cost is identified by the cost of flying only on the *AB* and *BC* markets so HS operator can utilize from economies of density if the fixed cost doesn't increase under HS network. Given the symmetry between both directions in each connection, the profit, earned by the carrier from operating the flights under a HS network is given by

$$\overline{\Pi}(m, \overline{p}, \overline{q}) = 4(\overline{p} - c_h) X(m, \overline{p}) + 2(\overline{q} - c_h) \overline{X}(m, \overline{q}) - 4md_h \, . \tag{4-20}$$

where $X(\overline{\mu})$ and $\overline{X}(\overline{\mu})$ are demands for the flights of the direct and connecting market, respectively. The former has the same form as (4-9). Then, substituting (4-9) and (4-19) into (4-20), we can write the profit of the monopolist as a function of $\overline{p}$ and $\overline{q}$ and m. Taking the first derivatives with respect to the price of the local market and the price of the connecting market yield the followings

$$4M\left\{\frac{\overline{s}-\left(f+\pi/m\right)}{\overline{s}}\right\}^2\left(\frac{\overline{w}-2\overline{p}-c_h}{\overline{w}}\right)=0\,. \tag{4-21a}$$

$$2M\left\{\frac{\overline{s}-\left(2f+\pi/m\right)}{\overline{s}}\right\}^2\left(\frac{\overline{w}-2\overline{q}-c_h}{\overline{w}}\right)=0\,. \tag{4-21b}$$

Solving (4-21a) and (4-21b), the optimum prices for one leg of the two-way trip in both markets are found as

$$\overline{p}^*=\overline{q}^*=\frac{1}{2}\left(w+c_h\right). \tag{4-22}$$

From the equation (4-22), we can say that the monopolist sets the same ticket prices for the passengers of direct and connecting markets. Additionally, it is the same as the optimum price, set in the PP case. After substituting (4-22) into (4-20), we can rewrite the total profit function of the monopolist under HS network as

$$\overline{\Pi}\left(m,\overline{p}^*,\overline{q}^*\right)=\frac{M\left(\overline{w}-c_h\right)^2}{2\overline{s}^2\overline{w}}\cdot\left\{\left(\overline{s}-2f-\frac{\pi}{m}\right)^2+2\left(\overline{s}-f-\frac{\pi}{m}\right)^2\right\}-4md_h \tag{4-23}$$

Taking the first derivative of (4-23) with respect to *m* and rearranging the first order yields the condition for frequency

$$\frac{3M\pi\left(\overline{w}-c_h\right)^2}{4\overline{s}^2\overline{w}}\left\{\left(\overline{s}-\frac{4}{3}f\right)m-\pi\right\}=d_hm^3\,. \tag{4-24}$$

If d_p=d_h is assumed, the RHS of the condition is the same as that in (4-15). However, the slope and the intercepts of the LHS are different. The diagram of the condition resembles the one shown in Figure 4.3. As before, there are two positive intersection points of the S-shaped curve and the line, which are economically relevant. When the second-order condition is scrutinized, the second one, which has a higher position than the other, represents the optimum flight frequency. Focusing on heterogeneity in costs under two alternative network types, we hand out the comparison of the frequency levels in the next section.

4.4.3 Comparison of Two Alternative Networks

In previous sections, the optimum price and frequency solutions of the monopolist under two network structures are scrutinized without discussing which type of network offers higher fares or frequency or traffic volumes. As cost heterogeneity in network types is assumed, a change in one of cost parameters alters the levels, causing a difficultly in identifying the network choice of the monopolist. However, following results can be established:

Proposition 4.1. The comparison of fare levels between the two alternative networks does not depend on the frequency parameters so an observation of the equations (4-13) and (4-22) concludes that "*the fares in direct markets as well as connecting one under a HS network is higher (lower) than those under a PP* *network if the variable cost of a passenger when operating a HS network is higher (lower) than that when operating a PP network*".

The comparison of frequency levels under both network types will be held on for two cases: under the assumption $d_p=d_h$ and $c_p=c_h$; and the assumption $d_p<d_h$ and $c_p<c_h$.

Proposition 4.2. Under first case, comparing the first-order conditions for flight frequency in equation (4-15) and (4-24) yields the solution, "*flight frequency is higher in the HS network than in the PP network,* $n^* < m^*$ ". Because the left-hand-side of HS network in equation (4-24) has a higher position than that of PP network in (4-15) while the right-had-sides of two conditions are the same (Appendix 1). As cost assumptions of the first case are the same as in Brueckner (2004), the result, established in Proposition 4.2, is also same. The reason that the line of HS network has a higher level than that of PP network is the passenger volumes in each connection. In other words, the marginal flight cost on each HS route is paid by the local market and the connecting market passengers. However, in the PP case, only the passengers of that route pay the flight cost. The fact that higher frequency under HS network on one connection doesn't yield the result that the total flights, operated under HS network is more than those under PP one. If this expectation is true, it can be said that the HS operator saves costs and benefits from economies of density.

Under second case, if the costs of the airline are low enough when operating a PP network, the comparison of frequency levels yields $n>m$, implying that the number of flights in a PP network is higher than in a HS network on each connection because the positions of both sides of the condition (4-15) change. While a decline in the variable cost makes the intercept of the line more negative, a decline in fixed cost makes the rate of change in the slopes of the curve less steep so the intersection point in the positive quadrant moves to the right, raising n. A decrease in ticket fare causes an increase in the number of passengers who find the trip worth taking so adapting low variable cost per passenger under a PP network the monopolist sets lower fares, which results in an increase in flight frequency. Lower operating flight cost also causes greater traffic volumes because the higher frequency, lowering the schedule delays results in an increase in the probability of passengers whose inter-activity times are large enough to cover actual flight time and schedule delay. As a result, it can be said that the higher flight frequency is, the more the PP operator utilizes economies of frequency as a result of higher demand.

In the case that Proposition 4.2 is valid, comparison of the traffic levels of the PP and HS network concludes the same result for direct markets of HS network, that is the traffic volumes in city-pair markets *AB* and *BC* is higher in the HS network than in the PP network. However, this transaction between higher frequency and higher demand can not be said for the connecting market of HS network. The level of traffic in city-pair market *AC* can be higher or lower than that under PP network because the increase in trip duration for connecting passengers as a result of flying two-legs causes a shift in the demand curve downward. Hence, it is difficult to conclude that offering higher frequency generates higher profit level.

To show the effect of parameter changes in the comparison of the HS and PP solutions and to reconfirm the results established above, two numerical examples are illustrated. The focus of the first example is to capture the changes in frequency and profit levels under both network types as a result of an increase in actual travel time and the difference between two fixed costs per flight, d_h and d_p.

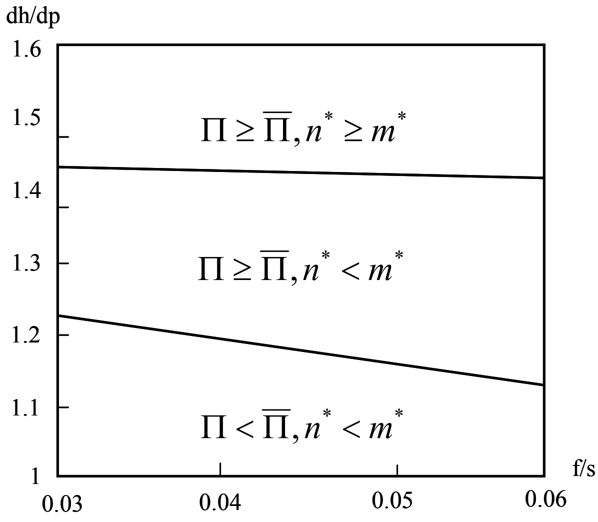

Figure 4-4 The effect of flight time

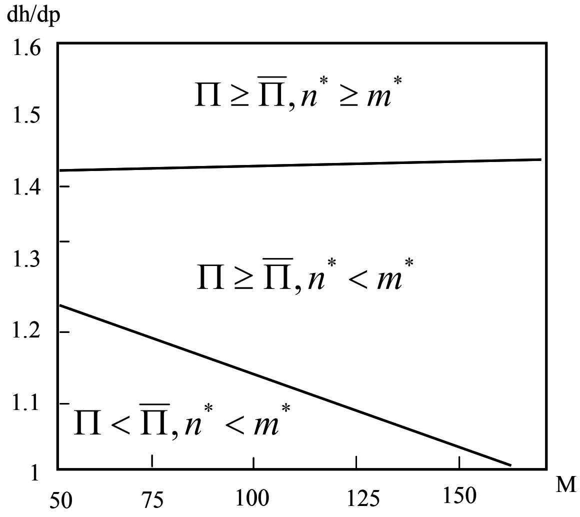

Figure 4-5 The effect of market size

Given a set of parameters as $M=100$, $\overline{w} = \pi / 2, \overline{s} = \pi/6$, $c_p=c_h=\pi/10$ and $d_p=1$, the HS and PP solutions are illustrated in Figure 4-4 in which the lower and upper lines show the boundaries between profit and frequency levels, respectively. While the former one is determined by setting equilibrium profit $\Pi = \overline{\Pi}$, the latter one is from setting equilibrium flight frequency $n^* = m^*$. Therefore, the lower line delimitates the regions where the profit level of the monopolist under the HS case is lower than that under the PP network. However, in both regions, flight frequency is higher in the HS than in the PP network. It can be seen from the diagram that the profitability of the HS network decreases when either the actual flight time or the ratio between two fixed flight costs, d_h/d_p increase. If the ratio continues to increase, implying that the carrier's operating cost is lower under the PP network than under the HS one; frequency is higher in the PP than the HS network. The impact of the increase in the actual travel time on the equilibrium frequency line is less than that on the equilibrium profit line.

In addition, the effect of market size, *M*, on the frequency and profit levels under both network types is examined. Holding the actual travel time equal to $\pi/100$, this result is given in Figure 4-5 in which the lower and upper lines again show the boundaries between profit and frequency levels, respectively, except that the demarcation lines have different slopes (Figure 4-5 is the same as Figure 4-4). As it can be followed from the diagram, the increase in *M* causes a decrease in the profitability of the monopolist under the HS network, concluding that the effect of the downward shift in the demand curve of the connecting market under the HS network on the profit dominates the effect of the upward movement due to the higher frequency.

4.5 Social Welfare Analysis

In this section, we analyze the first-best allocation, which maximizes social welfare. While the monopolist maximizes his profit level, the social planner focus on the maximization of consumer benefits minus airline costs. At this stage, the company is not required to break-even so it is assumed that the fixed costs can be financed from general budget. To derive the social welfare differences between network types, aggregate consumer surplus and profit level of the monopolist is specified for each type. Consumer welfare is the sum of the individual utilities and affected by the ticket price in the case that trip generates. Otherwise, it is equal to income. As the average consumer surplus in a direct city-pair market is found as $\frac{\overline{w}+p}{2}$, the aggregate consumer surplus under PP case can be expressed as

$$CS = 3M\left\{\frac{\overline{s}-(f+\pi/n)}{\overline{s}}\right\}^2\left(\frac{\overline{w}+p}{2}-p\right). \tag{4.25}$$

If the airline operates a HS network, the average consumer surplus in the direct markets as well as the connecting market is the same as that under PP case because the monopolist sets the same prices for the passengers of both markets. However, the demand level for the connecting flights is different from the level for the direct flights under HS case because of the additional cost that arises from additional flight time. Then the consumer welfare under HS case is

$$\begin{aligned} C\overline{S} = 2M&\left\{\frac{\overline{s}-(f+\pi/m)}{\overline{s}}\right\}^2\left(\frac{\overline{w}+\overline{p}}{2}-\overline{p}\right)+ \\ M&\left\{\frac{\overline{s}-(2f+\pi/m)}{\overline{s}}\right\}^2\left(\frac{\overline{w}+\overline{q}}{2}-\overline{q}\right) \end{aligned}. \tag{4-26}$$

As the sum of the consumer surplus and firm's profit gives the total surplus, the social planner maximizes the following two functions to compare the network types,

$$W = CS + \Pi(\mu), \tag{4-27a}$$

$$\overline{W} = \overline{CS} + \overline{\Pi}(\overline{\mu}). \tag{4-27b}$$

Differentiating (4-27a) with respect to p and (4-27b) with respect to $\overline{p}$ and $\overline{q}$ yields marginal cost pricing in the first-best allocation. Then we can rewrite the welfare functions as

$$W(n) = \frac{3M(\overline{w}-c_p)^2}{2\overline{s}^2\overline{w}}\left\{\overline{s}-f-\frac{\pi}{n}\right\}^2 - 6nd_p, \tag{4-28a}$$

$$\overline{W}(m) = \frac{M(\overline{w}-c_h)^2}{2\overline{s}^2\overline{w}}\left\{\left(\overline{s}-2f-\frac{\pi}{m}\right)^2 + 2\left(\overline{s}-f-\frac{\pi}{m}\right)^2\right\} - 4md_h. \tag{4-28b}$$

Taking the first derivative of (4-28a) and (4-28b) with respect to *n* and *m*, respectively and rearranging the terms, the first order conditions for the flight frequency under PP and HS case are given as

$$\frac{M\pi(\overline{w}-c_p)^2}{\overline{s}^2\overline{w}}\{(\overline{s}-f)n-\pi\} = d_p n^3 \tag{4-29a}$$

$$\frac{3M\pi(\overline{w}-c_h)^2}{2\overline{s}^2\overline{w}}\left\{\left(\overline{s}-\frac{4}{3}f\right)m-\pi\right\} = d_h m^3. \tag{4-29b}$$

The form of frequency condition (4-29a) and (4-29b) under first-best allocation is the same as that in (4.15) and (4.24), respectively. However, they differ from traffic levels only in the replacement of *2* by *1* in the denominator of the LHS in (4-15) and *4* by *2* in (4-24).

Proposition 4.3. The comparison of frequency levels between the monopolist and the social planner concludes that "*the monopolist sets a lower frequency than what would be socially optimal. Therefore, the traffic level under monopoly solution is lower than under social optimum solution*".

The relation between the traffic level and the frequency is a kind of feedback mechanism. Once the number of the passengers that travel has been raised by the planner; the market size increases and it results in higher frequencies.

Finally, we compare the network choices of the monopolist and social planner. The welfare difference between network types is found from (4-29a) and (4-29b). The comparison under both regimes will be held on in the case that $d_p = d_h$ and $c_p = c_h$ are assumed. Denoting the difference in profit and social welfare levels between under PP and HS case as $\Delta = \Pi - \overline{\Pi}$ and $\Gamma = W - \overline{W}$, respectively, we focus on Δ and Γ as functions of fixed cost. Even though the impacts of the change in fixed cost on the functions are same, the levels of impact are different. The welfare difference is affected from a change in *d* value twice as large as that the profit difference is affected.

Proposition 4.4. The comparison between the network choices of the monopolist and the social planner shows that "*the choice of the profit maximizing monopolist toward the HS network causes inefficiency according to the social welfare*".

To show the difference between the choices and to reconfirm the evaluation established above, one numerical example is illustrated. Given a set of parameters as $M = 100, \overline{w} = \pi/2, \overline{s} = \pi/6$, $c_p = c_h = \pi/10$, which is the same as the set in previous examples, Δ and Γ as functions of *d* are illustrated in Figure 4.6 in which Δ intersects the horizontal axis at a value, smaller than that Γ intersects. Denoting these values as *d** and *d***, respectively, we conclude that at the values below *d**, both the monopolist and social planner prefer the PP network and at the values above *d***, both prefer the HS network. However, between *d** and *d***, the monopolist prefers the HS network while the planner favors the PP one. Hence, over this range of fixed cost values, the choice of the profit maximizing monopolist toward HS network is inefficient.

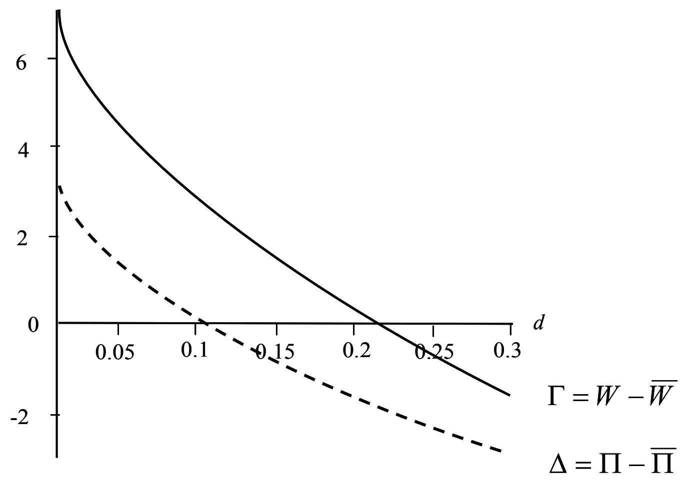

Figure 4-6 Δ and Γ as functions of fixed cost, *d*.

Given the same parameter set as in previous examples where the profit maximization solutions of PP and HS are compared, the social welfare solutions under PP and HS networks are specified in Figure 4-7 and 4-8 as before. While Figure 5-1 is drawn to capture the changes between profit and welfare maximization in terms of flight time f and the ratio between two fixed costs per flight, d_h and d_p, Figure 5-2 is to capture the changes in terms of market size and fixed cost ratio. As it can be observed from diagrams, the choice of social planner is towards PP network, implying the same result, pointed in Proposition 4.4.

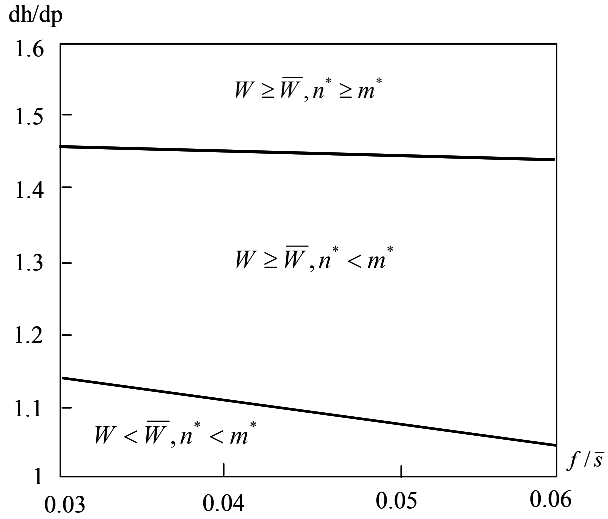

Figure 4-7 The effect of f under welfare max

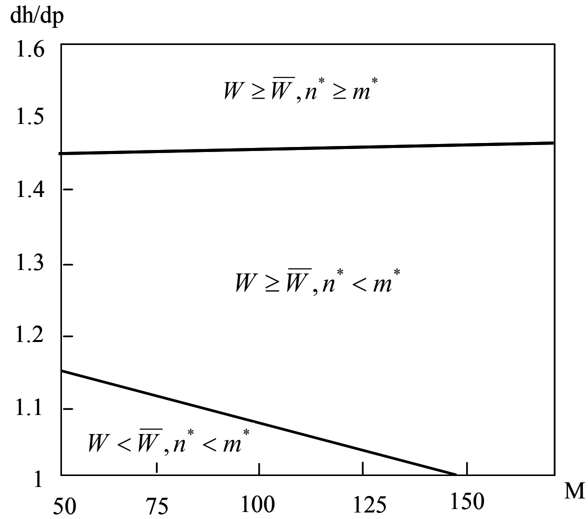

Figure 4-8 The effect of M under welfare max

4.6 Conclusion

This chapter is established to model the success, development and competitive advantages of new entrants maintained over large, major airlines in a theoretical base. While the incumbents offer indirect connections via hub city and benefit from economies of density, new entrants develop low cost operating strategies that make them afford very low fares. The reason of their lower costs is the simplicity in their operations, which involves offering direct frequent services in a PP network, using uncongested secondary airports, servicing with the same type of aircraft and providing no-frill services. As a result, new entrants 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. Hence, distinguishing a simple network model between two basic network types, a PP network and a HS network under cost heterogeneity, we examine the effects of the network structure on the fares, flight frequency and traffic volumes.

The analysis shows that offering services in a HS network leads to increase in flight frequency under the equal cost assumption. However, the operating and variable costs are low enough, PP operator offers more services. As the ticket price covers the variable cost per passenger so the difference between variable costs under two networks affects the levels of fares. The decrease in ticket fares, causing an increase in the number of passengers who find the trips worth taking, results in higher frequency.

Additionally, introducing inter-activity times, which are consumer-specific, we observe market thickness under both alternative networks. The inter-activity time for a consumer has to be longer than the duration of travel and schedule delay. Hence, extra travel time required for the passengers of connecting markets under the HS network declines the probability that a potential passenger can take one of the flights during his inter-activity time, causing a decrease in market thickness. In any case, the demand curve is shifted up when the frequency increases as a result of decrease in schedule delays. There is a positive interaction between the number of services in the market and the market thickness, termed as thick market externality, which implies that the higher the frequency the airline offers, the more the passengers, it carries.

Analyzing the factors that affect the airline's choice about network type, the model captures the advantages of each network structure as compared to the other. However, it is only to compare the fare, frequency and traffic levels for a monopolist. A further discussion on the duopoly case can be conducted. Schipper (2001) and Schipper et al (2003) analyze the frequency choice in air transport markets without distinguishing between two basic network types.

Appendix 1

Proof of Proposition 2: Using $d_p=d_h$ and $c_p=c_h$, compare (4-15) and (4-24) after replacing *m* in (4-24) with *n*. The right-hand-sides and the first expression $\frac{M\pi(\overline{w}-c_h)^2}{4\overline{s}^2\overline{w}}$ in left-hand-sides are same in both. Denoting the second expression in the LHS of (4-15) and (4-24) as $g_p(n)$ and $g_h(n)$, the difference can be written that $g_h(n)-g_p(n)=(\overline{s}-2f)n\text{-}\pi$. The condition $g_h(n)-g_p(n)=(\overline{s}-2f)\text{-}\pi/n\geq 0$ is satisfied, the frequency is higher in HS than PP. On the other hand, the condition for the satisfaction of positive demand in *AC* city-pair market is $n\geq\frac{\pi}{\overline{s}-2f}$. Since both are same, $g_h(n)>g_p(n)$, implying that in HS network, the monopolist offers more flights than in PP network.

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5 THICK MARKET EXTERNALITY IN DAY RETURN DEMAND

5.1 Introduction

As travelers' preferences are affected from time costs as well as from actual fares, direct frequent services increase time flexibility for consumers. In this research, the economy of scale which occurs as a result of the increase in consumers' flexible time is called "economies of frequency". Under scale economies, the increase in the number of flights in the market causes an increase in the possibility that the consumers make trips, which automatically results in a thickness in the market size. Thus, a positive feedback mechanism is observed.

On one hand, trip demand in aviation market is for two-way trips and the possibility of a potential passenger to take a trip depends on her schedule on both legs. On the other hand, consumers have tied schedules. Even though the number of meetings and appointments they have to reach is increasing, they also try to keep their private and leisure time untouched so they become busier now, compared to past. As a result, these two complementary effects augment the weight of frequency in consumers' preferences and cause an increase in day return demand. In order to provide time flexibility for consumers and respond to demand for return trips within one day, the airlines offer more frequent services. Then the increase in the number of scheduled flights in the market raises the number of available flights for consumers, which automatically results in an upward demand shift.

As the number of flights, set on both directions in a city-pair market is identical, the frequency increase affects the consumers' preferences on both legs. When the flight availability for a consumer on one leg increases, there is a symmetric increase in the availability on the other leg and the impact of frequency on the choice of total trip is in an increasing scale. Hence, in this research, the scale economies arise from the transaction between the requisite of consumers for time flexibility and the flight frequency, set by airlines is focused on.

This chapter is organized as follows: After explaining the basic thoughts of this research in Section 5.2, we introduce the model for a monopoly airline in a point-to-point and hub-and-spoke one under two-way trip. In Section 5.4, we find the market equilibrium solutions of a PP and HS network under one-way trip demand and compare the network choice of a monopolist under two-way demand case with under one-way demand case to capture the impact of thick market externality. Concluding remarks follow in Section 5.5.

5.2 Model Basics

5.2.1 Previous Literature

This chapter analyzes the effect of thick market externality on the network choice of a monopolist airline. To capture this, the frequency level under two alternative network types, a PP network and a HS one is examined in two cases: when the demand is for two-way and when the demand is for one-way. In the literature, a few theoretical papers that analyze scheduling decisions of the airlines exist. Berechman and Shy (1998), Brueckner and Zhang (2001), Wojahn (2001) and Brueckner (2004) provide solutions for two network types in a monopoly case and show that switching to a HS network leads to increase in flight frequency. Even though trips occurring in both directions in a city pair market are assumed in those papers, the profit maximization solutions are characterized in the case that the carrier sets prices and flight frequency according to one-way trip demand. However, in our model, the optimum price and frequency are found for two-way trip demand in the monopolist maximization problem and the impact of the market thickness is captured in the network choice of the monopolist. Matsushima (2004) analyze the external effects and strategic complementarities in transportation markets and Matsushima and Kobayashi (2004 and 2005) propose a market equilibrium model to investigate the structure of a bus and taxi spot market and the externality effects.

5.2.2 Thick Market Externality

In the past, economies of scale which has rationalized HS network formations are considered to have two dimensions: 1) economies of density, 2) decreasing total fixed costs. Economies of density reflect decreasing unit operating costs per passenger. As the number of connections decreases in the HS network, total fixed cost decreases. However, congestion cost increases as the number of enplanements at the airport increases so at concentrated hubs, congestion cost are larger and the benefits obtained by the HS networks are impaired. To circumvent congestion costs associated with HS networks, recently, PP networks have become popular. In reality, PP networks are inferior to HS networks with respect to the economies of density. However, the congestion observed in HS networks does not occur in PP networks. This characteristic of PP networks allows increasing flight frequency with ensuing lower fares. In this respect, PP networks seem to be promising. Besides, PP network requires not much operating costs when compared to the HS network. Thus, fixed costs on a route where PP service is available decreases with increasing flight frequency, which cannot be observed in the hub-and-spoke network because of the congestion costs.

In this chapter, it is assumed that flights are available round-the-clock (24hours) and each potential passenger has a start time of the activity in the destination city. As well as the ticket fare, consumer's choice for travel depends whether she has enough time to take a flight, originating after her previous scheduled activity ends and terminating before her next scheduled activity starts. In the model, the impact of scheduling flexibility is captured with an external expression that incorporates the duration of travel and the frequency of flights. As both are related with network configuration, the network choice of a monopolist determines the demand. PP networks possess shorter trips as compared to HS ones so operating a PP network and offering more flights increase the possibility that a consumer takes a flight. Then, the increase in the number of passengers gives an additional payoff to the airline. Besides, when a potential passenger considers taking a trip, she normally considers not only the outbound leg but also the return leg so increasing flight frequency in one day the airline makes return flight possible without a sleepover. Thus we can expect that the demand for flight services also increases.

In this research, our aim is to show the impact of thick market externality on the network choice of a monopoly airline. Economies of scale are captured by economies of density and decreasing fixed cost in HS networks. If positive externality of the market thickness achieves economies of scale, new entry with a point-to-point service to the market becomes profitable. To make this happen, it is necessary to maintain the high frequency of flights between two connections. Thus in this research, embodying the demand for two-way trips, we aim to investigate the market thickness where flight selection works well.

5.3 Market Equilibrium under Two-way Trip Demand

The model is discussed in three steps. In the first step, the model is formulated according to the case that a monopolistic carrier chooses a PP/HS network under two-way trip demand while in the second, the case when the carrier operates the PP/HS network under one-way trip demand is presented. The model and equilibrium solutions under two-way trip demand is the same as those in Yetiskul et al (2005). Finally, the comparison between these two cases is interpreted. In doing so, we find the optimum ticket fares, frequency and profit levels for the carrier when operating the PP/ HS network and under the two-way demand/ one-way demand. Briefly, optimization solutions are determined at four times.

We consider a network with 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. We assume that the duration of a nonstop travel between any city pairs is identical and it is shown as *f*. In a PP network, the airline offers direct services in each city-pair market while in a HS, the airline carries the passengers of connecting trips indirectly by transferring at the hub city (city *B*). We formulate the behavior of passengers who are taking two-way trips, originating from city *A* and terminating in city *C* and back.

It is assumed that each potential passenger has a scheduled activity in the destination city *C* in a circular time interval $[0, 2\pi]$ where the end joins to the beginning. Additionally, there is a start time for her activity, denoted by θ. Besides, we assume that the number of this corresponding group is equal to *M*. On the other hand, these consumers have to return to city *A* after staying for a time in the destination city until the end of their activities. In Figure 4-1, α denotes time duration of the activity for a potential passenger. For simplicity, we normalize α to a fixed value, zero, for each consumer. In addition to consumer heterogeneity in the start times of the activities, consumers differ in their gross utilities, derived from taking trips to the destination city. *w* denotes the consumer-specific gross utility and has a uniform distribution with support $[0, \overline{w}]$.

5.3.1 Passengers

The travel demand for the outbound trip is generated as follows. The potential passenger who has a specific activity start time in the destination city *C* has to complete another activity in the origin city *A* before taking the trip. We suppose that the potential passenger can not leave city *A* before the time $\theta_A = \theta - s$. Here, *s* denotes the time interval from the activity before leaving the origin city until after arriving in the destination city, for a consumer. Hereafter, *s* is called as "inter-activity time". We assume that inter-activity times are consumer specific times and distributed uniformly and continuously in an interval $[0, \overline{s}]$. On the other hand, the travel demand for the return trip is similar to that of the outbound trip. The term *s'*, distributed in an interval $[0, \overline{s}]$, denotes the inter-activity time of the consumer for the outbound trip. Additionally, the inter-activity times of a consumer are independent. Thus, a two-way trip exists only if both inter-activity times are long enough to complete/reach the activities in the origin city, otherwise there is no trip.

The airline company offers *n* flights on each direction in each city-pair market and the intervals between departure times of flights are the same. The flights, originating from city *A* to city *C* are indexed by *i* and $t(n)=(t_1, \ldots\ldots, t_n)$ denoting the set of arrival times of the flights *i*. The headway is equal to $2\pi / n$. Then, the arrival time of each flight that originates from city *A* and terminates in city *C* is

$$t_i = (i-1)\frac{2\pi}{n} \qquad (i = 1, \ldots, n) \; . \tag{5-1}$$

In the model, the demand in the market is determined by solving two independent probability expressions. While first of them is dependent on the vertical differentiation, arises from the heterogeneity in the inter-activity times of potential passengers and is employed to define the condition, related with scheduling;

the second is dependent on the heterogeneity in the gross valuations of potential passengers and is to characterize the impact of ticket price on the demand. The role of the inter-activity times runs in defining the first probability so the condition can be written as $f + \theta \leq s$, implying that a potential passenger can take one of flights only if the flight originates at the city after his activity ends and terminates at the other city before next activity starts. To incorporate the effect of ticket price on the demand and find the second probability, the indirect utility of a passenger is given by

$$U(\theta, w, p, n) = \begin{cases} Y + w - p & \text{if condition } f + \theta \leq s \text{ is satisfied} \\ -\infty & \text{otherwise} \end{cases} \tag{5-2}$$

where Y is a fixed amount of income for him and p is the price of one-way ticket. Trip utility for each consumer can be found from the specific gross utility w minus the price. Then, the utility condition is written as $U(\theta, w, p, n) \geq Y$. The key demand expression that gives the probability of potential passengers whose inter-activity times on the outbound legs are large enough to cover actual flight time f and rescheduling time is

$$P(n, f, \bar{s}) = \frac{\bar{s} - (f + \pi / n)}{\bar{s}}. \tag{5-3}$$

Taking the square of (5-3), the probability of potential passengers whose both inter-activity times are large enough to travel on both legs is found. Additionally, writing the second demand expression from the utility condition, the overall two-way demand for the flights on one direction can be expressed as

$$X(p, n) = M \left\{ \frac{\bar{s} - (f + \pi / n)}{\bar{s}} \right\}^2 \frac{\bar{w} - p}{\bar{w}}. \tag{5-4}$$

5.3.2 Firm Behavior and Market Equilibrium

The airline's fixed cost per flight on each connection between two cities is denoted as d_i and differs belonging to network types, $i=p,h$ where the former one denotes the PP network, and the latter one is the HS. Additionally, the passenger cost, c_i, is different under each network type. Assuming that the demands for two-way trips are symmetric in *AC* city-pair market (from city *A* to *C* and back, from city *C* to *A* and back)and in each city-pair market, the profits, earned by the carrier from operating the flights on both directions in three city-pair markets can be written as

$$\Pi(p, n) = 6(p - c_p)X(p, n) - 6nd_p. \tag{5-5}$$

Taking the first derivative with respect to p yields the optimum price p^* for one-leg of the two-way trip,

$$p^* = \frac{1}{2}(\bar{w} + c_p). \tag{5-6}$$

Then rewriting the profit function (5-6), conditional on n and equalizing the first derivative into zero, the frequency choice of the monopolist from the following first order condition is found.

$$\frac{M\pi(\bar{w} - c_p)^2}{2\bar{s}^2\bar{w}} \{(\bar{s} - f)n - \pi\} = d_p n^3. \tag{5-7}$$

As under PP network, the airline serves each of three city-pair markets, *AB*, *BC* and *AC* directly, p^* and n^* are same for all.

When the monopolist chooses a HS network, the passengers' behavior in *AB* and *BC* city-pair markets is the same as that in the markets of the PP network but the behavior of *AC* market passengers is different because of traveling via hub. Hence, the inter-activity time of a connecting passenger has to be large enough to cover the duration of the total travel time, $2f$ and this condition can be written as $\theta + 2f \leq s$. As the aircrafts of the monopolist fly only on the *AB* and *BC* routes, he sets the flight frequency according to total passenger volume in one connection. The revenue comes from carrying the passengers of two direct markets and one indirect market. Optimum price solutions yield the same price for the passengers of direct and connecting markets, which is also the same as (5-6), set in PP network if $c_p=c_h$ is assumed. Optimum flight frequency in HS network is higher that in PP network if $d_p=d_h$ and $c_p=c_h$ are assumed.

5.3.3 The Impact of Thick Market Externality

In this section, the relation between the flight demand, equation (5-4) and the frequency is analyzed. Taking the first and second derivatives of (5-4) with respect to *n* yield the following

$$\frac{\partial X(n)}{\partial n} = \mathrm{Y}\,\frac{1}{n^2}\left\{\left(\bar{s} - f\right) - \frac{\pi}{n}\right\} \geq 0\,, \tag{5-8}$$

$$\frac{\partial^2 X(n)}{\partial n^2} = \mathrm{Y}\,\frac{2}{n^3}\left\{-\left(\bar{s} - f\right) + \frac{3\pi}{2n}\right\} \tag{5-9}$$

where $\mathrm{Y} = 2\pi M\left(\overline{w} - p^*\right)/\left(\bar{s}^2\overline{w}\right)$. To investigate the second order condition, expression in (5-9) is reduced to

$$\frac{\partial^2 X(n)}{\partial n^2} = \begin{cases} \geq 0 & \text{if} \quad \dfrac{3\pi}{2n} \geq \bar{s} - f \\ < 0 & \text{if} \quad \dfrac{3\pi}{2n} < \bar{s} - f \end{cases} \tag{5-10}$$

in which the second inequality indicates the satisfaction of the second order condition.

5.4 Market Equilibrium under One-way Trip Demand

In this section, the set-up of the model is changed to examine whether some kind of influence of thick market externality is captured on the monopolist network choice so the optimum price and frequency level in two alternative networks, PP and HS, are solved for one-way trip demand. In the previous section, the profit maximization solutions are characterized in the case that each consumer travels on both legs of the itinerary so the consumers have two time constraints, one of which is on the outbound leg while the other is on the return leg so the probability that shows the total number of passengers taking two-way trips is found by multiplying the probabilities defined for both ways. In the following optimization problem, it is assumed that a potential passenger considers taking a one-way trip so time restriction runs in only one-way. Therefore, assuming the cases in which the potential passengers have time limitations on the outbound leg or vis-à-vis, the model is outlined again. Terms with subscript $_o$ are assigned to one-way trip demand. Then, the indirect utility of a potential passenger is given by

$$U(\theta, w, p_o, n_o) = Y + w - p_o \tag{5-11}$$

where p_o and n_o are the ticket fare and the frequency on each connection in one-way case, respectively. Considering that the consumers with identical θ and s also differ in their gross utilities, w, that a consumer finds a one-way trip worthwhile satisfies

$$w - p_o \geq 0\ . \tag{5-12}$$

On the other hand, the condition, related with the time restrictions of consumers can be written as $\pi/n_o + f \leq s$ because it is assumed that the inter-activity times of consumers are distributed uniformly and continuously. Then, the total one-way demand for the flights on one connection is

$$X(p_o, n_o) = M\left\{\frac{\overline{s} - (f + \pi/n_o)}{\overline{s}}\right\}\frac{\overline{w} - p_o}{\overline{w}} \tag{5-13}$$

and the profit of the monopolist from operating the flights on both directions in *AC* market can be written as

$$\pi_o(p_o, n_o) = 2(p_o - c_p)X(p_o, n_o) - 2n_o d_p. \tag{5-14}$$

From (5-14), the optimum ticket fare for one-way trip is found as

$$p_o^{\ *} = \frac{1}{2}(\overline{w} + c_p). \tag{5-15}$$

Taking the first derivative with respect to the number of flights yields the following condition

$$\frac{M\pi(\overline{w} - c_p)^2}{4\overline{s}\,\overline{w}} = d_p n_o^{\ 2}\ . \tag{5-16}$$

and the frequency solution is given by

$$n_o^* = \frac{(\overline{w} - c_p)}{2}\sqrt{\frac{M\pi}{\overline{w}\,\overline{s}\,d_p}}\ . \tag{5-17}$$

To solve the maximization problem for the monopolist under HS case in one-way trip case, we assume that the monopolist offers m_o flights on each of two connections in a circular time interval [$0,2\pi$] under one-way trip demand. As noted in Section 5.3.2, when the monopolist chooses a HS network, the behavior of *AC* market passengers is different because of traveling via hub. Hence, the traffic level of the connecting market is different because the inter-activity time of a connecting passenger has to be large enough to cover the duration of the total travel time, $2f$ and this condition can be written as $\theta + 2f \leq s$. Denoting $\overline{q}_o$ as the ticket price of a connecting passenger, we can write the demand for the connecting market as

$$\overline{X}(\overline{q}_o, m_o) = M\left\{\frac{\overline{s} - (2f + \pi/m_o)}{\overline{s}}\right\}\frac{\overline{w} - \overline{q}_o}{\overline{w}}\ . \tag{5-18}$$

As the revenue of the monopolist comes from carrying the passengers of two direct markets and one connecting market while its aircrafts fly only on the *AB* and *BC* routes under HS network, the profit expression is given by

$$\overline{\Pi}(m_o, \overline{p}_o, \overline{q}_o) = 4(\overline{p}_o - c_h)X(m, \overline{p}_o) + 2(\overline{q}_o - c_h)\overline{X}(m, \overline{q}_o) - 4m_o d_h \,. \tag{5-19}$$

Using (5-19), optimum prices are found as

$$\overline{p}_o^{\,*} = \overline{q}_o^{\,*} = \frac{1}{2}(\overline{w} + c_h)\,. \tag{5-20}$$

As seen from the equation (5-20), the monopolist sets the same ticket prices for the passengers of direct and connecting markets.

After substituting (5-20) into (5-19) and taking the derivative of $\overline{\Pi}(m_o, \overline{p}_o, \overline{q}_o)$ with respect to m_o, the following condition is given as

$$\frac{3M\pi(\overline{w} - c_h)^2}{8\overline{s}\,\overline{w}} = d_p m_o^{\,2}\,. \tag{5-21}$$

and the optimum frequency under HS network under one-way trip case is

$$m_o^* = \frac{(\overline{w} - c_h)}{4}\sqrt{\frac{6M\pi}{\overline{w}\,\overline{s}\,d_h}}\,. \tag{5-22}$$

5.4.1 Comparison

To analyze the effect of thick market externality on the monopolist's network choice, two numerical examples are illustrated. Given a set of parameters as $M=100$, $\overline{w} = \pi/2, \overline{s} = \pi/6$, $c_p=c_h=\pi/10$ and $d_p=1$, the HS and PP solutions under one-way trip demand are specified in Figure 5-1 and 5-2 in which the lower and upper lines indicate the boundaries for equilibrium profit and equilibrium flight frequency levels under both networks, respectively. While Figure 5-1 is drawn to capture the impact of the actual flight time f and the ratio between two fixed costs per flight, d_h and d_p on the profit and frequency levels in one-way trip demand case, Figure 5-2 is to capture the effect of the market size M.

The goal of calculating these numerical examples is to compare the regions, showing that the profit level of the monopolist under the PP case is higher than that under the HS network between under two-way trip demand and one-way trip demand cases. It can be seen from the diagrams 4-4 and 5-1 that the profitability of the PP network under two-way trip demand is higher. Additionally, checking the difference in sizes of the regions in Figure 4-5 and 5-2, we conclude that the monopolist network choice is inclined toward the PP case under two-way demand case. Finally, a comparison between two-way and one-way trip solutions is focused on the regions, delimitated by setting equilibrium flight frequency under both types of network. As seen from the diagrams 4-4 and 5-1, the equilibrium line under two-way case has a slight lower position than in one-way case. Besides, the comparison between diagrams 4-5 and 5-2 implies the same result.

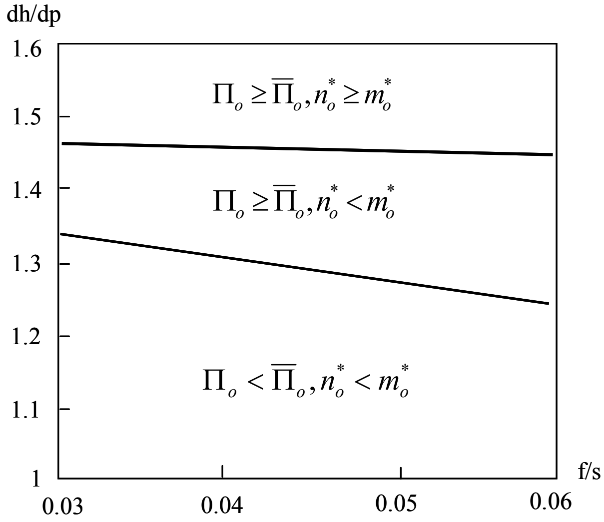

Figure 5-1 The effect of *f* under one-way

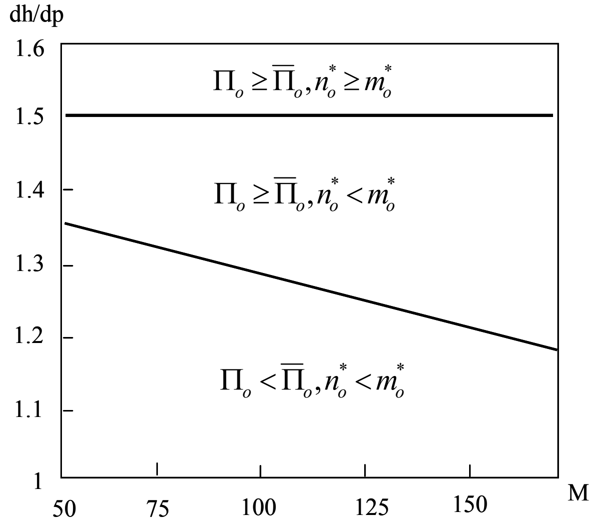

Figure 5-2 The effect of *M* under one-way

5.5 Conclusion

This chapter is established to model the airline network choice for the monopolist with day return demand. On one hand, the requisite of consumers for time flexibility increases because of having many scheduled activities in limited time and the desire of leisure time. On the other hand, travel demands in airline markets are for two-way trips. As a result, the impact of the availability of day returns for consumers causes a positive externality in the airline market if the carrier supplies more frequent services within one day. Hence, we introduce inter-activity times for consumers and characterize an external expression that embodies the duration of travel and the frequency of flights to define the market thickness. Focusing on the equilibrium frequency and profit levels in PP and HS network under two-way and one-way demand cases separately, we captures the advantages of offering direct and more frequent flights in PP networks.

Preferences

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6 FREQUENCY AND AIRFARE COMPETITION BETWEEN TWO INCUMBENTS

6.1 Introduction

Firm behavior in airline industry has been amply analyzed in the literature. In Chapter 2, we outlined the empirical studies that cover the impacts of deregulation on prices, demand and competition while in Chapter 3, theoretical ones are reviewed. Most of the theoretical ones have been based on homogenous product oligopoly models where price or quantity levels are endogenized. The duopoly market structure of airline firms is generally modeled in non-cooperative behavior. The firms choose their strategic variables once and simultaneously, believing that the competitor's variable level remains unchanged. If the strategic variable is price, the market structure is Bertrand type and if the strategic variable is quantity, the model is Cournot type.

In the literature, there are many Cournot-type models that analyze competition in airline markets. However, there are only a few analyses which discuss the market structure with respect to location or addresses in consumers' preferences. This can be observed from Figure 3.9 in Chapter 3. Consumers have different incomes, tastes or location so they are heterogeneous. The models in which consumers have different preferences for the brands/ service qualities offered in the market are location models. However, the interpretation of "location" can be the physical location of a consumer or a distance between brand characteristics that a consumer has a level of loyalty to a special brand. Passengers' choices also depend on not only pecuniary costs but also brands in air transport markets so the homogenous product models are one dimensional.

6.1.1 Location Type Models of Horizontal Differentiation

Modern theories of product differentiation have been very much affected by Hotelling (1929) who proposed a spatial framework to describe product and price competition in oligopolistic industries. The address (location) approach provides an alternative method for modeling product differentiation by considering the range of potential variants of a product; a consumer's location with respect his ideal product. Two products are said to be horizontally differentiated when the products have a positive demand whenever they are sold at the same price. None of products dominates the other in terms of characteristics. The consumer heterogeneity in preferences over characteristics explains how the firm can raise its price above that charged by its competitor without losing all market. In Hotelling analysis, the characteristics of the products arise from the location where it is sold so transportation cost decreases the utility of consumers when consuming the product.

In Hotelling's model, the choice of locations is analyzed in the first stage of a sequential game while price competition is held in the second stage. In our model, we assume that potential passengers have ideal brands to a particular carrier like in Brueckner and Whalen (2000). However, we formulate a discrete location model where there are two types of potential passengers who are differentiated with respect to their preference for brands. We also do not go so far and treat brand levels as exogenous. However, we introduce the possibility of another differentiation that causes heterogeneity in the frequency levels, offered by the carriers. Hence, we are aware of the difference between two types of differentiation associated respectively with heterogeneity in brands and flight frequencies. While the former is location type differentiation, playing a secondary role, the latter one is vertical differentiation as the primary for product differentiation. Hence, we offer a complete characterization of flight frequency and ticket price choices in a duopoly model where the carriers simultaneously choose the flight frequencies and then compete in ticket prices.

This research aims to offer an explanation for flight frequency and airfare competition between two major carries. We analyze equilibrium solutions in a duopoly market in which two carriers sell differentiated products and compete in a city-pair market for two types of potential passengers who are also differentiated with respect to their preference for brands. Additionally, we distinguish the potential passengers between two different time-flexibilities.

As mentioned above, in the transport market literature there are a few papers, analyzing the equilibria in both frequencies and prices of airline firms and these are used to capture the economic effects of transport deregulation policies and compare the welfare changes. While Evans (1987) and Ellis and Silva (1998) modelize the competition in bus services, Schipper (2001) discuss the equilibrium solutions in airline competition. Evans (1987) makes a theoretical comparison of four economic regimes: competition, maximization of net economic benefit subject to the constraint that the bus service must break even; unregulated monopoly; and unconstrained maximization of net economic benefit. Ellis and Silva (1998) show that the market is unstable if demand is uncoordinated, but stable otherwise. Schipper (2001) presents the symmetric and asymmetric frequency model by assuming that departure configurations are given as: interlaced and non-interlaced duopoly configuration.

This chapter is organized as follows: Section 2 presents the assumptions and the set-up of a duopoly market model in which two carriers sell differentiated products for two types of consumers who are also differentiated with respect to their preference for brands and time flexibility. In Section 3, firstly symmetric equilibrium, later asymmetric equilibrium solutions are analyzed by changing the levels of time flexibility between passengers groups. To check the stability of equilibria, we assume linearity in variable cost function of passengers and describe the profitability conditions of airline firms in Section 4 and concluding remarks follow in Section 5.

6.2 The Model

We model the behavior of passengers who are traveling from one city to another in a market with two carriers called airline A and B. We assume that there are two types of potential passengers who are differentiated with respect to their preference for brands. The first type who are strongly preferred to fly by the airline A is called brand A oriented passengers and it is assumed that they lose a utility of δ, ($\delta>0$), if they fly by the airline B. The second type is called brand B oriented passengers and they also lose a utility of δ, ($\delta>0$), if they fly by the airline A. Besides, we assume that both types have the same number of potential passengers, M.

6.2.1 Assumptions

In the model, it is assumed that each airline company offers flights that are available round-the-clock (24hours) and each potential passenger has a start time of the activity in the destination city. As the ticket fare is chosen as a strategic variable in the duopoly market of the airlines, each airline tries to capture the passengers from two differentiated markets by setting his price. On the other hand, uncovered market configuration, arising at the price competition is also not taken into consideration in the model. The case of inelastic demand with respect to prices is assumed. However, whether the consumer takes one of the flights of the airline depends on her schedule. Each consumer travels if only she has enough time to take a flight, originating after her previous scheduled activity ends and terminating before her next scheduled activity starts. Hence, only the consumers whose inter-activity times are long enough take trips while others cancel so flight scheduling also affects the demand for each airline. In the model, we try to capture this impact with an external expression that incorporates the frequency of each airline.

The external expression which is the same as that in Yetiskul et al (2005) is formulated as follows. Assuming that the characteristics of the potential passengers of each type, related with scheduling is similar, we firstly clarify brand A oriented passengers then extend to the other type. Each potential passenger of the first type has a scheduled activity in the destination city and for each consumer; there is a start time for her activity, denoted by θ. Assuming that the number of potential passengers whose activity start times are distributed continuously and uniformly in a circular time interval $[0,2\pi]$ is equal to M, we address the potential passengers of the first type in the time interval $[0,2\pi]$ where the end joins to the beginning.

The potential passenger who has a specific activity start time in the destination city has to complete another activity in the origin city before taking the trip. Assuming that the time duration of the activities is equal to zero, we suppose that the potential passenger can not leave the origin city before the time $\theta_O=\theta-s$. Here, s denotes the time interval from the activity before leaving the origin city until after arriving in the destination city, for a consumer. Hereafter, s is called as "inter-activity time" which can be also defined as the possible time to take a flight. We assume that inter-activity times of the first type passengers are consumer specific times and distributed uniformly and continuously in an interval $\left[0, \bar{s}_1\right]$. If there is a consumer whose inter-activity time is short enough to arrive in the destination city, it is supposed that his priority is to complete the activity in the origin city so the trip to the destination city is cancelled.

On the other hand, the characteristics of the potential passengers of the second type are similar to those of the first type. The second type potential passengers who have scheduled activities in the destination city are also addressed in the same circular time interval $[0,2\pi]$ according to their activity start times, denoted by θ'. Each potential passenger can not take a flight before the time $\theta'_O = \theta' - s'$. Like s, s' denotes the time interval from the activity before leaving the origin city until after arriving in the destination city, for a second type consumer. The term s' is also consumer specific and has a uniform distribution with support $\left[0, \bar{s}_2\right]$. As noted above, in the case that there is no enough time to arrive in the destination city after the activity in the origin city ends, we assume that the priority of the consumer is the activity in the origin city so the trip is cancelled. Additionally, the inter-activity times of each group passengers are independent.

6.2.2 Passengers

In the city-pair market carrier A offers consumers n_A flights while carrier B offers n_B flights. Recalling that each airline company offers flights that are available round-the-clock, the flights of each airline arrive in the destination city in the time interval $[0,2\pi]$ and we suppose that there is no restriction in the capacity of aircrafts. The flights of carrier A is indexed by i and $t(n_A)=(t_1,......, t_{nA})$, denoting the set of arrival times of the flights i. On the other hand, the flights of carrier B is indexed by j and $t(n_B)=(t_1,......, t_{nB})$. The flights of each airline are spaced equally on the circular market. Hence, the headway for each airline is found endogenously from the division of the time length by the total number of flights offered by corresponding airline. Then, the arrival times of each flight, offered by airline A and B are

$$t_i = (i-1)\frac{2\pi}{n_A} \qquad (i = 1,\dots,n_A) \ , \tag{6-1a}$$

$$t_j = (j-1)\frac{2\pi}{n_B} \qquad (j = 1,\dots,n_B) \ . \tag{6-1b}$$

As noted in the previous section, in the model, the demand changes with respect to the frequencies are determined by characterizing the external expressions which are dependent on the heterogeneity in the inter-activity times of potential passengers. These expressions give the number of potential passengers who can take one of flights only if the flight originates at the city after her activity ends and terminates at the other city before next activity starts. As the time components of a passenger trip involves actual flight time, inter-activity time of each potential passenger has to be longer than the actual flight time. As both airlines offer services on the same route in the same city-pair market, we normalize actual trip time to a fixed value, zero for simplicity. Therefore, only frequency level is used in characterizing external demand expression.

To outline the external expression and solve the elasticity with respect to frequency, we suppose a small group of first type potential passengers whose activity start time in the destination city is located in an infinitesimal interval [$\theta,\theta+d\theta$]. As the inter-activity times of consumers are distributed uniformly in $[0, \bar{s}_1]$, the number of the passengers for whom inter-activity time is sufficiently long to take the trip after the activity in the origin city ends and before the activity in the destination city starts, can be expressed as

$$R(\theta)d\theta = \frac{\bar{s}_1 - \theta}{\bar{s}_1} d\theta \ . \tag{6-2}$$

If the infinitesimal group, defined above, fly by airline *A* (due to taking more utility instead of flying by airline *B*), the demand of first type potential passengers for one flight of airline *A* can be identified by focusing on all infinitesimal groups that are addressed in the interval [$0,2\pi/n_A$]. As the distribution of θ is uniform and continuous and the headway is equal to $2\pi/n_A$, (6-2) is the same for each group and the patronage of one flight of airline *A* in the case that airline *A* sets a ticket price that is low enough to carry only brand *A* oriented passengers can be calculated by the integral of small changes in $d\theta$ over the time scale from 0 to $2\pi/n_A$. Thus, it is

$$\frac{1}{2\pi}\int_0^{\frac{2\pi}{n_A}} R(\theta)d\theta = \frac{1}{n_A} - \frac{\pi}{\bar{s}_1 n_A^{\,2}} \ . \tag{6-3}$$

As each interval [$(i-1)2\pi/n_A, i2\pi/n_A$], $(i=1,\dots,n)$, that is located sequentially along the circular time scale from 0 to 2π, defines one headway for airline *A*, the patronage of all flights of airline *A*, scheduled between 0 to 2π can be found in the case that airline *A* carry only first type passengers. The probability of the first type potential passengers whose activity start times in the destination city are located in one of the intervals and whose inter-activity time are long enough to take the flights of airline *A* is the same as the probability, given in (6-3). Then, aggregating the probabilities for all sequential intervals yields

$$P(n_A, \bar{s}_1) = \frac{\bar{s}_1 - \pi/n_A}{\bar{s}_1} \ . \tag{6-4}$$

This is key demand expression that gives the patronage of the flights of airline *A* when it sets a ticket price which is low enough to carry only first type passengers. The expression, π/n_A in the equation (6-4) shows the average schedule delay time of the first type passengers in case that they fly by airline A. On the other hand, if they fly by airline B, their average schedule delay is equal to π/n_B. As the same way, average schedule delay times of the second type can be written.

While $\eta_A^1 = P(n_A, \bar{s}_1)M$ gives airline A's traffic in the market of first type of passengers when its frequency is n_A and if first type passengers take the flights of airline A, the demand of second type passengers for the flights of airline A can be expressed as $\eta_A^2 = \dfrac{\bar{s}_2 - \pi/n_A}{\bar{s}_2}M$ if airline A sets a ticket price which is low enough to carry them. Rewriting the similar formulations for the passenger types when they fly by airline B as a result of taking more utility than when flying by airline A, η_B^1 and η_B^2 are also found.

In addition to activity start times of each type over $[0, 2\pi]$, given the inter-activity times of first and second type potential passengers over $[0, \bar{s}_1]$ and $[0, \bar{s}_2]$, respectively, we consider the case of elastic demand, arising from rescheduling times of passengers. Finally, to investigate the equilibrium frequency and price choices of the airlines, the utility functions of the first and second type passengers are given by

$$V_1 = \begin{cases} -p_A & \text{flying by airline A if } \pi/n_A \le s \text{ is satisfied} \\ -p_B - \delta & \text{flying by airline B if } \pi/n_B \le s \text{ is satisfied} \\ -\infty & \text{otherwise} \end{cases} \tag{6-5a}$$

and

$$V_2 = \begin{cases} -p_A - \delta & \text{flying by airline A if } \pi/n_A \le s' \text{ is satisfied} \\ -p_B & \text{flying by airline B if } \pi/n_B \le s' \text{ is satisfied} \\ -\infty & \text{otherwise} \end{cases} \tag{6-5b}$$

where p_A and p_B denotes the ticket fare, set by airline A and B, respectively.

6.3 Airline Firms and Market Equilibrium

Airline's fixed cost involves maintenance cost, landing fee and services provided to the aircraft while it is on the ground as well as salaries of the flight crew. d denotes the fixed cost per flight on one connection between two cities. In the model we don't distinguish airline fixed cost between two airline companies.

In characterizing the equilibrium solutions for both airlines, we consider a two-stage game where the frequency levels are simultaneously chosen first and then ticket fares are set simultaneously. In this type of game, it is assumed that the frequency decision is less flexible than the price decision. To find equilibrium prices, we use "No mill-price Undercutting" conjectures that a firm in general sets its own price taking the price of the other firm as given, but he expects the competitor to match price cuts that would, if unmatched, drive the competitor out of business because there is no Nash equilibrium in pure price-strategies for the differentiated products. Shy (2001) also looks for an Undercut-proof equilibrium in airfares competition in airline industry.

In the Undercut-Proof Equilibrium, if airline B sets a ticket price that undercuts the ticket price set by airline A and captures both markets, it has to set the price as $p_B = p_A - \delta$ that is a value, compensating the individual preference for airline A. On the other hand, airline A also sets a price to serves both types of passengers. Hence, this equilibrium is the pair of prices (p_A^* , p_B^*) that satisfies the followings:

i) Airline A chooses the highest ticket price subject to

$$\pi_B^* = X_B p_B^* - n_B d \geq \left(\eta_B^1 + \eta_B^2\right)\left(p_A - \delta\right) - n_B d \ , \tag{6-6a}$$

ii) Airline B chooses the highest ticket price subject to

$$\pi_A^* = X_A p_A^* - n_A d \geq \left(\eta_A^1 + \eta_A^2\right)\left(p_B - \delta\right) - n_A d \tag{6-6b}$$

where X_A and X_B denote the number of passengers, taking the flights, offered by airline A and airline B, respectively. While the first condition implies that airline A sets the highest ticket price that prevents airline B from undercutting its price p_A^* and captures both types of passengers, the second one implies that airline B sets the ticket price as high enough to prevent airline A from undercutting its price and serves for both markets.

6.3.1 Symmetric Equilibria

Given the same parameters for the utility loss of each type passengers when they fly by their unpreferred airline in a horizontally differentiated airline market, we analyze the frequency and price decisions of both as the outcome of a two-stage game. As the solution is derived backwards, we calculate firstly the equilibrium prices and secondly the frequency levels. To analyze the solutions and capture the effects of time flexibility of passengers on the flight frequencies, traffic volumes and profit levels, the results are investigated under two cases. While under the first case, it is assumed that time flexibility of first and second type passengers are the same so the distributions of the interactivity times of both are in the same interval, $\bar{s}_1 = \bar{s}_2$, under second case, it is assumed that the potential passengers of the first type has less time flexibility than those of the second type so the interactivity times of first type is distributed in a shorter interval, $\bar{s}_1 < \bar{s}_2$.

Under the first case, imposing symmetry of the inter-activity times for both groups ($\bar{s}_1 = \bar{s}_2 = \bar{s}$), we search the equilibrium prices in the case that first type passengers take the flights of airline A while second type passengers travel by the flights of airline B. Furthermore, an additional symmetry with respect to the equilibrium is introduced. The condition is that the frequency equilibrium is symmetric, i.e., both airlines operate the same number of departures in the time interval $[0,2\pi]$ in equilibrium. Hence, the demand for each airline can be expressed as:

$$X_A = \begin{cases} 0 & \text{if} \quad p_A > p_B + \delta \\ \eta_A^1 & \text{if} \quad p_B - \delta \leq p_A \leq p_B + \delta \\ \eta_A^1 + \eta_A^2 & \text{if} \quad p_A < p_B - \delta, \end{cases} \tag{6-7a}$$

$$X_B = \begin{cases} 0 & \text{if} \quad p_B > p_A + \delta \\ \eta_B^2 & \text{if} \quad p_A - \delta \leq p_B \leq p_A + \delta \\ \eta_B^1 + \eta_B^2 & \text{if} \quad p_B < p_A - \delta \end{cases} \tag{6-7b}$$

Solving (6-6a) with X_A and X_B for the airline A's price and (6-6b) for the airline B's price and substituting one of which to the other yields the equilibrium ticket prices. While the symmetric inter-activity time distribution of passengers' groups results in the equality between the demand levels of each type for the same airline, i.e., $\eta_A^1 = \eta_A^2$ and $\eta_B^1 = \eta_B^2$, the symmetric frequency equilibrium results in the equality between the demand levels of each type for both airlines, i.e., $\eta_A^1 = \eta_B^1$ and $\eta_A^2 = \eta_B^2$ so the symmetric competition yields the following equilibrium ticket prices,

$$p_A^* = p_B^* = 2\delta \, , \tag{6-8}$$

After finding the equilibrium prices, substituting them into (6-7a) and (6-7b), we get $X_A = \eta_A^1$ and $X_B = \eta_B^2$, which means that the number of passengers, carried by airline A is the same as that, carried by airline B. Equation (6-8) shows that under the first case, the equilibrium prices are increasing when brands become highly differentiated. As the equilibrium price of an airline is independent from its own flight frequency as well as its competitor's, the second stage frequency equilibrium levels can be found independently and taking first order conditions of each profit function with respect to its own frequency level yields the following:

$$n_A^* = n_B^* = \sqrt{\frac{2M\pi\delta}{\bar{s}d}} \, , \tag{6-9}$$

The interpretation of the equation (6-9) is that the frequency level is increasing when the passengers become more time sensitive (when $\bar{s}$ decreases) and when the differentiation between passenger groups with respect to their brand preference is increasing (when δ increases). The impact of the change in the inter-activity parameter on the traffic levels can also be derived from the external demand expressions. The demand for each airline decreases when $\bar{s}$ decreases even though the carriers increase their frequency. This says that the raise in demand as a result of higher frequencies is less than the fall as an effect of shorter inter-activity time intervals. Finally, the equilibrium pay-offs are also the same and the following results can be established.

Proposition 6.1. When the model has a vertical type differentiation associated with heterogeneity in time flexibility, in addition to the discrete-location type differentiation, given a symmetric frequency equilibrium results in a price equilibria where the prices of the competing carriers are the same.

Proposition 6.2. Under symmetric locations and time flexibilities as well as given symmetric frequency equilibrium, the flight frequencies rise when the number of potential passengers increases (when M increases), when brands become highly differentiated (when δ rises), when fixed cost falls (when d falls) and when passengers become more time sensitive (when $\bar{s}$ decreases). Traffic η_A^1 and η_B^2 moves upwards with flight frequency, except that it responds a decrease to a decrease in $\bar{s}$.

6.3.2 Asymmetric Equilibria

The above analysis focuses on symmetric equilibria, where it is assumed that the time-flexibilities of two differentiated passengers are symmetric and the equilibrium frequency levels are symmetric. In order to investigate two-stage game equilibrium solutions under the asymmetric case where the interactivity times of first type passengers is distributed in a shorter interval than those of second type passengers, airline competition as a two-stage game in frequency and prices is modeled. Furthermore, symmetric equilibrium frequency is replaced by the assumption of asymmetric frequency equilibrium as a result of the asymmetric time flexibilities of passenger types. As it is assumed that the potential passengers of the first type has less time flexibility than those of the second type, $\bar{s}_1 < \bar{s}_2$ under second case and the finding of Proposition 6.2 is that flight frequency rises when passengers become more time sensitive, the case of $n_A > n_B$ is considered. Then, the demand for each airline can be expressed as:

$$X_A = \begin{cases} (\eta_A^1 - \eta_B^1) + (\eta_A^2 - \eta_B^2) & \text{if} \quad p_A > p_B + \delta \\ \eta_A^1 + (\eta_A^2 - \eta_B^2) & \text{if} \quad p_B - \delta \le p_A \le p_B + \delta \\ \eta_A^1 + \eta_A^2 & \text{if} \quad p_A < p_B - \delta, \end{cases} \tag{6-10a}$$

$$X_B = \begin{cases} 0 & \text{if} \quad p_B > p_A + \delta \\ \eta_B^2 & \text{if} \quad p_A - \delta \le p_B \le p_A + \delta \\ \eta_B^1 + \eta_B^2 & \text{if} \quad p_B < p_A - \delta \end{cases} \tag{6-10b}$$

The demand functions of both duopoly airlines have the same forms as those in (6-7a) and (6-7b) except for demand levels that arises from the difference between frequencies. As the case of $n_A > n_B$ is considered and if the prices satisfy the condition, defined in the middle lines of demand functions, airline *A*, operating more flights, captures a group of the second type passengers whose inter-activity times are short to satisfy the condition $s' \ge \pi / n_B$ for taking one of the flights of airline *B* while long enough to satisfy the condition $s' \ge \pi / n_A$. When $n_A = n_B$, the middle lines of the two demand functions become the same forms as in symmetric equilibria. Solving (6-6a) with X_A and X_B for the airline *A*'s price and (6-6b) for the airline *B*'s price yields the second-stage equilibrium prices:

$$p_A^* = \frac{\delta\left(\eta_A^1 + \eta_A^2\right)\left(\eta_B^1 + 2\eta_B^2\right)}{\eta_B^1\eta_B^1 + \eta_A^2\eta_B^1 + \eta_A^2\eta_B^2}, \tag{6-11a}$$

$$p_B^* = \frac{\delta\left(\eta_B^1 + \eta_B^2\right)\left(2\eta_A^1 + 2\eta_A^2 - \eta_B^2\right)}{\eta_B^1\eta_B^1 + \eta_A^2\eta_B^1 + \eta_A^2\eta_B^2}. \tag{6-11b}$$

After finding the equilibrium prices, substituting them into (6-10a) and (6-10b), we get $X_A = \eta_A^1 + \left(\eta_A^2 - \eta_B^2\right)$ and $X_B = \eta_B^2$. As the optimum ticket price of an airline is conditional on not only its own frequency level but also its rival's, the profit function is also conditional on both flight frequencies. Taking first order conditions of each profit function with respect to its own frequency level yields the followings:

$$\frac{\partial \pi_A}{\partial n_A} = \frac{\partial X_A^1}{\partial n_A} p_A^* + X_A^1 \frac{\partial p_A^*}{\partial n_A} - d = 0 \tag{6-12a}$$

$$\frac{\partial \pi_B}{\partial n_B} = \frac{\partial X_B^2}{\partial n_B} p_B^* + X_B^2 \frac{\partial p_B^*}{\partial n_B} - d = 0 \tag{6-12b}$$

Both first order conditions are solved by writing best response functions of frequency levels. Solving them yields the equilibrium frequency levels, n_A^* and n_B^* in differentiated flight services. After substituting them into (6-11a) and (6-11b), the equilibrium prices are also found.

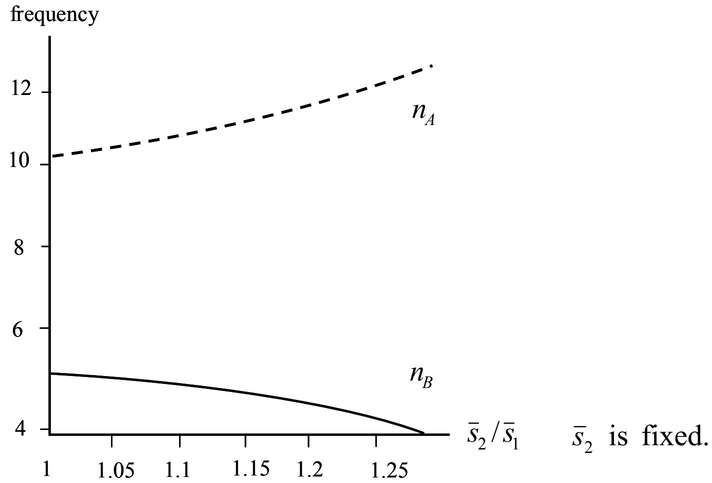

Figure 6-1 Equilibrium frequencies under asymmetric competition

In order to investigate the equilibrium solutions, (n_A^*, n_B^*) and (p_A^*, p_B^*) under the asymmetric case, a numerical example is specified. Given a set of parameters as *M=1*, $\delta = 1, \bar{s}_2 = \pi / 2$ and *d=0.1*, changing the upper value of the interval that belongs the first type passengers and solving (6-12a) and (6-12b) yields the flight frequencies, illustrated in Figure 6-1 in which the upper and lower lines show the number of flights, set by airline *A* and *B*, respectively. When the interval of first type passengers becomes shorter while the other is fixed, airline *A* increases its frequency level not to loose the market of more time sensitive first type passengers while airline *B* decreases the level because of the increase in asymmetry of time flexibility between two groups. Additionally, airline *A* increases the number of passengers, captured from its competitor's market as a result of the increase in the frequency. The change in the frequency is more in airline *A* than in airline *B*, implying that own market effect dominates the cross market effect. As a result, this discussion has established the following results:

Proposition 6.3. In the model of a vertical type differentiation associated with heterogeneity in time flexibility, in addition to the discrete-location type differentiation and given the frequency asymmetry that the flights of the airline, carrying more time sensitive passenger type is higher than its rival's, a unique frequency equilibrium exists under symmetric locations.

Proposition 6.4. The airline, carrying more time sensitive passenger type responds an increase in its flight frequency while its rival decreases to an increase in vertical differentiation under symmetric locations.

Using the equilibrium flight frequencies, the traffic volumes in each passenger type are also found when the level of asymmetry between time flexibilities of each type is given under symmetric locations. Airline *A* carries the passengers of its own market as well as its competitor's passengers who are so time-sensitive not to catch the activities by taking the flights of airline *B* while it is possible by taking the flights of airline *A*. On the other hand, airline *B* carries its own market passengers whose inter-activity times are long enough to take its own flights. Hence, in general, the demand of first type passengers is equal to η_A^1 while the second type demand is η_A^2 and $\eta_A^2 > \eta_A^1$ when $\bar{s}_1 > \bar{s}_2$. With $n_A > n_B$, the result $X_A > X_B$ follows immediately, so that the total demand for the flights of airline *A* is more than the demand for those of airline *B*, which is shown in Figure 6-2.

To compare fares across airline *A* and *B*, equilibrium flight frequencies and traffic levels are used. With the same parameter set, the equilibrium fares are illustrated in Figure 6-3. With $X_A > X_B$, the result $p_B > p_A$

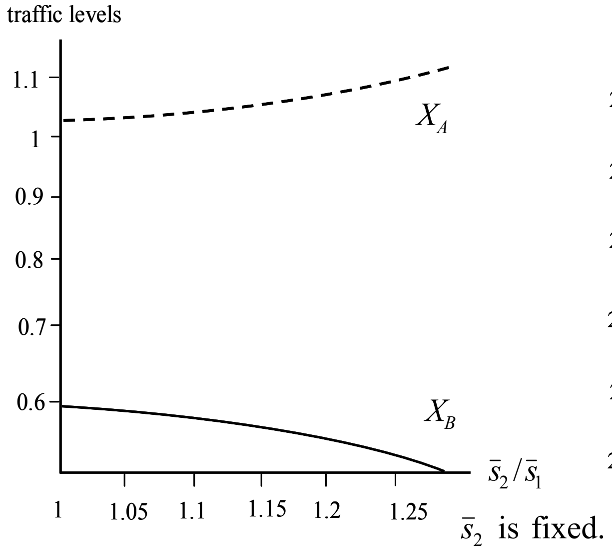

Figure 6-2 Traffic volumes

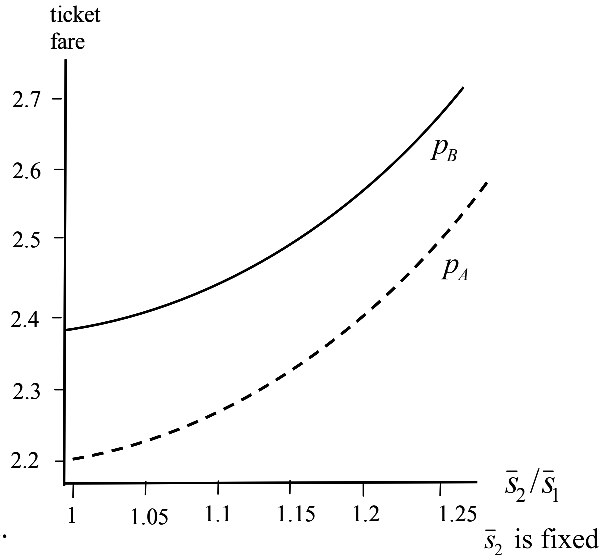

Figure 6-3 Ticket fares

follows, so that the fare, set for the market of more time sensitive first type passengers is lower than the fare, set for the other type because airline A sells to the larger number of passengers. Note that this result is not obtained in the conventional Hotelling-linear city location model which predicts the store with higher market shares sells at a higher price. The comparison that focuses on the level of fares results in

Proposition 6.5. The ticket fare of the airline that offers more frequency is lower than that charged by its rival as a result of the increase in the demand from its rival's market under symmetric locations.

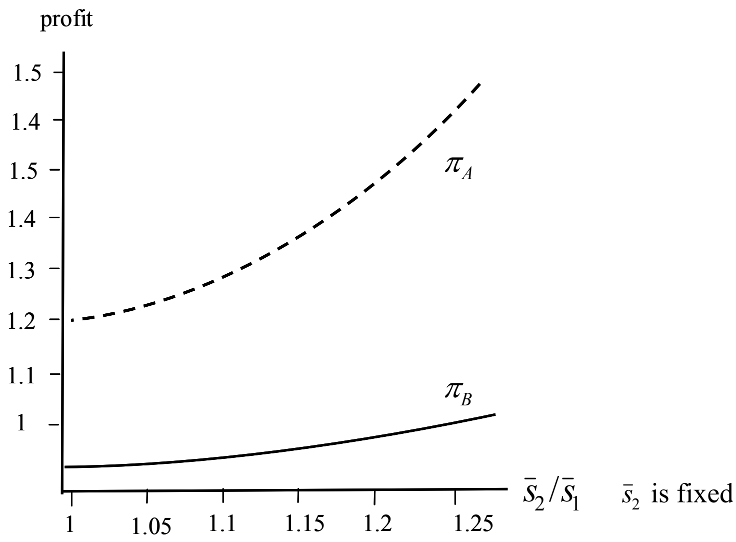

Figure 6-4 Profit levels

After solving the equilibrium frequency and ticket fares, the profit levels of both carriers are analyzed. As airline *A* carries the passengers of its own market as well as its competitor's passengers whose inter-activity times are so short to catch the activities by taking the flights of airline *B* while long enough by taking the flights of airline *A* so airline A, carrying a larger number of passengers makes higher profit than despite charging lower prices. The results of the same example for the profit levels are illustrated in Figure 6-4.

6.4 Conclusion

This chapter has provided a simple analysis of the effects of the variety in passengers' time flexibilities on the airlines' frequency and price choices when two incumbents are competing for two groups of passengers. We use the discrete location type of horizontal differentiation where two types of potential passengers are characterized by their location that corresponds to their ideal brand in their trip choices when they are traveling from one city to another in a market. In the model, to determine the relation between flight frequency and time flexibility of potential passengers and find the market thickness, associated with frequency level, we utilize the external demand expression, composed of inter-activity time and rescheduling time. By this way, we introduce the possibility of another differentiation that causes heterogeneity in the frequency levels. The two types of differentiation associated respectively, with heterogeneity in brands and flight frequencies are different. In the former type differentiation, the level of brands is exogenously given while in the latter one, the level of frequencies are found as a two-stage game where the carriers simultaneously choose the flight frequencies and then compete in ticket prices.

The analysis shows that the flight frequency of the airline, carrying more time sensitive passenger type is higher than its rival's under symmetric locations if two types of potential passengers are differentiated with respect to their preferences for brands as well as their time flexibilities. Additionally, the airline, carrying more time sensitive passenger type responds an increase in its flight frequency while its rival decreases to an increase in the heterogeneity of time-flexibilities, implying that the airlines prefer to move away from each other's market in order to soften price competition. Additionally, the ticket fare of the airline that offers more frequency is lower than that charged by its rival under symmetric locations.

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7 FREQUENCY AND AIRFARE COMPETITION BETWEEN INCUMBENT AND ENTRANT

7.1 Introduction

The research that analyze the impacts of the entry of smaller carriers into aviation market show enough econometric evidence indicating that not only on routes they operate but also on routes other carriers operate at the same airport, fares are decreasing and frequency and traffic levels are increasing. The research includes Cohas, Belobaba, and Robert (1995), Dresner, Lin, and Windle (1996), U.S. DOT (1996), Windle and Dresner (1999) and (Volwes 2001). According to the US DOT (1996), the principal and fundamental advantage of these carriers over larger, established network airlines is their lower unit operating costs. However, in Gillen and Lall (2004), firstly, the choice of business model is identified as the source of competitive advantage and then the operational efficiency as a complementary to this choice is pointed out. According to Takebayashi and Kanafani (2005), the principal and fundamental advantages of these carriers over larger, established network airlines are the reduction of operational costs and the improvement of performance when entering the airport.

7.1.1 Models of Vertical Differentiation

This research aims to offer an explanation for how regional carriers can enter into the aviation market and survive. We analyze equilibrium solutions in a duopoly market in which a traditional and regional carrier sell products of different qualities while the former is the high quality firm. It is assumed that both carriers compete in a city-pair market for two types of consumers who are differentiated with respect to their preference for the quality. In addition, we introduce the possibility that both passenger types have different time-flexibility and then, offer a complete characterization of flight frequency and ticket price choices in a duopoly model where the carriers simultaneously choose the flight frequencies and then compete in ticket prices. In doing so, we suppose that the degree of product differentiation and passengers' heterogeneity in quality preferences are given.

After considering the accommodating equilibria case where the high quality traditional carrier finds profitable to allow the entrance of the regional carrier, offering lower quality services, we analyze the entry deterrence case in which the incumbent airline firm develops some strategic actions when he faced with a threat of entry into the market. Finally, we define the conditions to enter the market and draw the boundary between the entry accommodating and deterrence cases. By showing the possibility of entry for a regional carrier into a city-pair market, we offer an explanation for how a number of airlines such as Southwest Airlines, Ryanair and Skymark have succeeded to enter and survive in the market.

To enroll the vertical differentiation associated with scheduling between both passenger types into the model, equilibrium solutions are held on for different cases in which the time flexibility of passenger types is varied. Under the first case, it is assumed that time flexibility of high and low type passengers are the same so the price and frequency equilibrium solutions are found as dependant only on the degree of product differentiation in quality. However, under the other cases where asymmetric time flexibility between passengers is assumed, the equilibrium flight frequencies and ticket prices are affected not only from the degree of quality differentiation but also the level of asymmetry in schedules. The less the time flexibility of the potential passengers is, the more the flight frequency the airline firm offers. Hence, in the model, the airline that carries the more time sensitive passengers tries to increase its own flight frequency not to withdraw its services while the other airline decreases. This change in frequency levels is similar to the result of maximal differentiation in duopoly. When the heterogeneity between the consumers increases, airline firms offer different levels of frequency in order to move away from each other's position and soften the price competition.

If a situation in which more time sensitive potential passengers have no willingness to pay more for extra quality is considered, due to the increase in vertical differentiation the entry of a regional carrier becomes easier. The respond of the airline firm, carrying more time sensitive passenger type for the increase in the asymmetry of time flexibility is increasing the number of flights while the respond of the other, carrying less sensitive one is decreasing the frequency. Therefore, as much as the entrant has enough capital to offer more frequent flights, he can succeed to survive in the market. This case is related with the tendency of the traditional business travelers to change flights from high fare-high restriction traditional carriers toward either less travel overall or lower cost carriers, stated in Rhoades (2003).

In the model, the problem of quality choice of airline firms is not considered. Wauthy (1996) analyzes quality choice of prices as well as prices. The impact of product differentiation as well as passengers' heterogeneity in quality on the competition between the traditional and regional carrier are pointed out. The level of vertical differentiation related with the quality is a kind of threshold in entering the market so we define the boundary between entry accommodating and deterrence cases, conditional on quality differentiation. On the other hand, uncovered market configuration, arising at the price equilibrium is also not held in the model. The case of inelastic demand with respect to prices is assumed under the entry accommodating equilibria while the case of preempted market is investigated in defining the entry deterrence conditions.

This chapter is organized as follows: Section 2 presents the assumptions and the set-up of a duopoly market model in which two carriers sell products of different qualities to two types of consumers, differentiated with respect to their preference for the quality and time flexibility. In Section 3, firstly symmetric equilibrium, later asymmetric equilibrium solutions are analyzed by changing the levels of time flexibility of passenger types. To check the stability of equilibria, entry deterrence conditions are scrutinized in Section 4 and concluding remarks follow in Section 5.

7.2 The Model

We model the behavior of passengers who are traveling from one city to another in a market. We assume that there are two types of potential passengers who are differentiated with respect to their preference for the quality. These are a high type and a low type with the former valuing a given quality more than the latter. This difference is taken into account by a parameter $\delta \in \{\underline{\delta}, \overline{\delta}\}, \overline{\delta} \geq \underline{\delta} > 0$. The measure of two types of passengers is equal. We assume that each type involves *M* passengers.

In the market, there are two carriers that can provide air services between these cities, a national carrier and a regional one. We consider that the national one is the incumbent and the regional one is the new entrant. The carriers are also differentiated in terms of quality. For the sake of simplicity, we suppose that the quality level, offered by the incumbent is more than the level, offered by the entrant. That is $\overline{u} > \underline{u}$ in which $\overline{u}$ and $\underline{u}$ denote the quality level of the incumbent and the entrant, respectively.

7.2.1 Assumptions

In the model, it is assumed that each airline company offers flights that are available round-the-clock (24hours) and each potential passenger has a start time of the activity in the destination city. As the ticket fare is chosen as a strategic variable in the duopoly market of the airlines, each airline tries to capture the passengers from two differentiated markets by setting his price. On the other hand, uncovered market configuration, arising from the price competition is also not taken into consideration in the model. The case of inelastic demand with respect to prices is assumed. However, whether the consumer takes one of the flights of the airline depends on her schedule. Each consumer travels if only she has enough time to take a flight, originating after her previous scheduled activity ends and terminating before her next scheduled activity starts. Hence, only the consumers whose inter-activity times are long enough take trips while others cancel so flight scheduling also affects the demand for each airline. In the model, we try to capture this impact with an external expression that incorporates the frequency of each airline. The formulation of the external expression is the same as that in Yetiskul et al (2005).

Assuming that the characteristics of the potential passengers of each type, related with scheduling is similar, we firstly clarify high quality passengers then extend to the other type. Each potential passenger of the high quality type has a scheduled activity in the destination city and for each consumer; there is a start time for her activity, denoted by θ. Assuming that the number of potential passengers whose activity start times are distributed continuously and uniformly in a circular time interval $[0,2\pi]$ is equal to M, we address the potential passengers of the high quality in the time interval $[0,2\pi]$ where the end joins to the beginning.

The potential passenger who has a specific activity start time in the destination city has to complete another activity in the origin city before taking the trip. Assuming that the time duration of the activities is equal to zero, we suppose that the potential passenger can not leave the origin city before the time $\theta_O=\theta-s$. Here, s denotes the time interval from the activity before leaving the origin city until after arriving in the destination city, for a consumer. Hereafter, s is called as "inter-activity time" which can be also defined as the possible time to take a flight. We assume that inter-activity times of the high quality type passengers are consumer specific times and distributed uniformly and continuously in an interval $[0,\bar{s}]$. If there is a consumer whose inter-activity time is short enough to arrive in the destination city, it is supposed that his priority is to complete the activity in the origin city so the trip to the destination city is cancelled.

On the other hand, the characteristics of the potential passengers of the low quality type are similar to those of the high type. The low quality type potential passengers who have scheduled activities in the destination city are also addressed in the same circular time interval $[0,2\pi]$ according to their activity start times, denoted by θ'. Each potential passenger can not take a flight before the time $\theta'_O = \theta' - s'$. Like s, s' denotes the time interval from the activity before leaving the origin city until after arriving in the destination city, for a low type consumer. The term s' is also consumer specific and has a uniform distribution with support $[0,\underline{s}]$. As noted above, in the case that there is no enough time to arrive in the destination city after the activity in the origin city ends, we assume that the priority of the consumer is the activity in the origin city so the trip is cancelled. Additionally, the inter-activity times of each group passengers are independent.

7.2.2 Passengers

In the city-pair market the incumbent offers consumers $\overline{n}$ flights while the entrant offers $\underline{n}$ flights. Recalling that each airline company offers flights that are available round-the-clock, the flights of each airline arrive in the destination city in the time interval [$0,2\pi$] and we suppose that there is no restriction in the capacity of aircrafts. The flights of the incumbent is indexed by i and $t(\overline{n}) = (t_1, ..., t_{\overline{n}})$, denoting the set of arrival times of the flights i. On the other hand, the flights of the entrant is indexed by j and $t(\underline{n}) = (t_1, ..., t_{\underline{n}})$. The flights of each airline are spaced equally on the circular market. Hence, the headway for each airline is found endogenously from the division of the time length by the total number of flights offered by corresponding airline. Then, the arrival times of each flight, offered by the incumbent and entrant are

$$t_i = (i-1)\frac{2\pi}{\overline{n}} \qquad (i = 1,..., \overline{n}) , \tag{7-1a}$$

$$t_j = (j-1)\frac{2\pi}{\underline{n}} \qquad (j = 1,..., \underline{n}) . \tag{7-1b}$$

As noted in the previous section, in the model, the demand changes with respect to the frequencies are determined by characterizing the external expressions which are dependent on the heterogeneity in the inter-activity times of potential passengers. These expressions give the number of potential passengers who can take one of flights only if the flight originates at the city after her activity ends and terminates at the other city before next activity starts. As the time components of a passenger trip involves actual flight time, inter-activity time of each potential passenger has to be longer than the actual flight time. As both airlines offer services on the same route in the same city-pair market, we normalize actual trip time to a fixed value, zero for simplicity. Therefore, only frequency level is used in characterizing external demand expression.

To outline the role of flight frequency and inter-activity times of consumers and solve the effect of time flexibility on the market demand, we suppose a small group of high quality type potential passengers whose activity start time in the destination city is located in an infinitesimal interval [$\theta,\theta+d\theta$]. As the inter-activity times of consumers are distributed uniformly and continuously in $[0, \overline{s}]$, the number of the passengers for whom inter-activity time is sufficiently long to take the trip after the activity in the origin city ends and before the activity in the destination city starts, can be expressed as

$$R(\theta)d\theta = \frac{\overline{s} - \theta}{\overline{s}} d\theta . \tag{7-2}$$

If the infinitesimal group, defined above, fly by the incumbent (due to taking more utility instead of flying by the entrant), the demand of high quality type potential passengers for one flight of the incumbent can be identified by focusing on all infinitesimal groups that are addressed in the interval $[0, 2\pi/\overline{n}]$ because the distribution of θ is uniform and continuous and the headway is equal to $2\pi/\overline{n}$. Then (7-2) is the same for each group and the patronage of one flight of the incumbent in the case that the incumbent sets a ticket price that is low enough to carry only high type passengers can be calculated by the integral of small changes in $d\theta$ over the time scale from 0 to $2\pi/\overline{n}$. Thus, it is

$$\frac{1}{2\pi}\int_0^{\frac{2\pi}{\overline{n}}} R(\theta)d\theta = \frac{1}{\overline{n}} - \frac{\pi}{\overline{s}\,\overline{n}^2} . \qquad (7\text{-}3)$$

As each interval $[(i-1)2\pi/\overline{n}, i2\pi/\overline{n}]$, $(i = 1,.....,\overline{n})$, that is located sequentially along the circular time scale from *0* to *2π*, defines one headway for the incumbent, the patronage of all flights of the incumbent, scheduled between *0* to *2π* can be found when the incumbent carries only high quality type passengers. The probability of the high type potential passengers whose activity start times in the destination city are located in one of the intervals and whose inter-activity time are long enough to take the flights of the incumbent is the same as the probability, given in (7-3). Then, aggregating the probabilities for all sequential intervals yields

$$P(\overline{n}, \overline{s}) = \frac{\overline{s} - \pi/\overline{n}}{\overline{s}} . \qquad (7\text{-}4)$$

This is key demand expression that gives the patronage of the flights of the incumbent when it sets a ticket price which is low enough to carry only high type passengers. The expression, $\pi/\overline{n}$ in the equation (7-4) shows the average schedule delay time of the high type passengers in case that they fly by the incumbent. On the other hand, if they fly by the entrant, their average schedule delay is equal to $\pi/\underline{n}$. As the same way, average schedule delay times of the low type can be written.

While $\overline{\eta}_H = P(\overline{n}, \overline{s})M$ gives the incumbent's traffic in the market of high type of passengers when its frequency is $\overline{n}$ and if high type passengers take the flights of the incumbent, the traffic for the same flights can be expressed as $\overline{\eta}_L = \frac{\underline{s} - \pi/\overline{n}}{\underline{s}} M$ if low type fly by the incumbent. Considering the similarities between the characteristics of high and low type and the incumbent and the entrant, $\underline{\eta}_H$ and $\underline{\eta}_L$ are also written for the entrant's traffic level.

In addition to activity start times of each type over $[0, 2\pi]$, given the inter-activity times of high and low type potential passengers over $[0, \overline{s}]$ and $[0, \underline{s}]$, respectively, we consider the case of elastic demand, arising from rescheduling times of passengers. Finally, to investigate the equilibrium frequency and price choices of the airlines, the utility functions of the high and low type passengers are given by

$$\overline{V} = \begin{cases} \overline{\delta}\overline{u} - \overline{p} & \text{flying with incumbent if } \pi/\overline{n} \le s \text{ is satistied} \\ \overline{\delta}\underline{u} - \underline{p} & \text{flying with entrant if } \pi/\underline{n} \le s \text{ is satistied} \\ -\infty & \text{otherwise} \end{cases} \qquad (7\text{-}5a)$$

$$\underline{V} = \begin{cases} \underline{\delta}\overline{u} - \overline{p} & \text{flying with incumbent if } \pi/\overline{n} \le s' \text{ is satistied} \\ \underline{\delta}\underline{u} - \underline{p} & \text{flying with entrant if } \pi/\underline{n} \le s' \text{ is satistied} \\ -\infty & \text{otherwise} \end{cases} \qquad (7\text{-}5b)$$

where $\overline{p}$ and $\underline{p}$ denotes the ticket fare, set by the incumbent and the entrant, respectively.

7.3 Airline Firms and Market Equilibrium

Airline's fixed cost involves maintenance cost, landing fee and services provided to the aircraft while it is on the ground as well as salaries of the flight crew. *d* denotes the fixed cost per flight on one connection between two cities. In the model we don't distinguish airline fixed cost between two airline companies.

In characterizing the equilibrium solutions for both airlines, we suppose that the quality levels are exogenously given so frequency levels are endogenous. To find tractable solutions, it is assumed that the incumbent offers a quality level which is equal to the parameter of high type passengers while the entrant offers a level, equal to the parameter of low type. In a model where firms produce at zero cost a good of the quality, suggesting maximum product differentiation is sensible. Tirole (1988) assumes that firms cover the market and shows that firms maximize product differentiation over the available range of qualities. Hence, we fix $\overline{u} = \overline{\delta}$ and $\underline{u} = \underline{\delta}$. To this end, we consider a two-stage game where the frequency levels are simultaneously chosen first and then prices are set simultaneously. In this type of game, it is assumed that the frequency decision is less flexible than the price decision.

To find equilibrium prices, we use "No mill-price Undercutting" conjectures that an airline in general sets its own price taking the price of the other airline as given, but he expects the rival to match price cuts that would, if unmatched, drive the rival out of business because there is no Nash equilibrium in pure price-strategies for the differentiated products. Shy (2001) also looks for an Undercut-proof equilibrium in airfares competition in airline industry.

In the Undercut-Proof Equilibrium, if the entrant sets a ticket price that undercuts the ticket price set by the incumbent and captures both markets, it has to set the price as $\underline{p} = \overline{p} - \overline{\delta}^2 + \overline{\delta}\,\underline{\delta}$. This is a value that compensates the passengers with high quality preference for traveling by the low quality service. On the other hand, the incumbent also sets a price that is low enough to travel for both types of passengers. Hence, this equilibrium is the pair of prices ($\overline{p}^*, \underline{p}^*$) that satisfies the followings:

iii) The incumbent chooses the highest ticket price subject to

$$\underline{\Pi}^* = \underline{X}\,\underline{p}^* - \underline{n}d \geq (\underline{\eta}_H + \underline{\eta}_L)(\overline{p} - \overline{\delta}^2 + \underline{\delta}\,\overline{\delta}) - \underline{n}d \ , \tag{7-6a}$$

iv) The entrant chooses the highest ticket price subject to

$$\overline{\Pi}^* = \overline{X}\,\overline{p}^* - \overline{n}\,d \geq (\overline{\eta}_H + \overline{\eta}_L)(\underline{p} - \underline{\delta}^2 + \underline{\delta}\,\overline{\delta}) - \overline{n}\,d \tag{7-6b}$$

where $\overline{X}$ and $\underline{X}$ denote the number of passengers, taking the flights, offered by the incumbent and entrant, respectively. The first condition implies that the incumbent sets the highest ticket price that prevents the entrant from undercutting its price $\overline{p}$ and captures both types of passengers while the second one implies that the entrant sets the ticket price as high enough to prevent the incumbent from undercutting its price $\underline{p}$ and serves for both markets.

7.3.1 Symmetric Equilibria

In addition to quality parameters of high and low type passengers, given the same parameters for the quality levels of vertically differentiated two airlines, we analyze the frequency and price decisions of both as the outcome of a two-stage game. As the solution is derived backwards, we calculate firstly the equilibrium prices and secondly the frequency levels. To analyze the solutions and capture the effects of scheduling, the results are held on for two cases in which we change the assumptions about the frequency equilibrium.

Under the first case, symmetry with respect to the equilibrium is introduced while asymmetry is carried out under the second case. The condition is that the frequency equilibrium is symmetric, i.e., both airlines operate the same number of departures in the time interval [*0,2π*] in equilibrium. However, this condition can be achieved only when there is asymmetry between the intervals of the interactivity times of each passenger type because of the vertical differentiation. Assuming that the potential passengers with low quality preference has less time flexibility than those with high quality preference and the interactivity times of low type is distributed in a shorter interval, $\underline{s} < \overline{s}$ results in symmetric frequency equilibrium. In the equilibrium, we search the equilibrium prices in the case that high type passengers take the flights of the incumbent while low type passengers travel by the flights of the entrant. Hence, the demand for each airline with given symmetric frequency equilibrium can be expressed as:

$$\overline{X} = \begin{cases} 0 & \text{if} \quad \overline{p} > \underline{p} + \overline{\delta}^2 - \overline{\delta}\underline{\delta} \\ \overline{\eta}_H & \text{if} \quad \underline{p} - \underline{\delta}^2 + \overline{\delta}\underline{\delta} \le \overline{p} \le \underline{p} + \overline{\delta}^2 - \overline{\delta}\underline{\delta}, \\ \overline{\eta}_H + \underline{\eta}_L & \text{if} \quad \overline{p} < \underline{p} - \underline{\delta}^2 + \overline{\delta}\underline{\delta} \end{cases} \tag{7-7a}$$

$$\underline{X} = \begin{cases} 0 & \text{if} \quad \underline{p} > \overline{p} + \underline{\delta}^2 - \underline{\delta}\overline{\delta} \\ \underline{\eta}_L & \text{if} \quad \overline{p} - \overline{\delta}^2 + \underline{\delta}\overline{\delta} \le \underline{p} \le \overline{p} + \underline{\delta}^2 - \underline{\delta}\overline{\delta} \\ \underline{\eta}_H + \underline{\eta}_L & \text{if} \quad \underline{p} < \overline{p} - \overline{\delta}^2 + \underline{\delta}\overline{\delta} \end{cases} \tag{7-7b}$$

Solving (7-6a) with $\overline{X}$ and $\underline{X}$ for the incumbent's price and (7-6b) for the entrant's price and substituting one of which to the other yields the equilibrium ticket prices. The symmetric frequency equilibria results in the equality between the demand levels of each group for both airlines, i.e., $\overline{\eta}_H = \underline{\eta}_H$ and $\overline{\eta}_L = \underline{\eta}_L$. Letting the former and latter equality be denoted as η_H and η_L, respectively, the symmetric competition yields the following equilibrium ticket prices,

$$\overline{p}^* = \frac{(\eta_H + \eta_L)(\overline{\delta} - \underline{\delta})((\overline{\delta} - \underline{\delta})\eta_L + \overline{\delta}\eta_H)}{\eta_H^2 + \eta_H\eta_L + \eta_L^2} \tag{7-8a}$$

$$\underline{p}^* = \frac{(\eta_H + \eta_L)(\overline{\delta} - \underline{\delta})((\overline{\delta} - \underline{\delta})\eta_H - \underline{\delta}\eta_L)}{\eta_H^2 + \eta_H\eta_L + \eta_L^2} \tag{7-8b}$$

After finding the equilibrium prices, substituting them into (7-6a) and (7-6b), we get $\overline{X} = \eta_H$ and $\underline{X} = \eta_L$. As the optimum ticket price of an airline is conditional on not only its own frequency level but also its rival's, the profit function is also conditional on both flight frequencies. Taking first order conditions of each profit function with respect to its own frequency level yields the followings:

$$\frac{\partial\overline{\Pi}}{\partial\overline{n}} = \frac{\partial\overline{\eta}_H}{\partial\overline{n}}\overline{p}^* + \overline{\eta}_H\frac{\partial\overline{p}^*}{\partial\overline{n}} - d = 0 \tag{7-9a}$$

$$\frac{\partial \Pi}{\partial \underline{n}} = \frac{\partial \underline{\eta}_L}{\partial \underline{n}} \underline{p}^* + \underline{\eta}_L \frac{\partial \underline{p}^*}{\partial \underline{n}} - d = 0 \qquad (7\text{-}9b)$$

Both first order conditions are solved by writing best response functions of frequency levels. Solving them yields the equilibrium frequency levels, $\overline{n}^*$ and $\underline{n}^*$ in differentiated flight services. After substituting them into (7-8a) and (7-8b), the equilibrium prices are also found.

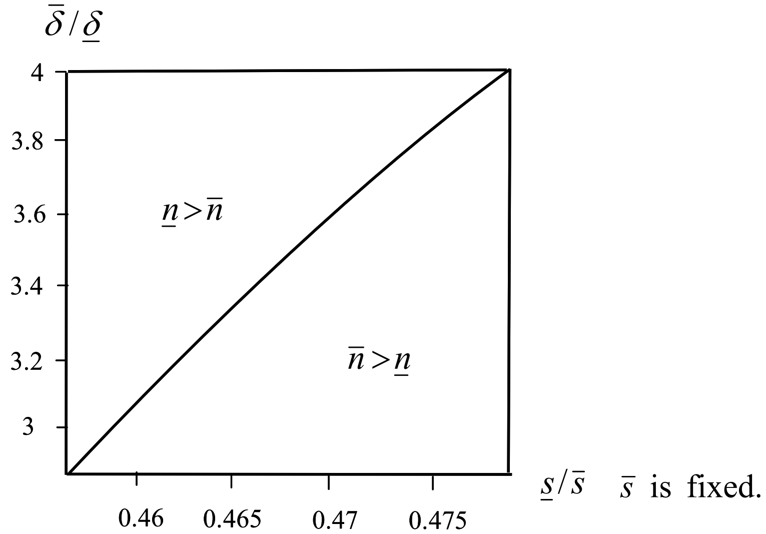

Figure 7-1 The condition of symmetric frequency equilibrium

Proposition 7.1. Under given symmetric frequency equilibrium, there exists a frequency and price equilibrium for the vertically differentiated discrete duopoly market where the airlines offer differentiated brand services and passengers are brand oriented if time flexibility of low type passengers is lower enough than the flexibility of high type passengers.

In order to specify the condition of symmetric frequency equilibria where both airlines operate the same number of flights in the time interval [*0,2π*], a numerical example is specified. Given a set of parameters as *M=1*, $\underline{\delta} = 1$, *d=0.1* and $\overline{s} = \pi / 2$ and varying the parameter of the high type passengers, we solve (7-9a) and (7-9b) and illustrate the boundary that delimitates the regions where the equilibrium frequencies are asymmetric in Figure 7.1 so the boundary line shows the conditions of symmetric frequency equilibrium.

7.3.2 Asymmetric Equilibria

The above analysis focuses on symmetric equilibria, where both airlines operate the same number of flights in equilibrium when the condition that the time flexibility of the low type passengers are lower enough than that of the high type is satisfied. Under the assumption of asymmetric frequency equilibria where an airline operates more flights than its competitor, two-stage game equilibrium solutions are found for two different cases. One of them is the case of $\overline{n} > \underline{n}$ while the other is the case of $\underline{n} > \overline{n}$. Even though the satisfaction of the condition that the interactivity times of high type passengers is distributed in a shorter interval than those of low type passengers is enough for the first case, the condition that the situation is reversed is not enough for the second case. The interactivity times of the low type has to be shorter enough than those of the high type because of the given vertical differentiation between passenger types. If the latter case that the entrant offers more frequency than the incumbent is considered, the demand for each airline can be expressed as:

$$\overline{X} = \begin{cases} 0 & \text{if} \quad \overline{p} > \underline{p} + \overline{\delta}^2 - \overline{\delta}\underline{\delta} \\ \overline{\eta}_H & \text{if} \quad \underline{p} - \underline{\delta}^2 + \overline{\delta}\underline{\delta} \le \overline{p} \le \underline{p} + \overline{\delta}^2 - \overline{\delta}\underline{\delta}\,, \\ \overline{\eta}_H + \underline{\eta}_L & \text{if} \quad \overline{p} < \underline{p} - \underline{\delta}^2 + \overline{\delta}\underline{\delta} \end{cases} \tag{7-10a}$$

$$\underline{X} = \begin{cases} \left(\underline{\eta}_L - \overline{\eta}_L\right) + \left(\underline{\eta}_H - \overline{\eta}_H\right) & \text{if} \quad \underline{p} > \overline{p} + \underline{\delta}^2 - \underline{\delta}\overline{\delta} \\ \underline{\eta}_L + \left(\underline{\eta}_H - \overline{\eta}_H\right) & \text{if} \quad \overline{p} - \overline{\delta}^2 + \underline{\delta}\overline{\delta} \le \underline{p} \le \overline{p} + \underline{\delta}^2 - \underline{\delta}\overline{\delta} \\ \underline{\eta}_H + \underline{\eta}_L & \text{if} \quad \underline{p} < \overline{p} - \overline{\delta}^2 + \underline{\delta}\overline{\delta} \end{cases} \tag{7-10b}$$

The demand functions of both duopoly airlines have the same forms as those in (7-7a) and (7-7b) except for demand levels (7-10b) that arises from the difference between frequencies. As the case of $\underline{n} > \overline{n}$ is considered and if the prices satisfy the conditions in the middle lines of the demand functions, the entrant, operating more flights, captures a group of the high type passengers whose inter-activity times are short to satisfy the condition $s \ge \pi / \overline{n}$ for taking one of the flights of the incumbent while long enough to satisfy the condition $s \ge \pi / \underline{n}$. When $\underline{n} = \overline{n}$, the forms of the two demand functions are the same as in symmetric equilibria. Solving (7-10a) for the incumbent's price and (7-10b) for the entrant's price yields the second-stage equilibrium prices. After finding the equilibrium prices, taking first order conditions of each profit function with respect to its own frequency level and solving them give the asymmetric equilibrium frequencies.

In order to investigate two-stage game equilibrium solutions, ($\overline{n}^*, \underline{n}^*$) and ($\overline{p}^*, \underline{p}^*$) under the asymmetry case where an airline operates more frequency than its competitor, two numerical examples are specified with the same set of parameters as $M=1$, $\overline{\delta} / \underline{\delta} = 3$ and $d=0.1$. In the first example, the case of $\overline{n} > \underline{n}$ is assumed and given a distribution of the inter-activity times of the low type passengers in an interval $[0, \pi / 2]$ and varying the maximum value of the interactivity time interval for the high type, we solve

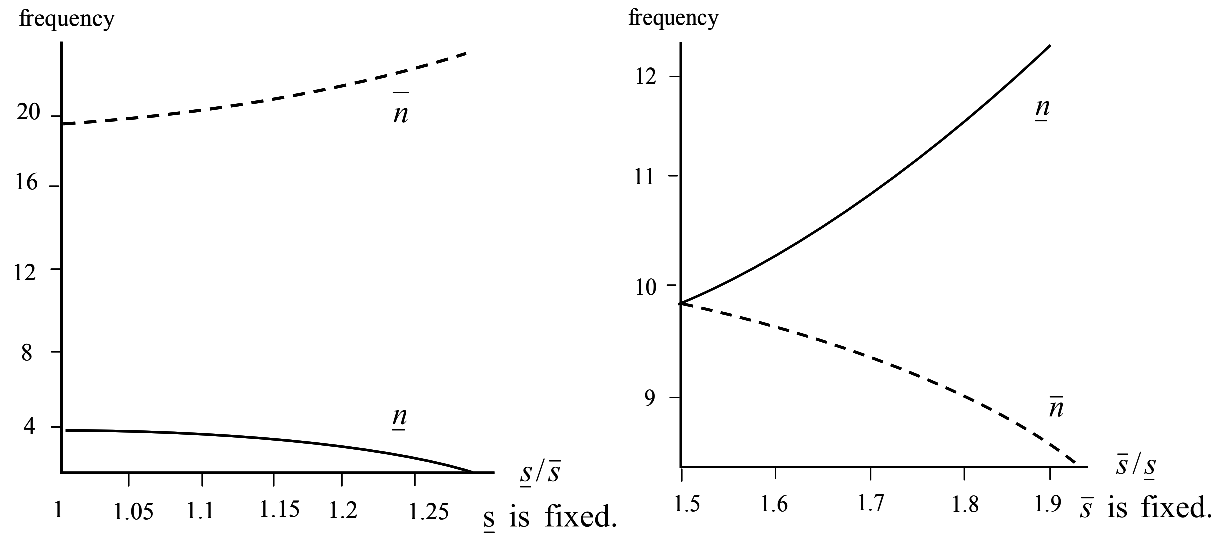

Figure 7-2 Frequencies under asymmetric equilibria

equilibrium frequencies and illustrate them in the left hand side graph of Figure 7.2 where the upper and lower lines show the equilibrium frequencies of the incumbent and entrant, respectively. In the second example that the case of $\underline{n} > \overline{n}$ is assumed and the situation of the time flexibilities of the passenger types is reversed, equilibrium frequencies are found and shown in the right hand side graph of Figure 7.2 where the positions of lines are reversed, implying that the entrant can be a low-quality, more frequent airline in a vertically differentiated market. In both cases, the airline, carrying more time sensitive passenger type responds an increase in its flight frequency while its rival decreases to an increase in vertical differentiation between interactivity time values of two groups. As a result, this discussion has established the following result:

Proposition 7.2. The frequency of the airline, carrying more time sensitive passenger type is increasing while its rival's is decreasing when the heterogeneity between two types of potential passengers with respect to their time flexibility is increasing in a vertically differentiated duopoly market.

By showing that the possibility of $\underline{n} > \overline{n}$ under the case where potential passengers who have less time flexibility have also no preference for high quality, the model supports the observations and hypotheses about the business model choice as the source of competitive advantages of regional carriers when entering into the market.

7.4 Entry Deterrence

In order to check the stability of equilibrium solutions, without considering whether this strategy is profitable or not, we suppose the case that the incumbent charges a ticket price to deter the entrance of the low quality airline. Therefore, the incumbent has to hold the entrant's ticket price as equal to its per-passenger cost. That is a value of zero-profit level for the entrant, i.e. $\dfrac{\underline{n}d}{\underline{\eta}_H + \underline{\eta}_L}$.

Then, carrying out the strategy of entry deterrence, the incumbent faces the following maximization problem

$$\max_{\overline{p},\overline{n}} \overline{\Pi}_d\left(\overline{p}_d, \overline{n}_d\right) = \left(\overline{\eta}_H + \overline{\eta}_L\right)\overline{p}_d - \overline{n}_d d. \tag{7-11}$$

subject to

$$\overline{\delta}\underline{\delta} - \overline{p}_d \geq \underline{\delta}\underline{\delta} - \frac{\underline{n}d}{\underline{\eta}_H + \underline{\eta}_L}.$$

Solving the only binding constraint for the incumbent's entry deterrence ticket price yields the solution,

$$\overline{p}_d^* = \underline{\delta}\left(\overline{\delta} - \underline{\delta}\right) + \frac{\underline{n}d}{\underline{\eta}_H + \underline{\eta}_L} \tag{7-12}$$

Equation (7-12) displays the highest price, charged by the incumbent to serve both markets and deter the entrance of the lower quality airline. Substituting the entry deterrence price into the profit function of the incumbent and taking the first derivative with respect to its own frequency gives the optimal $\overline{n}_d^*$ as

$$\overline{n}_d^* = \sqrt{\frac{M\pi \overline{p}_d^* \left(\overline{s} + \underline{s}\right)}{d\left(\overline{s}\underline{s}\right)}} \,. \tag{7-13}$$

As seen from (7-13), the frequency choice of the incumbent is conditional on the entrant's frequency choice. For that moment, it is assumed that the incumbent chooses the profit-maximization frequency given the equilibrium frequency, $\underline{n}^*$ chosen by the entrant under entry accommodating equilibria. The reason of this behavior is the threat of entry. Substituting $\underline{n}^*$ into (7-13), the profit level of the incumbent under entry deterrence case can be found.

In order to establish the boundary that delimitates the regions where the profit level of the incumbent under the entry deterrence case is higher than that under the entry accommodating one, we analyze the conditions under the two examples. As one of the goals of this chapter is to capture the impact of time-flexibility changes on the entry accommodating threshold, the boundaries determined by setting the equilibrium profit $\overline{\Pi} = \overline{\Pi}_d$ are compared. To point out the effects of product differentiation as well as passengers' heterogeneity in quality on the competition between carriers, it is better to show the relations between the ratio of two type parameters, $\overline{\delta} / \underline{\delta}$ and the fixed cost, *d*.

Varying the time-flexibility of low type passengers, the boundaries between the entry accommodating and deterrence case are illustrated in Figure 7-4 where both lines refer to the cases that the interactivity times of low type passengers are lower than those of high type under given asymmetry. It can be seen from the diagram that entry into the market becomes easier when the ratio between both types is increasing and fixed cost is decreasing. If *d=0*, the condition for the entrance can be written as $\overline{\delta} / \underline{\delta} > 2$ under the first case where symmetric time flexibility between both types, which is the same as Wauthy's result (1996) that the incumbent supplies the entire market in equilibrium for $0 < \overline{\delta} \leq 2\underline{\delta}$ when provision of the quality is costless.

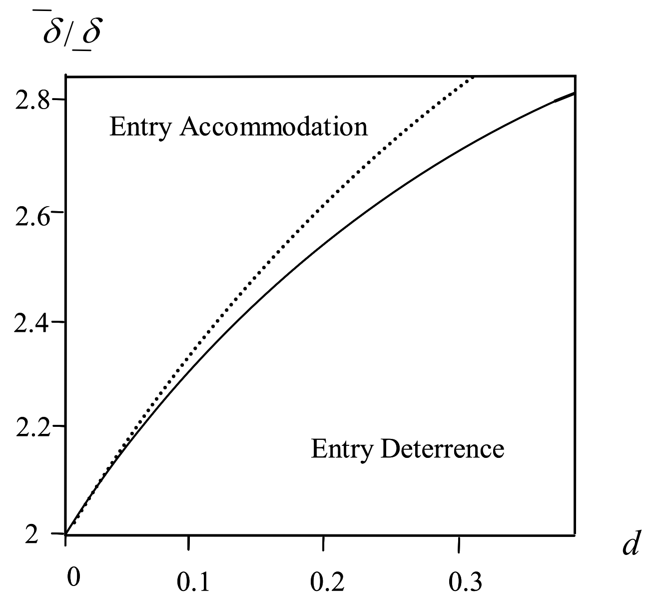

Figure 7-3 Entry accommodation and deterrence cases

While the dotted line shows the boundary line of a case where the parameters are given as $M=1$, $\bar{s} = \pi / 2$ and $\underline{s} = \pi / 2 * 0.65$, the solid one is the boundary of a case that $\underline{s}$ decreases to $\pi/2*0.6$ and $\bar{s}$ is the same as that under the first example.

The results about the entry accommodating conditions can be derived by inspection of Figure 7-4. If the potential passengers with low quality preference have less time flexibility while there is no change in the high type, the boundary curve steps down, implying that the entry into the market is easier for the low quality airline. This result is due to the increase in the heterogeneity between two passenger groups so the region that the incumbent finds the entry accommodating case more profitable than the entry deterrence case enlarges.

7.5 Conclusion

In this chapter, we investigate how regional carriers can enter into the aviation market and survive by formulating a vertical differentiation type model where two types of potential passengers are differentiated with respect to their preference for the quality and the high type values a given quality more than the low type. In the market, there are two carriers, providing differentiated air services between the cities in terms of quality. It is assumed that one of the carriers is incumbent and the other is entrant. To make realistic, we suppose that the quality level, offered by the incumbent is more than the level, offered by the entrant. Additionally, to determine the relation between flight frequency and time flexibility of potential passengers and find the market thickness, associated with frequency level, we utilize the external demand expression, incorporated with inter-activity times and rescheduling time when taking a trip decision. Assuming that the characteristics of the potential passengers of each type, related with scheduling is similar, we formulate the duopoly models. By this way, we introduce the possibility of another differentiation that causes heterogeneity in the frequency levels. The two types of differentiation associated respectively, with heterogeneity in quality levels and flight frequencies are different. In the former type differentiation, the level of qualities is exogenously given while in the latter one, the level of frequencies are found as a two-stage game where the carriers simultaneously choose the flight frequencies and then compete in ticket prices.

The analysis shows that under symmetric frequency equilibrium, the number of flights of both airlines increases when service qualities become highly differentiated and vertical differentiation with respect to time flexibilities of passenger groups decreases. If there is asymmetric frequency equilibrium, the airline, carrying more time sensitive passenger type responds an increase in its flight frequency while its rival responds a decrease to an increase in heterogeneity between time flexibilities. If the entrant carries the passengers who have willingness to pay for more frequency while no willingness to pay for extra quality, the frequency level of the entrant can be higher than that of the incumbent. By showing this possibility, the model supports the observations and hypotheses about the business model choice of regional carriers as the source of competitive advantages when entering into the market. These results are realistic. Additionally, they suggest some essential features of entry accommodation and deterrence behavior of the incumbent. In the case that the entrant carries the passengers who have less time flexibility but have no high quality preference, the incumbent finds the entry accommodating case more profitable than the entry deterrence case when the passengers become busier due to the increase in heterogeneity.

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8 CONCLUSION

Trip and airline scheduling

In this PhD Dissertation, we formulate an external demand expression, composed of frequency level, set by airline and time flexibility of travelers to examine the case of elastic demand with respect to frequency so we study a spatial framework. This expression is formulated as follows. A potential passenger has a start time of the activity in the destination city which is the same as desired arrival time or most preferred departure times. Besides, each has also inter-activity time which equals to the interval from the end of the activity in the origin city to the desired arrival time so the passenger's choice for travel depends whether his inter-activity time is large enough to take a trip.

The time components of a trip can be listed as the time to access the airport, the time spent at the airport, the actual travel time and the time to travel from the destination airport to final destination and rescheduling time at the destination. The rescheduling or schedule delay time arises from the difference between the actual and preferred arrival times while the latter is the same as the activity start time in this model. As rescheduling time falls on average when the flight frequency increases, demand curve shifts outward with the increase in flight frequency. On the other hand, frequency is costly so the airline tries to maximize his profit by balancing the gains from carrying more passengers against higher fixed costs. Hence, utilizing from the external demand expression, related with time components, we model the airline market equilibrium as a case of monopoly and duopoly, respectively in two main sections.

Summary of monopoly case

In the case of the monopoly, network choice of the airline under the effect of scheduling is scrutinized. Chapter 4 provides a simple comparison analysis between two alternative networks, a hub-and-spoke and point-to-point one for a monopolist airline on the profit levels. In a HS network, the airline carries the passengers whose city of origin or destination is that hub city directly and the passengers of connecting trips indirectly by transferring at the hub city while in a PP one, the airline offers services by connecting each pair cities directly so in the latter, the actual flight time is same on each city-pair while in the former the duration of the trip is equal to two actual flight times for the connecting market. Hence, in the case of monopoly, time components of the trip include the actual travel time and rescheduling time. Both of them are related with the network configuration. Demand depends on the length of the inter-activity times of the potential passengers so a consumer takes one of the flights of the airline if only her inter-activity time is longer than the actual travel and rescheduling times. By this way, we focus on the effect of network structure on scheduling.

In Chapter 5, as trip demand in aviation market is for two-way trips and the possibility of a potential passenger to take a trip depends on her time schedule on both legs, the representative potential passenger of the model has two-inter activity times in addition to an activity start time. While one of the inter-activity times equals to the interval from the end of the activity in the origin city to the desired arrival time, the other one arises from the time beginning from the end of the activity in the destination city until the next activity in the origin city so a passenger's choice for a two-way trip depends on her inter-activity times on both legs of the trip, which means both of her inter-activity times are long enough to cover the actual travel and rescheduling times otherwise there is no trip.

In this research, the impact of scheduling is captured externally as observed above so the consumer utility function doesn't contain the costs borne by actual travel and rescheduling times. However, whether a potential passenger finds worthwhile to take the trip is found from the condition that the utility of taking a trip exceeds his income. In addition to consumer heterogeneity in the start times of the activities as well as inter-activity times, we assume that consumers differ in their gross utilities, derived from taking trips to the destination city. Hence, the fare policy of the airline affects the trip demand and we capture the demand elasticity with respect to price as a result of the heterogeneity in the gross utilities.

Results of monopoly case

The sections about the monopoly provide a simple analysis of the effects of network structure on the airline scheduling of a monopoly airline under two-way trip demand case and compare the advantages of a PP network with a HS one when serving under two-way demand and under one-way demand. These analyses shows that

i. The flight frequency is higher in the HS network than in the PP one while the fares for the direct and connecting markets of the HS are the same as that for the markets of the PP under the assumption that fixed as well as variable costs are same when operating both networks.

ii. As PP network requires not much operating costs when compared to the HS network and fixed costs on a route where PP service is available decreases with increasing flight frequency, which cannot be observed in the HS because of the congestion, fixed costs are distinguished between two alternative network types. Under the assumption that operating a route in a PP network is lower than in a HS network, the flight frequency is higher in the PP network than in the HS one while the ticket fares are the same in both networks.

iii. Economies of scale arise from economies of density and decreasing unit operating costs per passenger in HS network formations while economies of scale in PP formations arise from the increase in consumers' flexibility time as a result of an increase in flight frequency, which is called economies of frequency. The increase in the number of flights automatically causes an outward shift in demand curve, which is the source of positive feedback mechanism.

iv. The increase in the number of passengers gives an additional payoff to the airline under two-way trip demand because when a potential passenger considers taking a trip, she normally considers not only the outbound leg but also the return leg so increasing flight frequency in one day the airline makes return flight possible without a sleepover. Thus the impact of thick market externality works well under day return demand.

v. The social welfare solution in the comparison of frequency levels concludes that the monopolist sets a lower frequency than what would be socially optimal. Therefore, the traffic level under monopoly solution is lower than under social optimum solution so the choice of the profit maximizing monopolist toward the HS network under symmetric cost assumption causes inefficiency according to the social welfare. The level of inefficiency increases under two-way trip demand.

Summary of duopoly case

In the case of duopoly, we utilize two families of models of product differentiation: the location or Hotelling-type models of horizontal differentiation and models of vertical differentiation. It is defined the characteristic of vertical product differentiation model is that all consumers have the same ranking of the variants of a product while horizontal product differentiation model is that there is no such natural ranking of the variants. In other words, it can be said that two horizontally differentiated products exist in the market when both products have positive demand even though they are charged at the same price. On the other hand, if one product captures the whole market when both are supplied at the same price, they are vertically differentiated products.

In Chapter 6, we use the discrete location type of horizontal differentiation where two types of potential passengers are characterized by their location that corresponds to their ideal brand in their trip choices when they are traveling from one city to another in a market. Additionally, we assume that there are two carriers called airline A and B in the market and the first type passengers are brand A oriented while the second type is brand B oriented. In Chapter 7, we formulate a vertical differentiation type model where two types of potential passengers are differentiated with respect to their preference for the quality and the high type values a given quality more than the low type. In the market, there are two carriers, providing differentiated air services between the cities in terms of quality. It is assumed that one of the carriers is national and the other is regional. For the sake of simplicity, we suppose that the quality level, offered by the national is more than the level, offered by the regional. By utilizing from two families of models of product differentiation, we offer an explanation for how two major carriers can compete for the potential passengers who have no natural ranking for the variety while we investigate how regional carriers can enter into the aviation market and survive in Chapter 7 due to the passengers' heterogeneity, for instance variety of a products differs in quality.

In both duopoly models, to determine the relation between flight frequency and time flexibility of potential passengers and find the market thickness, associated with frequency level, we utilize the external demand expression, explained above. Assuming that the characteristics of the potential passengers of each type, related with scheduling is similar, we formulate the duopoly models. Additionally, we introduce the possibility of another differentiation that causes heterogeneity in the frequency levels, offered by the carriers. We are aware of the difference between two types of differentiation associated with heterogeneity in brands, quality, mentioned above and flight frequencies. While the former type differentiation is playing a secondary role, the latter one is playing the primary role for product differentiation in the models. Assuming that the brand, quality parameters of the airlines and the preference levels of the potential passengers are given in both models, we offer market equilibrium solutions for the flight frequency and ticket prices in the duopoly market where the carriers simultaneously choose the flight frequencies and then compete in ticket prices.

In both duopoly models, ticket fares are chosen as a strategic variable in the duopoly market of the airlines, each airline tries to capture the passengers from two differentiated markets by setting its price. However, uncovered market configuration, arising from the price competition is not considered in the models, implying that the case of inelastic demand with respect to prices. On the other hand, the market thickness, related with scheduling is captured by the external demand expressions.

Results of duopoly case

The sections about the duopoly provide frequency and airfare competition between the airlines. While the competition between two incumbents is analyzed in Chapter 6, the competition between an incumbent and an entrant and entry accommodation/ deterrence cases are examined in Chapter 7. These analyses shows that

i. There exists a unique frequency and price equilibrium for the problem where there is a vertical type differentiation associated with heterogeneity in time flexibility, in addition to the discrete-location type differentiation, arises from brand loyalty or vertical type differentiation, arises from quality with symmetric or asymmetric frequency equilibria assumption.

ii. Under symmetric time flexibilities, when two incumbents compete, they are charging the same prices as well as setting the same flight frequencies and their traffic volumes and profit levels are also same in the case of symmetric locations with given symmetric frequencies. When the incumbent competes with the entrant, there exists symmetric frequency equilibrium if time flexibility of low type passengers is lower enough than the flexibility of high type passengers. The incumbent, offering high quality services, charges higher ticket prices and earns a higher profit than the entrant, offering low quality services.

iii. Under symmetric time flexibilities, the equilibrium flight frequencies increases when brands or service levels become highly differentiated and when passengers become more time sensitive.

iv. Under asymmetry, the airline, carrying more time sensitive passenger type responds an increase in its flight frequency while its rival responds a decrease to an increase in heterogeneity between time flexibilities.

v. Under symmetric locations and asymmetric time flexibility with asymmetric frequency assumption, the ticket fare of the airline that offers more frequency is lower than that charged by its rival.

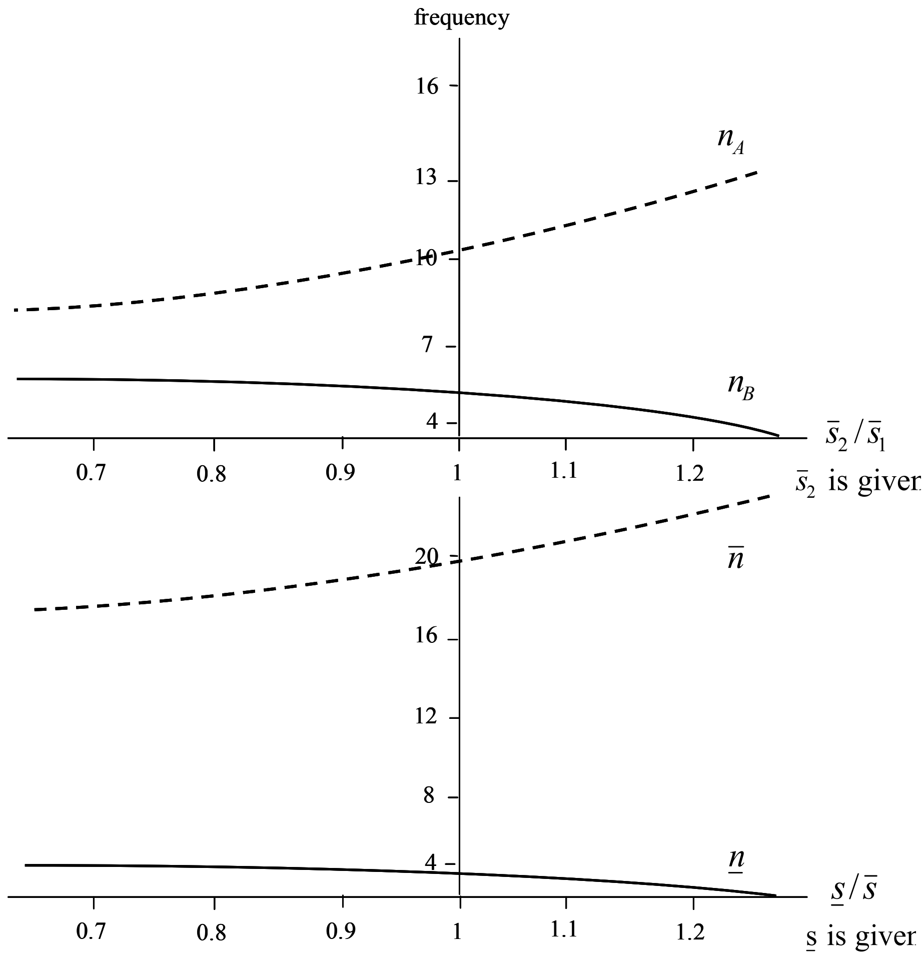

Figure 8-1 Frequencies under horizontal and vertical differentiation

vi. If the entrant carries the passengers who have willingness to pay for more frequency while no willingness to pay for extra quality, the frequency level of the entrant can be higher than that of the incumbent. By showing this possibility, the model supports the observations and hypotheses about the business model choice of regional carriers as the source of competitive advantages when entering into the market.

vii. In the case that the entrant carries the passengers who have less time flexibility but have no high quality preference, the incumbent finds the entry accommodating case more profitable than the entry deterrence case when the passengers have tied schedules due to the increase in heterogeneity.

viii. Finally, there is a relationship between two groups of models of product differentiation: the location or Hotelling-type models of horizontal differentiation and models of vertical differentiation. This result is the same as the result of the theoretical studies, which is that every model belonging to a very large class of Hotelling-type models is actually a case of a vertical product differentiation model.

To show the last theoretical result of the two groups of product differentiation in our duopoly models, we illustrate the equilibrium frequency solutions of the numerical examples, given in Chapter 6 and Chapter 7 in Figure 8-1.

In summary, this PhD Dissertation analyzes the effects of travelers' time flexibility on airline markets. As mentioned in previous chapters, passenger preferences are two dimensional: travelers pay for tickets and allocate time to the trips. However, in the literature there are a few theoretical papers that analyze scheduling decisions of the airlines in the case of monopoly as well as oligopoly. Hence, introducing the inter-activity times of potential passengers in taking the decision about traveling, we discuss the market structure with respect to location or addresses in consumers' preferences.

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