Three Essays on Air Transport Economics and Public Policy

by

Xiaowen Fu

B. Engineering (International Trade), Shanghai Jiao Tong University, 1997

B. Engineering (Computer Science), Shanghai Jiao Tong University, 1997

M. Business (Information Management), Nanyang Technological University, 2001

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Abstract

This dissertation examines two important issues in the air transport industry. The first one is airline competition in the presence of major Low Cost Carriers (LCCs). The second issue is airports' role in downstream airline competition. These issues are studied in three essays, which are chapter 2 to chapter 4 in this manuscript style dissertation.

Essay 1 empirically examines airline competition in the presence of a major LCC, especially in the period when the initial effects of LCC entry are stabilized. Using a panel data from the United States domestic markets, an Almost Ideal Demand System (AIDS) is estimated for carriers competing in the same city pair markets. This enables one to calculate carrier-specific demand equations and identify substitution possibilities between Full Service Airlines (FSAs), as well as substitution between LCCs and FSAs. Competition analysis is carried out by empirically estimating reduced form price equations for LCC and FSA. The study found strong evidence of product differentiation between the services provided by FSAs and LCCs. The average prices being charged by FSAs and LCCs are more sensitive to the competition from airlines of the same type. Airlines with higher market shares (regardless of whether they are FSA or LCC) tend to charge higher prices, indicating effect of market power on pricing. Contrary to most previous research results, this study found that the competition between FSAs is important even in the markets where a major LCC is present.

Essay 2 examines how pricing behavior of unregulated airports affect downstream airline competition, especially the competition between airlines offering differentiated services including the case of FSAs vs. LCCs competition. The study found that LCCs suffer more from an identical input price increase than FSAs and are, therefore, more vulnerable to an airport's monopolistic pricing. This implies a reduction of competition in downstream airline markets because in recent years LCCs have been a major source of competition in many airline markets.

Essay 3 studies the competitive and welfare implications when an airport offers the option of sharing its concession revenue with airlines. It is found that such revenue sharing allows airlines and airports to internalize positive demand externality, which could lead to substantial welfare gains. However, such practice may cause negative effects to airline competition. In fact, there are cases where an airport can maximize its profit by strategically aligning with dominant airlines. Such airport's strategy would, of course, further strengthen the dominant firm's market power since its market share is larger after revenue sharing. In addition, while sharing concession revenue with airlines an airport may still prefer to increase airport charge.

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I dedicate this thesis to my wife, Hui, for her unconditional love and support through all the up-and-downs in my life.

Chapter 1

Introduction

This dissertation examines two important issues in the air transport industry. The first issue is airline competition in the presence of major Low Cost Carriers (LCCs). The second issue is airports' role in downstream airline competition. These issues are studied in three essays, which are chapter 2 to chapter 4 in this manuscript style dissertation.

Since mid-1990s, there has been major growth of LCCs globally, often at the expenses of their established rivalries, Full Service Airlines (FSAs). This phenomenon has attracted much attention in the industry and academia, leading to numerous studies and reports. Many of those studies are qualitative, focusing on LCCs' management strategy, operational characteristics, unit cost competitiveness, network configurations etc. Another group of studies applied quantitative and/or econometric methods, but almost exclusively focused on measuring the effects of LCCs' entries. The key finding of those studies is that incumbent FSAs reduce their average prices substantially following the entry of an LCC. The average prices in those markets are much lower after LCC entry, which contributes to substantial growth in traffic volume and flight frequency (Bennett and Craun 1993, Whinston and Collins 1992, Windle and Dresner 1995, Morrison and Winston 1989, Dresner et al. 1996). Such fare reduction has not only been observed in routes where major LCC entered, but also on other routes to/from airports where LCCs have significant presence (Morrison 2001). Because substantial fare reduction has not been observed in the markets where FSAs compete each other, it is argued by some economists and practitioners that the presence of a major LCC alone would ensure sufficient competition in the airline market. Thus, they argue that airline mergers, especially those between FSAs, will not harm competition significantly if a major LCC is already in the market, or if there are no entry barriers such that LCCs can enter at any time.

Essay One, which is chapter 2 of this dissertation, empirically examines airline competition in the presence of a major LCC when the initial LCC entry effects have stabilized. Using a panel data from the United States domestic markets, an Almost Ideal Demand System (AIDS) is estimated for carriers competing in the same city pair markets. This allows us to calculate carrier-specific demand equations and identify substitution possibilities between FSAs, as well as substitution between LCC and FSA carriers. Competition analysis is also carried out by estimating LCC and FSA's reduced form price equations. The key results of this essay are as follows: (1) There is strong evidence of product differentiation effect between services provided by FSAs (American and United in our sample data) and the LCC carrier (Southwest in our sample data); (2) After removing the data for the first two quarters after the entry of the major LCC carrier, the reduced form fare equations show that the average prices of incumbent FSAs become more sensitive to the number of FSAs in the market than the number of LCCs. This shows that competition between FSAs will continue to be important even with the presence of a major LCC; (3) Furthermore, the average price offered by the major LCC (Southwest) is much more responsive to the number of LCCs present in the market while being pretty insensitive to the number of FSAs; (4) Airlines with higher market shares (regardless of whether they are FSA or LCC) tend to charge higher prices, indicating the effect of market concentration on pricing; (5) There is evidence that FSAs derive larger positive pricing benefit from an increase in their market shares of available seats, while LCCs obtain larger positive pricing benefits from an increase in their shares of flight frequency.

These results have the following policy implications: (a) importance of anti-trust scrutiny on mergers between FSAs even in markets where one or more LCCs are present, and (b) both carrier types (FSA and LCC) appear to exercise substantial market power, indicating the need for anti-competitive concern.

Essay One finds empirical evidence that FSAs and LCCs do provide differentiated services. This implies that a change of input price, such as the case when an airport increases its service charges, may have asymmetric impacts on the two types of carriers. In Essay Two, which is chapter 3 of this dissertation, this intuition is formalized in a duopoly airline competition model, where a monopoly airport levies an identical per-passenger service charge to an FSA and an LCC. The results of analytical and numerical investigations in this essay find existence of the asymmetric effects of an airport's monopoly pricing on LCC and FSA carriers. LCCs suffer more from an identical input price increase than FSAs and are, therefore, more vulnerable to an airport's monopolistic pricing. This may cause a reduction of competition in downstream airline markets. This reduction of airline competition constitutes a further detrimental effect on welfare over and above the first-order welfare loss caused by high airport charges above competitive level. Such results indicate that it is important for the governments to take into account of these asymmetric effects of increasing airport user charges on FSAs and LCCs when considering the form and extent of airport regulation or deregulation.

Essay Two points out an important issue which has been largely ignored by air transport economists, namely airports' role in downstream airline competition. However, the findings of this essay are obtained under the assumption that an FSA competes with an LCC using differentiated services. In addition, an airport's detrimental influences to airline competition come as a by-product of the airport's desire for higher service charge. An airport has no interests in airline competition *per se* in this study. In Essay Three, which is chapter 4 of this dissertation, I relax such assumptions by considering a special form of airport – airline agreement, where an airport offers an option of sharing its concession revenue with airlines. Competitive and welfare implications are studied with economic models and numerical simulations. It is found that revenue sharing allows airlines and airports to internalize positive demand externality, which could lead to substantial welfare gains. However, such practice may bring negative effects to airline competition. In fact, there are cases where an airport can maximize its profit by strategically aligning with dominant airlines. Such airport's strategy would, of course, further strengthen the dominant firm's market power since its market share is larger after revenue sharing. We show that a profit maximizing airport may still have incentives and methods to collude with dominant carriers even if it satisfies all of the following three conditions:

(a) aviation service price of the airport is regulated;

(b) the airport has no ownership interest in airlines;

(c) the airport is prohibited from price discrimination.

In addition, while sharing concession revenue with airlines an airport may still prefer to increase airport service charge. All of these results imply that the effects of airport revenue sharing may be two-sided and warrant close examination. The same conclusions may apply to other airline-airport agreements, and to the industries where a firm's action can affect competition in another market.

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Chapter 2 [1]

Airline Competition in the Presence of a Major LCC
- What Happened After the Effects of Southwest's Entries Stabilized

2.1 Introduction

Many studies have found that a Low Cost Carrier's (LCC) entry substantially reduces prices in the markets. Bailey et al. (1985) and Strassmann (1990), with data from the early 1980s, and Windle and Dresner (1995), Dresner et al. (1996), Windle and Drenser (1999), using data from the 1990s, have consistently found that the entry of low cost carriers lowered air fares significantly. For example, Windle and Dresner (1995) found that the entry of Southwest Airlines onto a route reduced fares by an average of 48%. Other studies that found substantial reduction of fares after LCC entries, include Bennett and Craun (1993), Whinston and Collins (1992), and Morrison and Winston (1989). In particular, Morrison (2001) found that Southwest not only benefited consumers directly via its low fares, but also increased economic welfare via its actual, adjacent, and potential competitive effects on other carriers' fares.

A similar magnitude of price reduction accompanying LCC entry has rarely been observed in the case of competition among FSAs. One may expect that the presence of LCCs alone would ensure healthy competition in the air travel market. For example, in Qantas Airlines and Air New Zealand's alliance-merger application to the Australian

[1] This study was initiated as an extension to Prof. Tae Oum's earlier work (Oum Gillen and Nobel 1986). I developed the models and conducted econometric work. Prof. Oum gave me overall guidance and supervision on this paper. Prof. Martin Dresner located and explained the US data to me, and provided the industrial background in the US LCC markets. Key results of this investigation were presented in the 2006 TPUG conference in Boston. (Fu, Dresner and Oum: FSA- LCC Competition: what happened after the Effects of Southwest's entries stabilized).

Competition and Consumer Commission (ACCC), the applicants argued that the proposed merger will not reduce competition as Virgin Blue Airlines, a major LCC in Australia, is very likely to enter into the routes affected by the proposed merger.[2] Although many economists analyzed an incumbent FSA's pricing behavior prior to and soon after an LCC entry, virtually no one has analyzed the competition between FSAs in the post-LCC-entry period after the initial entry effects have stabilized. Even less is known about LCC's competition strategy after entry. Despite the fact that substantial price reduction may have been brought by LCC entry, for the following reasons the competition between FSAs may remain non-trivial even compared to the competition between FSAs and LCCs :

- It is well documented that LCCs offer different, often inferior services compared to FSAs.[3] If there is indeed substantial product differentiation between FSAs and LCCs, one would expect sharper competition among FSAs as their services are more substitutable to each other.

- Unless LCCs want to monopolize the market with temporary predatory pricing, it may not be of LCCs' interests to pursue very aggressive pricing strategies once they secured sufficient market share and traffic density. That is, an LCC may not compete very aggressively in routes where it has market power.

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[2] See NECG's submission to ACCC. Public version of those submissions can be downloaded at http://www.accc.gov.au/content/index.phtml/itemId/526539.

[3] LCCs' operations are far from uniform. Although most LCCs still stick to the low cost inferior service model, many LCCs are now offering enhanced services onboard such as satellite TV, flexible tickets without restriction, or even first class services. However, most LCCs have at least inferior route network and alliance connections compared to major FSAs. This makes their frequent flyer programs less attractive compared to FSAs. Gillen and Morrison (2003) considered the product differentiation between FSA and LCC when treating air travel as a bundled service. Here we restrict our attention to the "traditional" LCCs such as Southwest as it is almost impossible to define a "representative" LCC.

In recent years, the airline market has witnessed the great success of LCCs and the failure of many FSAs. After decades of development, LCCs have already entered many key routes in the United States and around the world. Their competitive strategy *in the post entry era* is now a key issue to examine. Many financially troubled FSAs have sought mergers or strategic alliances. If competition between FSAs is trivial in markets with LCC presence, regulators do not need to worry about anti-trust issues arising from mergers and alliances between FSAs. On the other hand, if competition between FSAs is substantial even with LCC presence, regulators would need to worry about the reduced competition that such mergers may cause. For example, in Canada there are only one major FSA (Air Canada) and one major LCC (Westjet) serving the domestic market. Competition may be substantially enhanced if U.S. carriers were allowed to enter into Canadian domestic routes, for example, by creating a Canada-U.S. common aviation area.

This essay addresses the above issues by analyzing the nature of demand and competitive behavior of airlines serving U.S. domestic routes out of Chicago. An Almost Ideal Demand System (AIDS) is first estimated for two FSAs (American Airlines, United Airlines) and an LCC (Southwest Airlines). This enables us to measure the extent of product differentiation among airlines, calculate carrier-specific demand equations, and identify substitution possibilities between airlines. Competition analysis is then carried out by empirically estimating reduced form price equations for Southwest and United Airlines. Section two of this chapter reviews characteristics of airline operations and competition in the routes out of Chicago. Section three presents the AIDS estimation. Section four deals with airline pricing. Finally, section five summarizes and concludes the study.

2.2 Characteristics of Airlines' Operation

We choose to analyze the U.S. domestic routes market out of Chicago, as this is one of the biggest domestic aviation markets in U.S., and has been extensively analyzed in both FSA and LCC studies. For example, Brander and Zhang (1990), Oum, Zhang and Zhang (1993), and Richard (2001) have studied the duopoly between American and United. Dresner et al. (1996) studied Southwest's entry effects for the Chicago – Baltimore route.

To understand airline operations in the Chicago market, we purchased compiled airline and route specific data from Database Products, a company specialized in providing airline data services. The data are reported by airport pair, but we define a route market at the city-pair level. For example, ORD-BWI and MDW-BWI are defined as one route market for Chicago-Washington / Baltimore. The data are reported quarterly from 1990 to the third quarter of 2004. We noticed that traffic volumes are mostly symmetric in both directions, while variables such as scheduled departure are one-way in nature. We thus use data for routes out of Chicago. For each route, the following variables are compiled.

- *DEP*: Number of scheduled departures for each airline, compiled from the T-100 database, restricted to domestic scheduled departures only.
- *ODPax*: Origin-Destination (OD) paid passenger numbers for each airline, compiled from the DB1A database, a 10% survey data for air travelers. Zero fare passengers, typically travelers utilizing frequent flyer programs, are not included.[4]
- *Fare*: Average price paid by OD revenue passengers.

[4] Zero fared passengers are not included as such demands are often not affected by the pricing over a particular route. Given its small share, zero fared passengers is unlikely to have material impacts to the estimation anyway.

- *Enplane*: Number of passengers enplaned on the flights out of Chicago (i.e., passengers originated from Chicago).
- *Onboard*: Number of passengers on the non-stop flights out of Chicago for each airline (includes passengers from Chicago plus connecting passengers), compiled from the T-100 database;
- *Seat*: Available seats on the non-stop flights out of Chicago for each airline.

Using the above data, we found that:

1) Incumbent FSAs such as American and United reduced their network size significantly in our sample period, while Southwest expanded its network throughout the years, particularly in 1999 and 2002. The numbers of airports where airlines have non-stop flights out of Chicago are shown as in figure 2.1. Note a destination is counted only if it is served by flights actually operated by the reporting carrier. In this study, code sharing flights are regarded as marketing tools rather than operational characteristics, and thus, are not reported in the figure.

2) Southwest has a lower load factor than either American or United. Figure 2.2 shows the quarterly average load factors for the three airlines in our sample period. The load factors of all three airlines are closely correlated, but American and United achieved higher load factors for a majority of the quarters. Over the 15 year period, the average load factor for Southwest is 58.14%, while American and United achieved significantly higher load factors of 64.32% and 65.94%, respectively. This shows that Southwest has been very aggressive in adding frequency and capacity in the routes it serves.

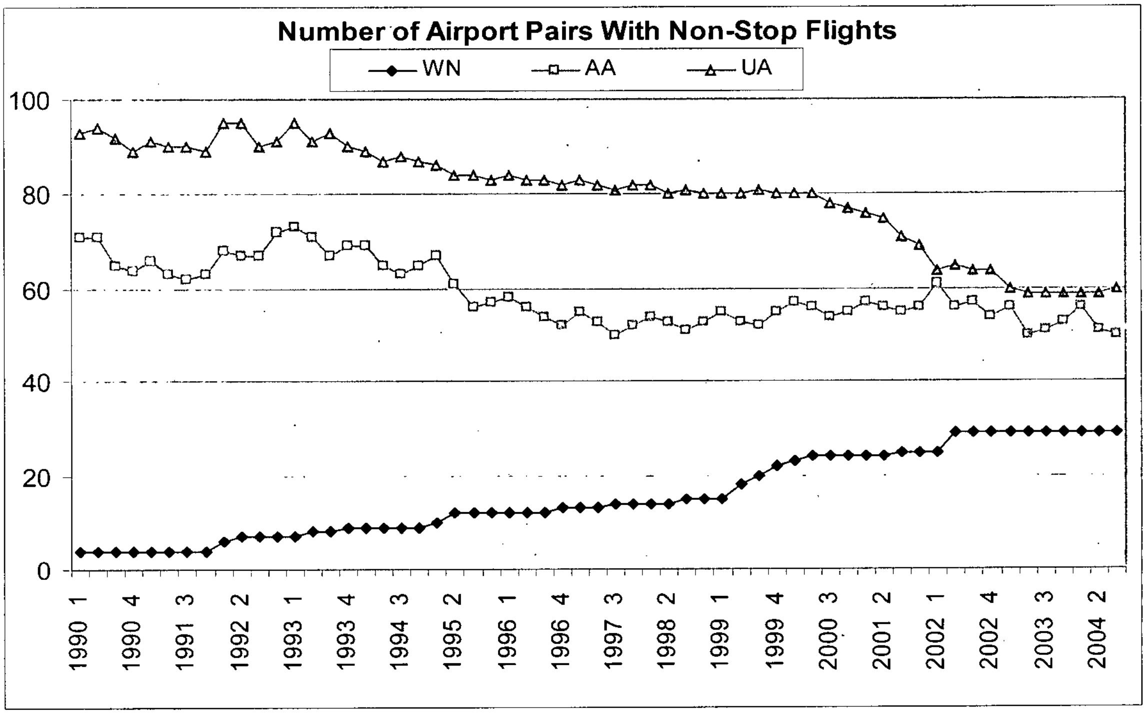

Figure 2.1 Number of Airport Pairs with Non-Stop Flights[5]

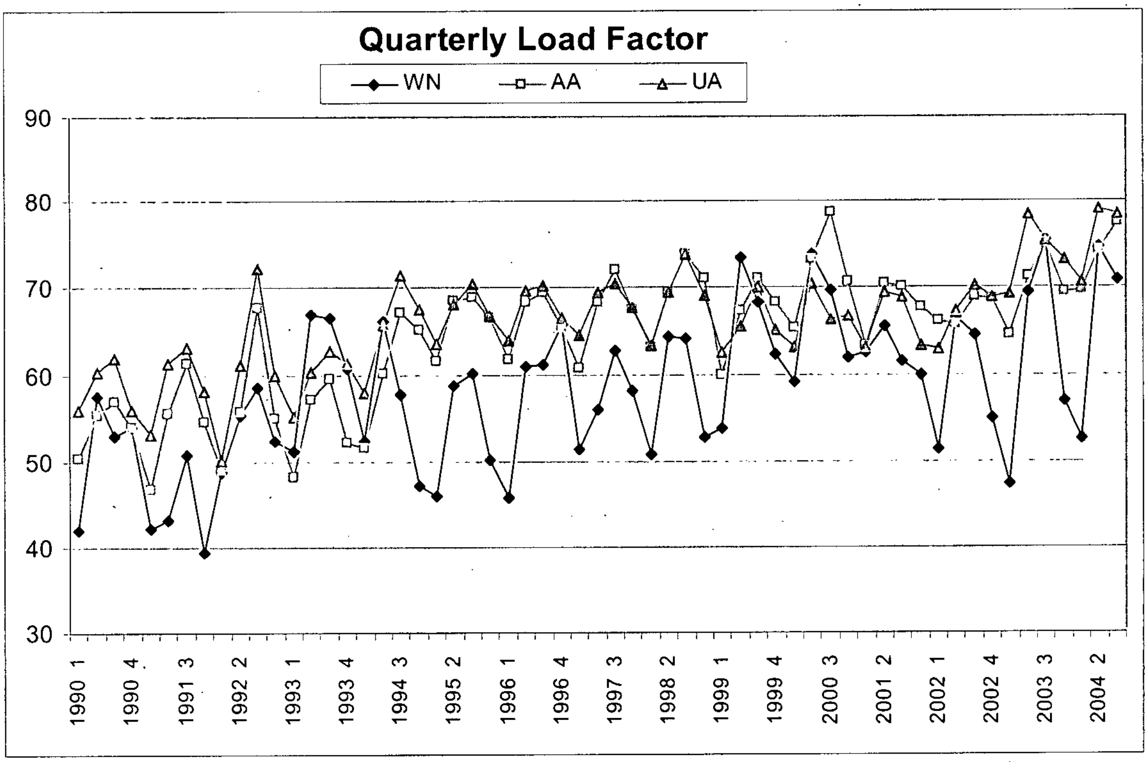

Figure 2.2 Quarterly Average Load Factors for Chicago Routes[6]

[5] Compiled from T100 data. A city pair is counted as being served by an airline if the carrier has more than 50 direct flights in a quarter.

3) Southwest combines air traffic via its linear network. While it is well known that Southwest Airlines mainly focuses on point-to-point operations via its linear network,[7] the extent of traffic combination by Southwest seems to be very large for routes out of Chicago. Figure 2.3 reports several average traffic ratios for Southwest over a sample of selected routes.[8] OD stands for the number of fared OD passengers.[9] Enplane stands for the number of passengers enplaned in Chicago. Southwest served only a few routes out of Chicago in the early 1990s. Average ratios shown in figure 2.3 during this period are thus very volatile as they may have been substantially affected by a single route. Still the figure reveals that (a) The ratio of OD passenger to enplaned passenger decreased from about 90% in the early 1990s to below 70% in 2004. That is, more and more Southwest passengers enplaning in Chicago go beyond their first stop. (b) The ratio of OD passengers to onboard travelers is only about 60% in the sample period. This again shows that Southwest operates flights in the form of City A → Chicago → City C, so it can combine traffic with an origin/destination in

[6] The quarterly average load factors are calculated using T-100 data for routes (airport pairs) where carriers have direct non-stop flight operations out of Chicago. An airline's load factor for a route is calculated by dividing Onboard Passengers by Available Seats. An airline's average load factor in a quarter is calculated as the simple average for all the routes it served at the time. Simple average is used so that the average value is not dominated by very large route markets.

[7] Some LCCs however also operate their own hubs. For example, Airtran operates a hub in Atlanta.

[8] Our data cover the period of 1990 to 2004. As of the second quarter of 1997, Southwest operated non-stop direct flights from Midway airport (MDW) to the following airports: BHM, BNA, BWI, CLE, CMH, DTW, IND, MCI, OMA, PVD, SDF, STL, LIT. The ratios in figure 2.3 are first calculated for each route. A simple average is then calculated for all the routes so that the value is not dominated by routes with large passenger volumes. The second quarter of 1997 is chosen as it is in the middle of our data period. This ensures that we get sufficient number of observations for the sampled routes. According to the U.S. Department of Transport (DOT) data specification, enplaned passengers are those flying between two airports, while on-board passengers are only reported for non-stop operations. Our comparisons in figure 2.3 are precise when passengers either take direct flights out of Chicago or use Chicago for connection. In the second quarter of 1995, Southwest introduced direct flight service between Chicago and Little Rock (LIT), Chicago and Birmingham (BHM). Meanwhile, it kept some flights from Chicago to Little Rock and Birmingham which connect via some other cities. This led to higher than 1 enplaned/Onboard ratio for this quarter in our calculation. Such cases are rare and temporary, as Southwest cancels connecting services once sufficient non-stop flights are introduced.

[9] There are some zero-fare passengers carried by Southwest, which are mainly passengers utilizing their frequent flyer program points. They typically are less than 5% of the revenue passengers.

Chicago with through traffic (much as traditional hub-and-spoke carriers combine traffic through their hubs). (c) The ratio of Enplaned passengers to Onboard passengers is increasing. This suggests that Southwest serves increasingly more local (Chicago) OD passengers as it expands its network. There are still many passengers connecting at Chicago, but more and more Southwest passengers fly a Chicago → City A → City B type of itinerary.

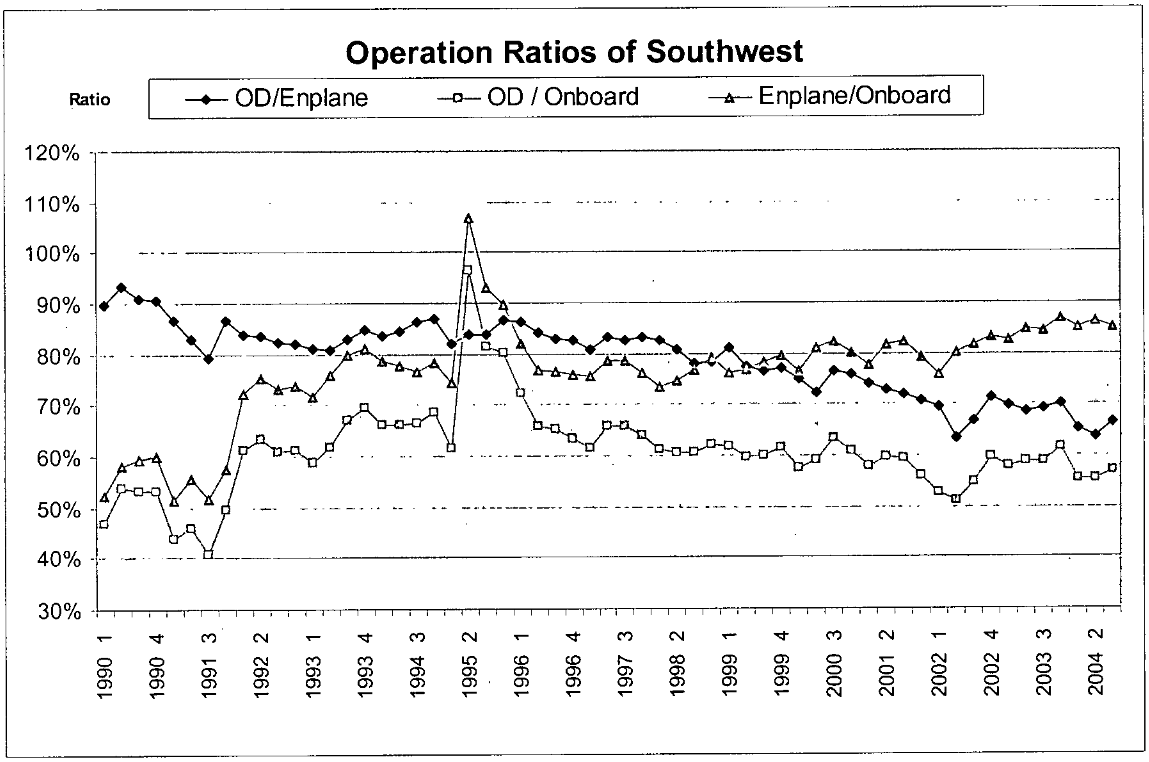

Figure 2.3 Average Ratios of Southwest's Traffic Pattern For Selected Routes

2.3 Demand Estimation

Though the operations and service characteristics of LCCs have been well documented, few studies have compared the demand difference between FSAs and LCCs or quantified such potential product differentiation. To fill this gap, we choose to estimate an Almost

Ideal Demand System (AIDS) for Southwest, American Airlines and United Airlines. We use a method similar to Oum, Gillen and Noble (1986) and Hausman, Leonard and Zona (1994) by assuming budgetable consumer demand. That is, travelers between two cities first allocate a certain budget to air transportation, and then allocate this budget among the competing airlines. Correspondingly, we assume a 2-level demand system as follows. The bottom level demand equations are specified as follow for a route market:

$$S_{it} = \alpha_i + \beta_i \ln\frac{Y_t}{P_t} + \sum_{j=1}^{I} \gamma_{ij} \ln p_{jt} + Z_t\theta + \varepsilon_t \tag{2.1}$$

Airline $i = 1..I$, Period $t = 1..T$

Z_t : Vector of route specific control variables including average income and population of City A and City B, quarter dummies and route distance·

p_{jt} : Airline J's average price;

Y_t : Air travel expenditure over this route

S_{it} is the revenue share of airline i in this route at time t:

$$S_{it} = \frac{p_{it} q_{it}}{Y_t} \tag{2.2}$$

And P_t is a price index for route i, a function of all airlines' prices. So that we have:

$$P_t = f(p_{1t}, p_{2t}, \dots, p_{It}) \tag{2.3}$$

$$Y_t = Q_t \times P_t \tag{2.4}$$

Where Q_t is the total volume of passengers traveled in this route:

$$Q_t = \sum_{i=1}^{I} q_{it} \tag{2.5}$$

For overall demand for air travel, the demand function is defined as:

$$\ln Q_t = a + b\ln I_t + \lambda \ln P_t + \eta Z_t + \tau_t \tag{2.6}$$

Q_t : Total number of air passengers in this route

I_t : Weighted income of the origin-destination cities

With equation (2.1) and (2.2) we have

$$\frac{p_{it}q_{it}}{Y_t} = \alpha_i + \beta_i \ln Y_t - \beta_i \ln P_t + \sum_{j=1}^{I} \gamma_{ij} \ln p_{jt} + Z_t\theta + \varepsilon_t \tag{2.7}$$

To calculate airline *i*'s partial / conditional price elasticity with the price of airline *j* when total air travel expenditure Y_t is constant, simply differentiate the above equation w.r.t. p_{it}. When *i* = *j*, we can derive airline's conditional own price elasticity as follows:

$$e_{iit} = \frac{\gamma_{ii}}{S_{it}} - \frac{\beta_i}{S_{it}} \cdot \frac{dP_t}{dp_{it}} \frac{p_{it}}{P_t} - 1 \tag{2.8}$$

When $i \neq j$, we can derive airline's conditional cross price elasticity as follows:

$$e_{ijt} = \frac{\gamma_{ij}}{S_{it}} - \frac{\beta_i}{S_{it}} \cdot \frac{dP_t}{dp_{jt}} \frac{p_{jt}}{P_t} - 1 \tag{2.9}$$

To calculate the (full / unconditional) price elasticity and cross price elasticity, we need to consider the total expenditure change when an airline changes its price p_{it}. Differentiate equation (2.7) w.r.t. to p_{it} but allow Y_t to change this time, we have when *i* = *j*:

$$E_{iit} = \left(\frac{\gamma_{ii}}{S_{it}} - \frac{\beta_i}{S_{it}} \cdot \frac{dP_t}{dp_{it}} \frac{p_{it}}{P_t} - 1\right) + \frac{S_{it} + \beta_i}{q_{it}} \frac{dY_t}{dp_{it}} \tag{2.10}$$

The first part is simply the partial elasticity. In addition, as $Y_t = Q_t \times P_t$, we have:

$$\frac{dY_t}{dp_{it}} = \frac{d(Q_t \cdot P_t)}{dP_t} \frac{dP_t}{dp_{it}} = (1+\lambda)\frac{dP_t}{dp_{it}} Q_t \tag{2.11}$$

The total demand price elasticity $\lambda = \frac{dQ_t}{dP_t}\frac{P_t}{Q_t}$ can be estimated through the total level demand equation (2.6). The case of $i \neq j$ can be derived similarly. The precise price index corresponding to AIDS demands can be specified and estimated. Ideally one may specify the model with a flexible functional form. For example, Deaton and Muellbauer (1980) specified the price index as:

$$LnP_t = \alpha_0 + \sum_{i=1}^{I} \alpha_i \ln p_{it} + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} \gamma_{ij} \ln p_i \ln p_j \tag{2.12}$$

While Oum et al. (1986) defined it as the following translog function:

$$\begin{aligned} \ln P_t = \alpha_0 + \sum_{i=1}^{I} \alpha_i \ln p_{it} + \sum_{k=1}^{K} \ln Z_k + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} \gamma_{ij} \ln p_{it} \ln p_{jt} \\ + \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K} b_{ij} \ln Z_i \ln Z_j + \sum_{i=1}^{I}\sum_{k=1}^{K} c_{ik} \ln p_i \ln Z_j \end{aligned} \tag{2.13}$$

Many empirical estimations and simulation studies, including Deaton and Muellbauer (1980), Alston et al. (1994) found a linear approximation is sufficient. We thus use the following Stone index, where w_i is the average revenue share of airline i during the sample period.

$$LnP_t = \sum_{i=1}^{I} w_i \ln p_{it} \tag{2.14}$$

So that $\frac{dP_t}{dp_{jt}}\frac{p_{jt}}{P_t} = w_j$ or $\frac{dP_t}{dp_{jt}} = w_j \frac{P_t}{p_{jt}}$, and firm's own price elasticity by equation (2.10) is:

$$E_{iit} = \frac{1}{S_{it}}(\gamma_{ii} - \beta_i w_i) - 1 + (1 + \frac{\beta_i}{S_{it}})(1 + \lambda) w_i \tag{2.15}$$

While the cross price elasticity is:

$$E_{ijt} = \frac{1}{S_{it}}(\gamma_{ij} - \beta_i w_j) + (1 + \frac{\beta_i}{S_{it}})(1 + \lambda) w_j \tag{2.16}$$

As the AIDS demands are derived from an AIDS cost function, the following restrictions shall hold so that the demand functions add up to total expenditure, are homogeneous of degree zero in prices and total expenditure taken together, and satisfy Slutsky symmetry:

$$\sum_{i=1}^{I} \alpha_i = 1,\ \sum_{i=1}^{I} \gamma_{ij} = 0,\ \sum_{i=1}^{I} \beta_i = 0 \tag{2.17}$$

$$\sum_{j}^{I} \gamma_{ij} = 0 \tag{2.18}$$

$$\gamma_{ij} = \gamma_{ji} \tag{2.19}$$

Slutsky symmetry failed to hold in most empirical studies. We thus do not impose restriction (2.19).[10] In addition, as we introduce additional regression variables such as route distance, the restriction $\sum_{i=1}^{I} \alpha_i = 1$ is also dropped. The other restrictions can be automatically satisfied when one estimates *I-1* share equations only.

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[10]When one estimates demand systems on the individual consumer data, regularity conditions shall be imposed. However, when estimating with an aggregate data set as our case, it is not necessary to impose symmetry. For example, Diewert (1980) states, "Systems of community excess demand (or aggregate market demand) functions, as opposed to individual demand functions, need not satisfy any restrictions other than an adding-up property (Walras' Law) if the number of consumers is greater than the number of goods (Sonnenschein (1972, 1973a, b), Debreu (1974), McFadden et al. (1974), Mantel (1974, 1975), Diewert (1977)). In particular, there will be no symmetry restrictions..." Lewbel (2001) proved that even if individual consumers are rational, symmetry may not hold in econometric estimation. Empirical studies rejected symmetry include Deaton and Muellbauer (1980), Browning (1991) and Blundell, Pashardes and Weber (1993) etc. A notable example is Lewbel (1995), where symmetry is rejected with non-parametric tests. When we estimated our demand system after imposing the symmetry condition, the results show wrong signs on the two key parameters of the model (own price and cross-price variables). Therefore, we decided to estimate our model without imposing the symmetry condition.

Airlines produce many services jointly. In this study, we only estimate travel demands for OD passengers between two cities where carriers operating non-stop direct flights. As of the second quarter of 1997,[11] there are only five routes out of Chicago where Southwest, American and United Airlines offer nonstop services at the same time. Those five routes are selected for our AIDS estimation. All other carriers on those routes are treated as the fourth carrier. Weighted average fare and the sum of OD passengers are used as the price and output of the hypothetic fourth carrier. In order to remove the transitory effect during the initial period after the entry, we decided to use the data from the third quarter after Southwest's entry.[12] In addition, the quarters when American or United exited a market are also removed so that our data should approximate the "equilibrium" period free from entry and exit effects. The result is a total of 251 observations for the five routes. Sample statistics for these routes are summarized as follows:

Table 2.1 Sample Statistics for the Selected Routes

Route (City)	Sample Period (year/quarter)	Average Pax Number			Average Revenue Share		
		WN	AA	UA	WN	AA	UA
BNA (Nashville, TN)	1990/1 - 2000/4	23045	13733	7220	41%	37%	19%
DTW (Detroit, MI)	1990/1 - 2004/3	36225	18967	28001	20%	15%	22%
MCI (Kansas City, MO)	1990/1 - 2004/3	45717	21299	23006	41%	23%	28%
PVD (Providence, RI)	1997/2 - 2004/3	11673	10444	13384	27%	28%	38%
STL (St Louis, MO)	1990/1 - 2004/3	47512	16913	18500	35%	18%	19%
Sample Average		35865	17096	19204	33%	23%	24%

[11] Again as our data cover the period from 1990 to 2004, the second quarter of 1997 is chosen as it is in the middle of our time coverage. This assures that we have enough observations for the routes selected.

[12] This decision was made on the basis of the following facts and statistical test: An examination of 25 entries of Southwest in the Chicago routes during our sample period (1990/1 – 2004/3) revealed the following: On average, Southwest increased its flight frequency by 80% in the second quarter after an entry, while increased flight frequency only by 6% and 5%, respectively, in the third and fourth quarters after the entry. ANOVA test shows that the average percentage of frequency increase (Average Increase) in quarters 2 to 4 are different (P value <0.01). In particular, two sample t – tests find that the average increase in flight frequency in quarter 2 is statistically different from those of quarter 3 and quarter 4 (p-values <0.01), while the average increase in quarter 3 is not statistically different from that of quarter 4 (p-value =0.79). Therefore, it appears that the initial entry effects stabilized within 6 months. Thus, we decided to use the data from the third quarter after Southwest's entry.

Given the small sample size, we pool the data from all five routes together. This however implies that parameters estimated are more accurate at the average of all five routes. Denote Southwest, American and United as firm 1, firm 2 and firm 3 respectively, the equation we use for estimating equation (2.1) is as follow:

$$S_{\text{int}} = \alpha_i + \beta_i \ln \frac{Y_{nt}}{P_{nt}} + \sum_{j=1}^{3} \gamma_{ij} \ln p_{jnt} + e_i Ln(Incom_{nt}) + f_i Ln(de_{\text{int}})$$

$$+ h_i Ln(Dist_n) + \sum_{m=1}^{3} c_{mi} QR_m + h_i Trend + \varepsilon_t \qquad (2.20)$$

Where S_{int} is airline i's revenue share in route n at quarter t. ($i = 1..3$, $n = 1..5$). $Incom_{nt}$ is the weighted average personal income of Chicago and the destination city.[13] Variable de_{int} is the number of scheduled departure of firm i on route n at time t. $Dist_n$ is the stage length for route n. To control for potential seasonal effects, quarterly dummy variables QR_m ($m = 1..3$) are used for the first three quarters of a year. The variable *Trend* is for a yearly linear trend.

In estimating the share equation i, firm i's price and scheduled departures may be endogenous to the regression.[14] Cost is often used as the main instrumental variable in demand estimations. Quarterly Costs Per Available Seat Mile (CASM) are calculated for Southwest, American and United's domestic operations. The current price CASM values for the airlines are shown in figure 2.4. It can be seen that Southwest maintained its lower costs throughout the period and strengthened its cost advantage over American and United. This suggests that Southwest has a clear strategy of staying as a low cost carrier,

[13] Annual personal income and population data are obtained from the REIS system available from the Bureau of Economic Analysis. Quarterly data are obtained by linear extrapolation.

[14] One may argue price for firm j ($j \neq i$) is also endogenous because of inter-firm rivalry. We are not aware of any empirical work that controlled for this second order factor.

which is different from the strategy observed for many other LCCs who gradually upgraded their services to attract business travelers. For example, Virgin Blue Airlines in Australia began to offer less restrictive services comparable to the full economy class of FSAs, and similarly, WestJet in Canada now provides satellite TV on many of its flights.

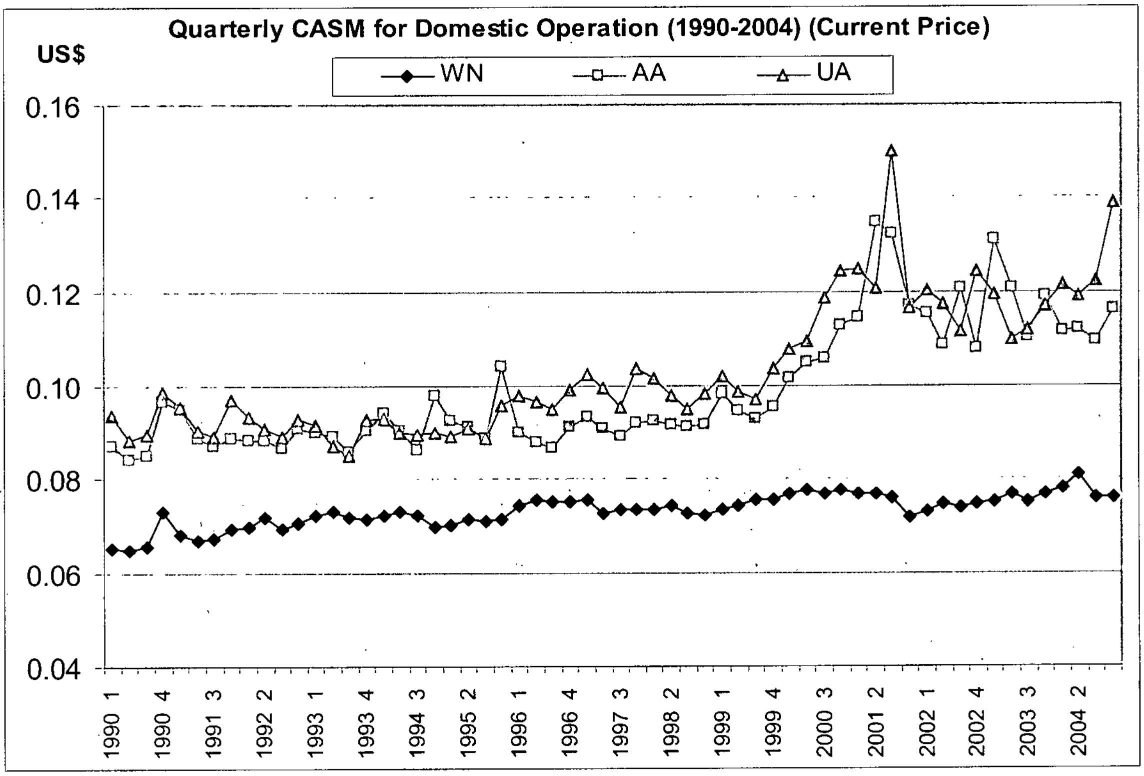

Figure 2.4 Quarterly CASM for Domestic Operations[15]

In summary, we used following variables as instrumental variables to estimate firm i's share equation:

- Firm i's CASM for its domestic operations $Ln(1000 \times CASM_{it})$. CASM is rescaled by multiplying 1000 in order to obtain positive logarithmic value of costs,

[15] Following the method used by the U.S. Department of Transportation, raw data are obtained from Bureau of Transportation Statistics form 41, Schedule P1.2 and T100. Calculated numbers in recent years are available at BTS website http://www.bts.gov/press_releases/airline_financial_data.html

- Product of populations $Ln(Pop_{ct} \times Pop_{nt})$, where Pop_{ct} is the population of Chicago, Pop_{nt} is the population of city *n*.

- Total onboard passengers for all airlines serving Chicago $Ln(Pax_t)$. This variable reflects the overall growth in the Chicago market.

- Number of onboard passengers for all routes out of Chicago served by airline *i*: $Ln(Pax_i)$. As an airline carries more passengers out of Chicago, its demand on each route may increase as there are more connecting or through traffic opportunities.

As our data covers a time series from 1990 to 2004, all price, income and cost data are deflated to the real price of 1990 using the CPI index compiled by the Bureau of Labor Statistics. The estimated parameters for the system of share equations (2.20) are summarized in table 2.2.

Table 2.2 Two Stage Least Square Parameter Estimates of Firms' Market Share Model (base: all other firms) (1 -WN; 2 - AA; 3 - UA)

Dependent variable: S_{int} airline *i*'s revenue share on route *n* in quarter *t*

Parameter	Estimate	t-ratio	Parameter	Estimate	t-ratio
β_1	-0.1167	-10.37	γ_{21}	0.048385	1.157
β_2	-0.10502	-3.028	γ_{22}	-0.25983	-2.261
β_3	0.03434	0.8578	γ_{23}	0.20637	1.762
γ_{11}	-0.12715	-3.807	γ_{31}	0.14609	2.747
γ_{12}	0.04863	1.656	γ_{32}	0.28379	2.769
γ_{13}	0.03936	0.9501	γ_{33}	-0.42945	-2.859

Equation (2.6) is estimated using following regression with pooled data:

$$\ln Q_{nt} = a + bLn(Incom_{nt}) + \lambda \ln P_{nt} + e_i Ln(Dist_n) + \sum_{m=1}^{3} c_m QR_m + Trend + \tau_t \quad (2.21)$$

The regression results are summarized as follows. As in the above regressions, all prices have been deflated before estimating the regression.

Table 2.3 Estimation for Market Level Elasticity

Dependent variable: $Ln(Q_{nt})$ where Q_{nt} is the number of air passengers in route n, quarter t

Parameter	Estimate	t-ratio	Parameter	Estimate	t-ratio
$Ln(Incom_{nt})$	2.4645	3.983	QR_1	-0.106	-2.41
$\ln P_{nt}$	-1.1511	-13.13	QR_2	0.10524	2.393
$Ln(Dist_n)$	-0.5484	-10.56	QR_3	0.1445	2.604
Trend	-0.02477	-3.965			

N = 251, R^2 = 0.79

Using the estimated parameters, elasticities are calculated using equations (2.15) and (2.16) at the mean of each route, and at the sample average revenue shares. Each airline's own price elasticity and cross elasticities are summarized in table 2.4:

Table 2.4 Calculated Firm Specific Elasticities
(1 -WN; 2 - AA; 3-UA)

	Own Price Elasticity			Cross Price Elasticity					
Route (Airport, City)	**E11**	**E22**	**E33**	**E12**	**E13**	**E21**	**E23**	**E31**	**E32**
BNA (Nashville, TN)	-1.24	-1.64	-3.32	0.19	0.13	0.20	0.57	0.62	1.36
DTW (Wayne County, MI)	-1.53	-2.69	-3.01	0.32	0.31	0.47	1.57	0.59	1.23
MCI (Kansas City, MO)	-1.24	-2.03	-2.59	0.16	0.15	0.36	0.99	0.39	0.93
PVD (Providence, RI)	-1.38	-1.84	-2.22	0.28	0.28	0.25	0.84	0.31	0.67
STL (St Louis, MO)	-1.28	-2.37	-3.35	0.18	0.15	0.46	1.26	0.65	1.45
Sample Average	**-1.30**	**-2.05**	**-2.85**	**0.21**	**0.18**	**0.34**	**0.99**	**0.50**	**1.10**

Note: Eij: price elasticity of demand for firm i's product w.r.t. firm j's price

As we estimated by pooling all five routes together, the estimated elasticities are most appropriately interpreted at the sample average, or the mean revenue shares of all five routes (when Southwest, American and United have revenue shares of 33%, 23% and 24%). Table 2.4 suggests the followings:

- The cross elasticities between FSAs (American and United, E23 = 0.99, E32 = 1.10) are much higher than their cross elasticities with Southwest (E21 = 0.34, E31 = 0.5, E12 = 0.21, E13 = 0.18). This indicates that Southwest appears to provide services differentiated from its FSA competitors. The services offered by American and United are, however, fairly homogenous as evidenced by their high substitutability implied by the high cross-price elasticities.
- The firm specific price elasticities of American and United are actually higher than that of Southwest. This does not necessarily indicate that FSA's firm-specific elasticity is higher than LCC's. This may reflect only the specific market situation we have dealt with in Chicago. In this particular data, we have two or more FSAs competing in the same market while there is primarily one LCC (WN). Therefore, the lower elasticity of WN than those of UA or AA is likely to have been caused largely by the aggregation level of the data.[16] Another reason for the lower WN's price elasticity may be partly caused by the fact that in many of the markets WN has a larger market share than AA or UA.[17]

Our empirical evidence indicates presence of product differentiation between Southwest and American or United. However, we probably need additional evidence to strengthen our conclusion because there are some factors not controlled in our estimation, such as firm-specific or route-specific attributes, or airline network effects.

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[16] Since Southwest represents essentially the only major LCC in the data set and it produces services fairly uniquely distinguishable from FSAs, its elasticity represents, in fact, the LCC's market price elasticity. On the other hand, AA and UA represent truly disaggregated firm-specific data and as such, their elasticities reflect competitive rivalry between two or more firms producing essentially homogeneous products. Therefore, if we were to aggregate these two firms (AA and UA) into a single FSA group the aggregate price elasticity of FSA products is likely to be lower than that of LCC (in this case, WN).

[17] In theory, when there are many firms producing a homogenous product, a firm's own price elasticity would be infinitely large as it can capture the whole market if it lowers its price by a very small amount.

2.4 Competition Analysis

If there are indeed sufficient product differentiation between FSAs and LCCs, as evidenced by the cross elasticities calculated in section 2.3, then one would expect the competition within each product segment to be sharper than the competition between LCCs and FSAs. To explore this possibility, we calculate the price correlation between airline i and j using the OD passenger fare data set in section 2.3. Intuitively, a high price correlation implies substantial interaction between the two airlines, such as the case when two airlines engage in sharp competition. However, collusive behavior may also lead to close interaction, or high price correlations. Low price correlation may be an indication of significant product differentiation. Price correlation coefficients for the sample routes in section 2.3 are as follows:

Table 2.5 Price Correlation for the Selected Routes

	Average Revenue Share			Price Correlation		
Route (Airport, City)	**WN**	**AA**	**UA**	**WN-AA**	**WN-UA**	**AA-UA**
BNA (Nashville, TN)	41%	37%	19%	0.192	0.299	0.943
DTW (Wayne County, MI)	20%	15%	22%	0.654	0.769	0.923
MCI (Kansas City, MO)	41%	23%	28%	0.670	0.699	0.878
PVD (Providence, RI)	27%	28%	38%	-0.113	0.375	0.347
STL (St Louis, MO)	35%	18%	19%	0.648	0.626	0.917

Except for the PVD route, it can be seen that price correlation between American and United is very high. This is consistent with our expectation. The negative price correlation between WN-AA in the PVD route is puzzling. A closer look at the data shows that after entry, Southwest actually responded to American's price cut with a slight price increase. It appears that this route was not in equilibrium.

Although the price correlations for WN-AA and WN-UA appear to be smaller than those for AA-UA, they are still of significant size for the routes of DTW, MCI, STL. We noticed that in all these routes, the combined market shares of WN, AA and UA are initially moderate (44%, 67% and 49%). However, the three airlines' total market share experienced substantial increase to more than 90% on the MCI route in 1992/1 and on the STL route at 2002/1 when one of their major competitors exited the market.[17] Using data after those two dates, the price correlation for the MCI and STL routes are as follows:

MCI Route: WN-AA 0.414; WN-UA 0.522; AA-UA 0.85

STL Route: WN-AA 0.162; WN-UA -0.051; AA-UA 0.771

This suggests that high correlation between FSA and LCC may result, in part, from low market concentration. Such anecdotal evidence suggests an airline's competition strategy also depends on market structure. For example, when airlines have a small market share thus are fringe players, they may follow dominant carriers' price leadership and actively compete with other fringe players. Such anecdotal evidence is consistent with the findings by Borenstein on FSAs' pricing in hub routes. Borenstein (1989) found that correlation between route concentration and high prices cannot be adequately explained by the traditional theories in which high concentration facilitates tacit or explicit collusion. The high average prices that some airlines are able to sustain in concentrated markets do not permit all participants in the market to charge similar prices. If the same conclusion applies to LCCs, then Southwest may engage in fairly aggressive competition with FSA rivals despite of product differentiation, when those airlines only have moderate market shares.

[17] For the Kansas City route, Midway airlines exited in the first quarter of 1992. For the St. Louis case, American purchased TWA and took over its routes out of the St. Louis hub.

To go beyond such anecdotal evidence, we need formal investigation with larger sample, and control for both product differentiation and market power at the same time. Reduced form price equations are estimated for routes where Southwest is present. The reduced form price equations for Southwest and United are as follows, where a superscript stands for an airline's name and a subscript *nt* stands for route *n* at time *t*:

$$\begin{aligned} Ln(P_{nt}^{WN}) &= \alpha_1 + \alpha_2 Ln(Frq_{nt}^{WN}) + \alpha_3 LF_{nt}^{WN} + \alpha_4 NFSA_{nt} + \alpha_5 NREG_{nt} + \alpha_6 S_{nt}^{WN} \\ &+ \alpha_7 Ln(Pax_t) + \alpha_8 Ln(Dist_n) + \alpha_9 Ln(Pop_{nt}) + \sum_{m=1}^{3} c_{mi} QR_m + \sum_{k=91}^{04} e_k Y_k + \varepsilon_t \end{aligned} \qquad (2.21)$$

$$\begin{aligned} Ln(P_{nt}^{UA}) &= \beta_1 + \beta_2 Ln(Frq_{nt}^{UA}) + \beta_3 LF_{nt}^{UA} + \beta_4 NFSA_{nt} + \beta_5 NREG_{nt} + \beta_6 S_{nt}^{UA} \\ &+ \beta_7 Ln(Pax_t) + \beta_8 Ln(Dist_n) + \beta_9 Ln(Pop_{nt}) + \sum_{m=1}^{3} C_{mi} QR_m + \sum_{k=91}^{04} E_k Y_k + \tau_t \end{aligned} \qquad (2.22)$$

P: Price of OD passengers in the route

Frq: Frequency as measured by number of scheduled departure in a quarter

LF: Load factor calculated by dividing on-board passenger by available seats.

NFSA: Number of FSAs serving the route with nonstop flights

NREG: Number of regional / commuter carriers and LCCs serving the route with nonstop flights.[18] Southwest is not counted as it is always present.

S: airlines' share of frequency in this route.

Pax: Number of onboard passengers for all airlines for all routes out of Chicago. This variable measures the overall market growth.

Dist: Route distance

Pop: product of populations of Chicago and the destination city

QR: Quarterly dummy variables for the first three quarters of a year

Y_k : Yearly dummy variables from 1991 to 2004

[18] In our sample, this group includes regional carriers such as American Eagle, Atlantic Coast airlines, Air Wisconsin, Mesa airlines, Express Jet (under the name Continental Express), Chicago Express, Chautauqua Airlines, Mesaba Airlines, Vanguard Airlines. Small national airlines such as Skywest, Middle Way airlines, Trans States etc. are also included. Those carriers are classified as group 1 and 2 carriers by DOT. LCCs such as American West and ATA were also present at certain routes.

As of the second quarter of 1997, Southwest provided non-stop flights between Chicago and following 13 airports: BHM, BNA, BWI, CLE, CMH, DTW, IND, MCI, OMA, PVD, SDF, STL, LIT. Except for LIT (Little Rock), United provided non-stop flight services to all those airports, as well. The sample statistics for the routes where United and Southwest compete are summarized as in Table 2.6. The normalized price variability (Standard Deviation / Average Price, or coefficient of variation) are similar for both Southwest and United. This suggests that average price is a valid indicator for the firm's average price for both LCCs and FSAs.

Table 2.6 Sample Statistics on Average Frequency, Average Price and Price Variability

Route City	Sample Period (Year/Quarter)	Average Frequency		Average Price		Normalized Price Variability*	
		WN	UA	WN	UA	WN	UA
BHM (Birmingham, AL)	1995/4-2001/1	170	180	96.96	120.77	0.085	0.078
BNA (Nashville, TN)	1990/1-2000/4	692	269	69.29	108.96	0.080	0.233
BWI (Baltimore, MD)	1994/1-2004/3	654	528	81.19	110.16	0.217	0.169
CLE (Cleveland, OH)	1992/3-2004/3	696	521	52.33	88.08	0.161	0.209
CMH (Port Columbus, OH)	1992/4-2004/3	468	525	51.62	96.84	0.223	0.202
DTW (Detroit, MI)	1990/1-2004/3	821	550	54.58	76.15	0.213	0.203
IND (Indianapolis, IN)	1992/3-2004/3	414	599	46.51	98.29	0.130	0.287
MCI (Kansas City, MO)	1990/1-2004/3	1247	499	57.19	79.25	0.148	0.151
OMA (Omaha, NE)	1995/3-2004/3	519	516	55.49	96.41	0.060	0.173
PVD (Providence, RI)	1997/2-2004/3	237	349	109.08	134.32	0.077	0.093
SDF (Louisville, KY)	1993/4-2000/1	589	199	46.77	103.72	0.165	0.221
STL (St. Louis, MO)	1990/1-2004/3	1168	467	54.59	75.03	0.163	0.156

* Coefficient of variation in prices

As ε_t and τ_t are likely to be correlated, estimating equations (2.21) and (2.22) jointly with Seemingly Unrelated Regression (SUR) model may be more efficient than Ordinary Least Squares (OLS). We first estimate price equations separately using OLS, then test the SUR model using quarterly data when both Southwest and United offer non-stop flights over a route. We found the two estimation methods yield essentially the same results, but the SUR model is more efficient in terms of a much higher R^2 for the Southwest price equation. In addition, using CPI deflated prices or current prices does not have a material impact on the results (other than on seasonal and yearly dummy variables). We thus only report the estimation results with the SUR model using CPI deflated real price.

Table 2.7 SUR Estimation of Price Equation With Flight Frequency

WN Price Equation			UA Price Equation		
Parameter	**Estimation**	**t-Ratio**	**Parameter**	**Estimation**	**t-Ratio**
Frq	-0.126	-6.482	*Frq*	-0.152	-5.589
LF	-0.001	-1.230	*LF*	-0.009	-6.910
NFSA	-0.013	-0.945	*NFSA*	-0.056	-3.290
NREG	-0.050	-5.911	*NREG*	0.007	0.700
S (freq. share)	0.255	3.012	*S(freq. share)*	0.040	1.154
Pax	0.253	1.356	*Pax*	0.191	7.511
Dist	0.356	16.400	*Dist*	0.249	1.003
Pop	0.152	5.900	*Pop*	0.402	3.685
QR_1	0.036	1.298	QR_1	0.008	0.229
QR_2	0.018	0.938	QR_2	0.087	3.645
QR_3	0.000	-0.018	QR_3	0.061	2.076
Y91	0.024	0.512	*Y91*	-0.098	-1.633
Y92	-0.099	-2.206	*Y92*	0.020	0.349
Y93	-0.178	-3.970	*Y93*	0.194	3.402
Y94	-0.218	-4.574	*Y94*	0.050	0.816
Y95	-0.159	-3.373	*Y95*	-0.055	-0.905
Y96	-0.056	-1.147	*Y96*	0.013	0.206
Y97	-0.029	-0.583	*Y97*	-0.001	-0.018
Y98	-0.030	-0.529	*Y98*	-0.019	-0.259
Y99	-0.009	-0.164	*Y99*	-0.017	-0.229
Y00	0.021	0.360	*Y00*	0.030	0.397
Y01	-0.055	-1.076	*Y01*	-0.092	-1.371
Y02	-0.033	-0.603	*Y02*	-0.159	-2.183
Y03	-0.036	-0.540	*Y03*	-0.027	-0.311
Y04	-0.072	-0.916	*Y04*	-0.062	-0.601
R^2	0.7365		R^2	0.4964	

N = 521

By checking the coefficient size and *t*-ratios for variables *NFSA* and *NREG*, it is clear that:

- Southwest charges lower price when there are more LCCs and/or regional carriers (henceforth "LCC") on the route. The number of FSAs offering nonstop flights does not have any substantial effect on Southwest's prices.
- When there are additional FSAs competing in the market, UA's prices decrease. With Southwest's presence, the number of LCCs in the market does NOT have additional impacts on United's price.

One potential problem with the regressions is that airlines' frequency (variable *Frq*) may be endogenous, leading to biased estimate for the coefficients. To check this, Ordinary Least Square regressions are carried out by removing variable *Frq*. For United airline's price regression, variable *NFSA* is still significant while the variable *NREG* is not significant. However, in the regression for Southwest, both *NFSA* and *NREG* are now significant, with coefficient (*t*-statistics) being -0.046 (-3.54) and -0.073 (-8.24) for the two variables respectively. In both WN and UA's price regressions, the coefficients for frequency shares are of the wrong sign (being negative), a clear sign of omitted variable bias. Two Stage Least Square (2SLS) regressions are performed by treating variable *Frq* as endogenous while using population as *IV*. There is little change in the estimates for United compared to SUR regression results in table 2.7. For WN's price regression, the variables *NFSA* and *NREG* are now both significant, while the coefficient for frequency became negative.

In summary, the estimated coefficients for *NFSA* and *NREG* in UA's price regressions are robust (close estimates in OLS with and without variable *Frq*, close estimates in 2SLS and SUR models). However, for Southwest, there is a possibility that its fare may be sensitive to both FSA competitors and LCCs, depending on which regression specification is used (as evidenced in the regression results from 2SLS and OLS without variable *Frq*.). The different estimation results for Southwest in the above regressions may be caused by the possibility that variable *Frq* is endogenous. Hausman Test for endogeneity is thus carried out for Southwest's fare regression. The null hypothesis that variable *Frq* is not endogenous is rejected at 0.1 level but not at the 0.05 level. As shown in figure 2.3, in Southwest's traffic out of Chicago, only about 60% of the travelers are O-D passengers. That is, the flight frequency between Chicago and other airports is not only determined by the OD passengers considered in our regressions, but also a significant amount of through traffic. This explains the moderate but not strong evidence of endogeneity. Removing variable *Frq* will introduce an omitted variable bias, while keeping this variable may introduce moderate risk of endogeneity. As such, we decide to retain the SUR model as it is.

These results imply that in the post LCC entry period, competition among LCCs and competition among FSAs are much sharper than the competition between LCCs and FSAs.

The coefficients for frequency (*Frq*) and share of frequency (*S*) show that an increase in flight frequency will influence an airline's pricing in two opposite directions: the increase in absolute frequency reduces its price, while the increase in frequency share increases its price. This is intuitively correct as frequency is closely correlated to capacity and output (available seats or OD-Passengers). A firm's output expansion leads to reduction of market price. However, the market power brought by increased market share enables an airline to gain a price premium at the same time. This is consistent with the anecdotal evidence on price correlation: a firm's competition strategy also depends on the market structure. An airline with considerable market power, being an FSA or LCC, would have less incentive to compete with very low fares. On the other hand, the entry of any airline would harm all existing carriers by reducing their market share and market power. Because of product differentiation, such detrimental effect is much more severe for airlines of the same type as the entrant.

The regression results show that frequency expansion effects are similar in size for Southwest and United (-0.126 vs. -0.152). Southwest, however, benefits more than United from an identical increase of frequency share (0.255 vs. 0.040). When using available seats instead of frequencies in the regressions, we found the output expansion effects for Southwest and United are again similar (-0.134 vs. -0.182). Southwest, nevertheless, benefits less than United from an identical increase in share of available seats (0.295 vs. 0.573). This may explain why Southwest had been very aggressive in scheduling more flights despite of its low load factors, while United continues to rely on hub-and-spoke network to combine traffic. Table 2.8 summarizes the key parameters estimated by using available seats instead of flight frequency (variable name *Seat,* the variable *S* stands for share of available seats accordingly). Dummy variables are used but not reported.

Table 2.8 SUR Estimation of Price Equation With Available Seats

WN Price Equation			UA Price Equation		
Parameter	**Estimation**	**t-Ratio**	**Parameter**	**Estimation**	**t-Ratio**
Seat	-0.13428	-7.399	*Seat*	-0.1816	-7.075
LF	-0.000812	-0.9438	*LF*	-0.0085	-6.956
NFSA	-0.008667	-0.6526	*NFSA*	-0.03628	-2.106
NREG	-0.05386	-6.748	*NREG*	0.00474	0.4838
S (seat share)	0.295	3.652	*S(seat share)*	0.5729	5.699
Pax	0.2616	1.407	*Pax*	0.2578	1.058
Dist	0.36177	17.55	*Dist*	0.20366	8.413
Pop	0.16186	6.189	*Pop*	0.05982	1.738
R^2	0.7386		R^2	0.5159	

N=521

Most studies on airline competition, including the current essay, relied on firm level average price or aggregate quantity. This of course is a simplification of reality. Airlines, especially FSAs, produce multiple services. There may be strong competition at the low (or high) range of fares and little competition at other ranges (or vice versa). For example, FSAs may follow LCC's price leadership in the low end market with price matching, but compete with each others for the high end market. We would miss these details if we just look at firm level average prices,

If FSAs are indeed better modeled as producing a full range of services, one would expect that before the entry of a major LCC, an FSA's pricing decision is affected by both LCCs and FSAs. To test this hypothesis, we run similar price regressions for United using the data for the period prior to Southwest's entry.[19] We found that the coefficients for the number of low cost carriers (*NREG*) are always significant. The coefficients for the number of Full Service Airlines (*NFSA*) are not significant, partly due

[19] To get a larger sample, we pooled observations from routes where Southwest entered after 1997 in addition to the 12 routes we used in previous SUR estimations.

to the fact that there has been very few FSA entry and exit in the sample routes. In addition, the coefficients for *NFSA* and *NREG* are comparable in size. This appears to support our hypothesis that before a major LCC's entry, an FSA's pricing will be constrained by both FSAs and LCCs. Further studies formally modeling FSA as a multi-product provider may bring very useful insights.

2.5 Summary and Conclusion

In this essay, we present our results for the firm-specific airline demand systems and the reduced form pricing equations estimated from the quarterly data for the 1990-2004 period on the routes out of Chicago. In particular, the demand estimation used data for routes where United, American and Southwest were always present. The pricing study used data for routes where United and Southwest were always present. Since our study involved routes out of a major hub city (Chicago) and a particularly successful LCC (Southwest), further work may be needed before our findings can be generalized to other markets and LCCs. Still the following results are worth emphasizing:

- The estimated values of the firm-specific price elasticities and cross-elasticities reveal that consumers recognize product differentiation between the services provided by FSAs and LCCs. This finding is strengthened by the results obtained via price equation estimation, and is consistent with the anecdotal evidence of high price correlation between FSAs.
- When we remove the data for the first two quarters after the Southwest's entry (during which most of FSA's initial price responses have occurred), our reduced form fare equations show that FSA's average prices become more sensitive to the

number of FSAs in the market than the number of LCCs present in the market. This shows that competition between FSAs will continue to be important even when a major LCC is present in the market.

- Further we find that Southwest's pricing is much more responsive to the number of LCCs present in the market while being pretty insensitive to the number of FSAs present in the market. This suggests that the services offered by LCCs are more substitutable to each other, so that the competition between LCCs is sharper than the competition between FSAs vis-à-vis LCCs.
- As expected, airlines with higher market shares (regardless of whether they are FSA or LCC) tend to charge higher prices, indicating market dominance effect on pricing. This implies that the presence of a successful LCC alone does not necessarily guarantee sufficient competition in the market.
- For an identical increase in frequency share, Southwest derives higher positive price benefit than United does. This may be one of the major reasons why Southwest had been very aggressive in scheduling more flights in spite of its low load factors.

Our results suggest that after taking into account of product differentiation, the competition between FSAs is important even in the markets where a major LCC is present. Despite of the drastic decrease in average price observed after an LCC entry, the entry and presence of LCC alone does not necessarily guarantee healthy on-going competition between carriers whether it is competition between FSAs or between FSA and LCC. In markets with only one major LCC and one FSA, such as the case of

Australia and Canada, both airlines may have considerable market power (usually, LCC in low-end of the market, and FSA in high-end of the market).

Our results also suggest that although the exit of an FSA would allow all airlines in the market to increase their prices, it would benefit the remaining FSAs much more than LCCs because of the existence of product differentiation. The exit of one or more FSAs from market would have only minor effects on competition in the low end of the product markets. A collorary to this finding is that only an LCC can effectively discipline other LCCs in the market place.

In our sample, since American and United mainly use the O'Hare airport while Southwest exclusively uses the Midway Airport, the product differentiation observed is partly due to airlines' usage of different airports. Gillen and Morrison (2003) argued that the product differentiation between LCCs and FSAs shall be considered when air travel is treated as a service bundle including both airline and airport services. This same assumption is imbedded in our analysis. Such treatment is of course consistent with the reality since most LCCs use secondary airports to conduct business. To separately identify the product differentiation due to airline and airport, we could have used the same methodology but treat an airline's services from primary and secondary airports as two different service bundles. This nevertheless requires a different data sample where each airline uses more than one airport. This is left for future study. In addition, since our study have focused on particular airlines out of a major hub airport, we feel that it is necessary to study further cases and hopefully use larger sample sizes before making a generalization of our results to other airline markets.

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Chapter 3 [20]

An Analysis of Airport Pricing and Regulation in the Presence of Competition Between FSAs and LCCs

3.1 Introduction

The competitive effects of input price increase form an important research and policy topic for two reasons. First, a lack of upstream competition may influence downstream competitiveness and reduce welfare. Secondly, markets with volatile input prices may influence competition in downstream market Both features are clearly present in aviation, where airports with market power provide indispensable inputs to airlines.

This subject is primarily important for the regulation of privatized airports. Starting with the privatization of the three airports in London area (Heathrow, Gatwick, and Stansted) and four other airports in the UK to form BAA plc. in 1987, many airports around the world have already been or are in the process of being privatized. The majority stakes of Copenhagen Kastrup International Airport, Vienna International Airport and Rome's Leonardo Da Vinci Airport have been sold to private owners. Many other European airports are in the process of being privatized. Auckland International Airport and Wellington International Airport in New Zealand and a large number of major Australian airports have been privatized as well. South Africa, Argentina, Mexico and many Asian countries including Japan are also considering privatizing their

[20]The need for doing this essay was stimulated via my participation in an anti-trust case between Sydney Airport and Virgin Blue Airlines before the Australian Competition Tribunal, the project for which was coordinated and supervised by Professor Tae H. Oum. I was responsible to develop analytical models and conduct numerical simulations for the project. Based on the findings of this study, a paper coauthored by the expert witness team of the case was published: Fu, Lijesen and Oum, "An analysis of Airport Pricing and Regulation in the Presence of Competition Between FSAs and LCCs", JTEP Vol. 40. pp. 425-447.

airports.[21] Canada has been reviewing the regulatory oversight issues on its local airport authorities which were set up as not-for-profit corporations to manage major airports.

Since the late 1990s economists have been arguing whether privatized airports need to be regulated in the first place. Studies of country-specific options and experiences on this issue include Forsyth (1997, 2002a, b), Beesley (1999), Starkie and Yarrow (2000), and Starkie (2001). In particular, Beesley (1999) argues that the price-cap regulation is inappropriate, particularly in the case of London's Heathrow. Starkie (2001) further concludes that *ex-ante* regulation for airports might be unnecessary because the airports are less likely to abuse their monopoly power due to the existence of complementarity between the demand for aviation services and the demand for concession and other commercial services (concession).[22] The latter usually associated with larger margins because of duty/tax free sales

Indeed, some countries have moved towards a situation in which there is no formal price regulation but only monitoring of privatized airports (Forsyth, 2002b). For example, New Zealand and Australia do not formally impose any price regulation on their privatized airports. Instead, since 1988, Auckland, Christchurch and Wellington airports have been required to disclose contractual terms, financial reports and some performance measures. In Australia, primarily based on the recommendation of the Productivity Commission,[23] on 1 July, 2002 the government ended the price-cap

[21] See Hooper (2002) for the list of Asian airports that are being considered for privatization.
[22] Besides *ex-ante* regulation (ROR, price-cap), there is also *ex-post* regulation (conduct regulation). It is important to point out that those economists who argue for deregulation usually have the former in mind and are not proposing that conduct regulation be abolished also.
[23] Unlike the Productivity Commission, however, the Australian Competition and Consumer Commission (ACCC) opposed the removal of price-cap regulation.

regulation on all privatized airports for a period of five years.[24] Towards the end of the five-year test period an independent review will be conducted in order to decide whether or not some sort of price regulation needs to be re-established.

Some evidence suggests that the airports attempted to raise prices after deregulation, and interested parties have had considerable concerns that airports may abuse their market power. Three regulatory reviews were conducted in New Zealand after the 1988 deregulation, the last of which started in May 1998 and took five years to finish. In Australia, Virgin Blue applied to the Australian Competition Tribunal to declare airside services at the Sydney Airport as commercial services to be treated according to the Trade Practices Act of Australia (TPA). The Declaration of the airside services at the Sydney Airport under the TPA would have forced the Sydney Airport's management to negotiate with the airlines before setting new fees or changing existing levels of airside service fees including aircraft landing charges. In case there is a major disagreement between the airport and the airlines, then the matter is referred to a binding arbitration by the Australian Competition and Consumer Commission (ACCC). Virgin Blue, a major LCC in Australia, believes that Sydney Airport under the current system has the ability and incentive to increase airside service charges substantially, and thus harm Virgin Blue's ability to compete. Interestingly, Virgin Blue's major competitor, Qantas Airlines, supported the Declaration Application.

The subject of the research treated in this essay has been motivated by my involvement in the Virgin Blue vs. Sydney Airport case before the Australian

[24] At the same time, the Parliamentary Secretary to the Treasurer directed the Australian Competition and Consumer Commission (ACCC) to undertake formal monitoring of prices, costs and profits (Price Monitoring) related to the supply of aeronautical services and related services at seven major airports: Adelaide, Brisbane, Canberra, Darwin, Melbourne, Perth and Sydney airports.

Competition Tribunal. This essay reports some analytical results obtained during our investigation for the case. In particular, we analyze how an increase in airport charges would affect the downstream airline competition, especially when competing airlines offer differentiated products (services) in the market place such as the case of competition between low cost carriers and full service airlines. A duopoly model with differentiated products is used to obtain analytical results. Due to strict confidentiality restrictions on the rich data to which we had access, however, we are not able to report empirical results obtained from using real market data. Instead, a numerical simulation and sensitivity tests on key parameters of our model are used to validate our analytical results on the differential effects of an identical increase in airside service charges on FSAs and LCCs.

Although we focus our analysis on air transport industry, our approach to analysis is likely to have a wider application to other industries and markets where a monopolist provides an essential input to competing firms in downstream markets. Other network-oriented industries such as railroads, seaports, electric power industries, and telecom local loop have limited competition in upstream markets due to the natural monopoly nature of these networks. The third party access pricing issue has been an important research topic in some of such network sectors, notably in telecommunication and energy networks. The third party access to the network is an important condition for effective competition in network sectors.[25] The third party access refers to both the possibility of access and the conditions under which the access can take place. One important condition is the price under which access is granted, i.e., the access fee.

[25] See, for instance Laffont *et al.* (1998), Lewis and Sappington (1999) and Granderson (2000)

The remainder of this essay is organized as follows. Section 3.2 discusses theoretical derivation of the impact of an identical increase in input prices (e.g., airport's airside service fees) on competition in the downstream airline markets. A numerical simulation and results are presented in Section 3.3. The final section concludes and discusses the results.

3.2 The Competitive Effects of Increase in Airport Charges on Competition in Downstream Airline Markets

As airports provide essential inputs to airlines, it follows immediately that when the airport charge is increased above socially optimal level (competitive level), air travel volume will be reduced below socially optimal level, leading to a welfare loss. This issue has been extensively studied in the literature of double marginalization and natural monopoly regulation. However, so far the impact of airport charges on downstream airline competition has received little attention. Even less attention has been given to the impacts of changing airport charges on the competition between Full Service Airlines (FSAs) and Low Cost Carriers (LCCs).

This problem is worth a scrutiny since LCCs' activities have been more sensitive to airport charges. Many LCCs around the world actually started their business by using secondary airports taking advantage of their lower airport charges and less congestion. For example, Ryanair could not have achieved such a successful service in the Dublin-London route if they had to use Heathrow airport. Also, it is well known that Southwest typically starts their operations at secondary airports in the United States. European LCCs, especially Ryanair, drive a hard bargain with airports and local business interests in order to extract best charges and service conditions. Some LCCs are apparently successful in gaining a subsidy from the airport for an initial period of their service initiation. The agreement between Brussels' Charleroi Airport and Ryanair was investigated by the European Commission as the commercial assistance to Ryanair by the airport was regarded as constituting an illegal state subsidy (Piling, 2003).[26] Ryanair paid, on average, $1 or less per passenger to eight provincial UK airports during the 1998 – 2000 period while the average aeronautical revenue at major airports in Europe were above $8 per passenger (Barrett 2004). LCCs' high sensitivity to airport charges is also evidenced by the fact that some LCCs chose to abandon an airport if they didn't succeed in negotiating for a deep discount on airport charges, especially when an airport seeks to recover investments made during its "promotional" periods. For example, Dublin, London's Luton airport and Manchester have experienced a reduction in LCC services after revising low airport charges they offered initially (see Francis, Fidato and Humphreys (2003) and Barrett (2000)). All of these suggest that LCCs are more sensitive to the terms of airport access than FSAs. Meanwhile, LCCs have been credited as a major contributor to airline competition and air fare reduction, as documented, for example, in Dresner, Lin and Windle (1996), Windle and Dresner (1999), Lin, Dresner and Windle (2001) and Hofer, Dresner, and Windle, (2004). In particular, Morrison (2001) estimated that in 1998, the savings due to actual, adjacent, and potential competition from Southwest were $12.9 billion. These savings amount to 20 percent of the U.S. airline industry's 1998 domestic scheduled passenger revenue and slightly more than half the fare reductions attributed to the U.S. airline deregulation. Understanding the

[26] In February 2004, EC declared that certain parts of such support violated European Union state aid rules. Ryanair was asked to repay EUR 4 million to the airport, but the airline reserved the right to appeal. (Aviation Daily, Nov 1, Vol.358, Iss. 22; pg. 6, 2004).

possible differential impacts of airport charge on LCCs and FSAs is, therefore, of a great importance to airport regulators and airline competition policy makers. Below, we begin our analysis by constructing a duopoly model between an LCC and an FSA.

3.2.1 A Duopoly Competition Model with Differentiated Products

Most previous studies have analyzed the effect of LCC entry and competition in airline markets without explicitly treating product differentiation between FSA and LCC. The implicit assumption that the competitors produce a homogenous product is embedded in many of such models and also in the reduced-form price equations often estimated by researchers. However, the assumption of homogeneous product is not realistic for modeling the competition between FSA and LCC. Both FSA and LCC offer multiple products in the market. FSAs typically offer a combination of first class and business class, full fare economy, shallow discount, and a fair amount of deep discount services. LCCs are well known for selling cheap deep discount tickets over point-to-point markets. Most LCCs do not offer on-line / interline connections or baggage transfer. Though LCCs also offer increasingly flexible services comparable to full fare economy and shallow discount tickets being sold by FSA, overall FSAs offer a superior product compared to LCCs but at higher costs. Previous studies such as Windle and Dresner (1999) and US Department of Transportation (1996) confirm that LCCs in general target more price sensitive travelers with inferior services. In chapter 2 of this dissertation, the empirical analysis on airline competition in the presence of a major LCC also provides strong evidence of product differentiation between FSAs and LCCs. In addition, LCC and FSA may behave differently in competition, as evidenced by their different entry and competition strategies found in previous LCC studies. Therefore, explicitly considering product differentiation and firm conduct are crucial for the evaluation of any change in external conditions such as changes in input prices, taxes, security charges, etc.

To analyze the competition between an FSA and an LCC taking into account of the product differentiation formally, we construct a differentiated duopoly model similar to those used by Dixit (1979) and Singh and Vives (1984). Throughout this section, we designate the FSA as firm 1 and the LCC as firm 2. These two firms face the following respective inverse demand functions over each city pair market.

$$\begin{cases} p_1 = a_1 - b_1 q_1 - k q_2 \\ p_2 = a_2 - k q_1 - b_2 q_2 \end{cases} \tag{3.1}$$

where p_i and q_i are the prices and quantity for airline i, respectively, while k measures the degrees of substitutability between the two airlines' services. The demand functions in (3.1) correspond to a representative consumer maximizing a quadratic and strictly concave utility function $U(q_1, q_2) = a_1 q_1 + a_2 q_2 - \frac{1}{2}(b_1 q_1^2 + 2k q_1 q_2 + b_2 q_2^2) + q_0$, where q_0 represents the numeraire good (money). The concavity condition implies $b_1 b_2 - k^2 > 0$.

The system of demand functions in (3.1) can be rewritten as:

$$\begin{cases} q_1 = \dfrac{1}{b_1 b_2 - k^2}[(a_1 b_2 - a_2 k) - b_2 p_1 + k p_2] \\ q_2 = \dfrac{1}{b_1 b_2 - k^2}[(a_2 b_1 - a_1 k) + k p_1 - b_1 p_2] \end{cases} \tag{3.2}$$

The condition of positive output quantities for both firms implies:

$$(a_1 b_2 - a_2 k) > 0 \text{ and } (a_2 b_1 - a_1 k) > 0 \tag{3.3}$$

The demand functions can be depicted as in figure 3.1, based on our empirical knowledge on FSA and LCC markets:

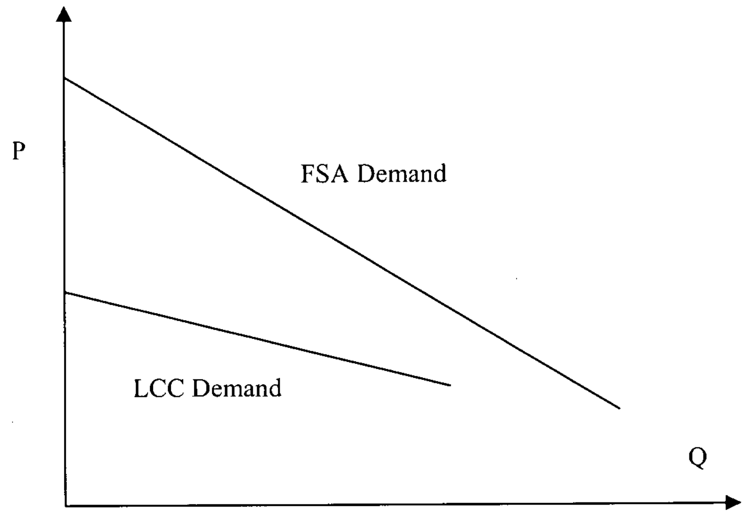

Figure 3.1 Stylized Demand System for an FSA and an LCC

Since LCCs focus on price-sensitive customers, they normally face more price-elastic demand. Utilizing the fact that, in general, a change in a firm's price impacts more on quantity of its own product than on quantity of the substitutes (competitor's output), the following additional constraints can be imposed:

$$\begin{cases} a_1 > a_2 > c_1 \\ b_1 > b_2 > k > 0 \end{cases} \tag{3.4}$$

Where c_i are firms' constant marginal costs. We restrict to the case where two firms produce substitutes to compete, which implies $k > 0$ and $a_2 > c_1$ used in (3.4).[27] Although mathematically, our duopoly model does not need condition $c_1 > c_2$, this condition is likely to hold in airline markets.

With these demand functions, the two firms maximize their profits $\pi_i = (p_i - c_i)q_i$. Assuming that both firms maximize profits by setting output quantities, then the First Order Condition (FOC) for firm i may be written as:

$$\frac{\partial \pi_i}{\partial q_i} = -(b_i + k\frac{\partial q_j}{\partial q_i})q_i + a_i - b_i q_i - kq_j - c_i = 0 \qquad (3.5)$$

where we can denote firm i's conduct parameter as $v_i = \frac{\partial q_j}{\partial q_i}$. Following Brander and Zhang (1990), Graddy (1995), Oum, Zhang and Zhang (1993) and Genesove and Mullin (1998), we treat such conduct parameter as a summary measure of firms' conduct. As Graddy (1995) described, such conduct parameter is "an index that measures the competitiveness of firm conduct in each market". It is also an indicator of what types of game firms play.[28] When firm's competition behavior are different in the same market, the conduct parameters of each firm is also different, as have been observed in empirical studies by Iwata (1974), Brander and Zhang (1990), Oum, Zhang and Zhang (1993) and Feenstra and Levinsohn (1995). Since conduct parameter can also be viewed as an

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[27] If $k = 0$, then the two firms offer totally independent products (no substitutability). As k approaches b_1 and b_2, or $\sqrt{b_1 b_2}$, two firms offer increasingly homogenous products.

[28] In particular, a zero conduct parameter corresponds to *Cournot* competition, while the value of -1 corresponds to *Bertrand* competition. When firms collude such that one airline's output reduction is accompanied by its competitor's output reduction, both firms' conduct parameters will be positive. We have not analyzed the case of collusion between the duopoly airlines in our model, i.e., the case of positive conduct parameters for firms 1 and 2, because none of the past empirical studies have found collusive behavior between an FSA and an LCC in a deregulated air transport market.

elasticity adjusted Lerner index, *ceteris paribus*, a lower conduct parameter implies the firm's price is closer to its marginal cost. That is, a lower conduct parameter of an airline means this airline behaves more competitively or prices more aggressively.

Firm 1 and 2's FOCs define their respective reaction functions, which constitute the following system of equations:

$$\begin{cases} a_1 - (2b_1 + kv_1)q_1 - kq_2 - c_1 = 0 \\ a_2 - kq_1 - (2b_2 + kv_2)q_2 - c_2 = 0 \end{cases} \tag{3.6}$$

When the two firms do not collude in the market, we have $-1 \le v_i \le 0$, which implies:

$$\begin{cases} m = (2b_1 + kv_1) > b_1 > k > 0 \\ n = (2b_2 + kv_2) > b_2 > k > 0 \end{cases} \tag{3.7}$$

Note that our earlier restriction that $b_1 > b_2$ implies that $m>n$ for all $v_1 \ge v_2$. Solving the system of First Order Conditions leads to firms' equilibrium outputs given each firm's conduct parameter:

$$\begin{cases} q_1 = \dfrac{n(a_1 - c_1) - k(a_2 - c_2)}{mn - k^2} \\ q_2 = \dfrac{m(a_2 - c_2) - k(a_1 - c_1)}{mn - k^2} \end{cases} \tag{3.8}$$

That is, each firm's output depends on the degree of product differentiation between two airlines' services (as measured by k),[29] firms' costs and conduct. Since $(mn - k^2) \geq [b_1 + (b_1 - k)][b_2 + (b_2 - k)] - k^2 > 0$, positive output implies that

$$\begin{cases} n(a_1 - c_1) - k(a_2 - c_2) > 0 \\ m(a_2 - c_2) - k(a_1 - c_1) > 0 \end{cases} \tag{3.9}$$

Restrictions in equation (3.9) ensure that two firms' reaction functions intersect each other so that a unique Nash Equilibrium exists. This is depicted in the following stylized figure 3.2. Where r_1 and r_2 are firm 1 and 2's reaction functions respectively, and $A = \frac{a_1 - c_1}{k}$, $B = \frac{a_2 - c_2}{n}$, $C = \frac{a_1 - c_1}{m}$, $D = \frac{a_2 - c_2}{k}$ are the points where these reaction functions intersect with each firm's output axis.

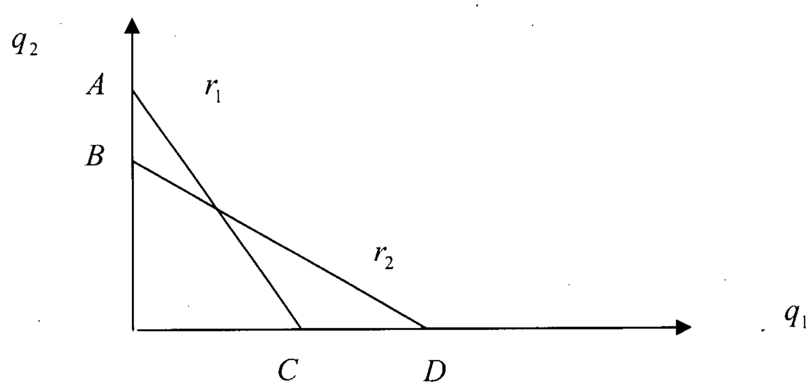

Figure 3.2. Two Firms' Reaction Functions Intersect

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[29] More precisely, the degree of product differentiation depends on the relative values of k, b_1 and b_2 in equation (3.1). In fact, $k^2/(b_1 b_2)$ may be regarded as a more appropriate measure of product differentiation.

3.2.2 Analytical Results on Firms' Outputs

As in the previous section, let us look at the effect of an identical increase in input prices (i.e. $dc_1 = dc_2 = dc$) on both firms' outputs. By applying such an input price increase to the system of equations in (3.8), we obtain:

$$\begin{cases} dq_1 = \left(\dfrac{\partial q_1}{\partial c_1} + \dfrac{\partial q_1}{\partial c_2} \right) dc = -\dfrac{n-k}{mn-k^2} dc \\ \\ dq_2 = \left(\dfrac{\partial q_2}{\partial c_1} + \dfrac{\partial q_2}{\partial c_2} \right) dc = -\dfrac{m-k}{mn-k^2} dc \end{cases} \tag{3.10}$$

Note it can be shown that $\dfrac{\partial^2 q_i}{\partial c \partial v_i} > 0$, implying that a firm's rate of output reduction caused by an identical input price increase[30] ($\dfrac{dq_i}{dc}$) will accelerate as its conduct parameter v_i becomes larger in negative value.

It can be seen that when two firms have similar firm conduct in competition ($v_1 = v_2 = v$), $k < (n = 2b_2 + kv) < (m = 2b_1 + kv)$, one has $|dq_1| < |dq_2|$. This result means that when duopoly firms adopt a similar strategy in setting quantity (when firms have the same conduct parameter, such as in Bertrand competition, Cournot competition or any form of competition in between), then the firm facing less price-elastic demand will end up reducing its output less than its competitor (the firm facing higher price-elastic demand). In our case, when an FSA and an LCC have similar firm conduct, the equilibrium passenger volume of LCC will be reduced more than that of FSA when an

[30] Let $\dfrac{dq_i}{dc} = (\dfrac{\partial q_i}{dc_1} + \dfrac{\partial q_i}{\partial c_2})$ be firm i's the rate of output reduction caused by an identical input price increase given two firm's conduct parameters.

identical increase in input prices occurs to both firms. It is important to note that this finding is strengthened if we assume that the LCC behaves more competitively than the FSA, implying $0 \geq v_1 > v_2 \geq -1$.

Then, what can we say about the relative reduction in outputs of the two firms from equations (3.10)? To answer this question, we express equation (3.10) in relative terms as below:

$$\begin{cases} \dfrac{dq_1}{q_1} = -\dfrac{n-k}{n(a_1-c_1)-k(a_2-c_2)}dc \\ \\ \dfrac{dq_2}{q_2} = -\dfrac{m-k}{m(a_2-c_2)-k(a_1-c_1)}dc \end{cases} \tag{3.11}$$

It can easily be shown that $(a_1 - c_1) > (a_2 - c_2)$ is a sufficient condition to ensure that the LCC's output is affected proportionally more than the FSA's output.

As c_i denotes the constant marginal costs of carrying one additional passenger, whereas a_i is the highest evaluation (for the first unit of consumption) for the service, we should have $a_i >> c_i$, which in general leads to $(a_1 - a_2) > (c_1 - c_2)$ when two firms' services are fairly differentiated. However, if firm 1 and firm 2 offer almost homogenous product (implying $a_1 \approx a_2$), then it can be shown that the firm with higher marginal cost will lose proportionally more output.

3.2.3 Analytical Results on Firms' Prices

Let us now turn our attention to the effects of the identical input price increase on air fares. With each firm's outputs at the equilibrium, the prices of each product can be obtained by substituting the equilibrium outputs in equation (3.8) into the respective demand functions:

$$\begin{cases} p_1 = \dfrac{(a_1 n - a_2 k)(m - b_1)}{mn - k^2} + \dfrac{b_1 n - k^2}{mn - k^2} c_1 + \dfrac{k(m - b_1)}{mn - k^2} c_2 \\ \\ p_2 = \dfrac{(a_2 m - a_1 k)(n - b_2)}{mn - k^2} + \dfrac{k(n - b_2)}{mn - k^2} c_1 + \dfrac{m b_2 - k^2}{mn - k^2} c_2 \end{cases} \tag{3.12}$$

Each firm's equilibrium price increase caused by the input price increase dc can be written as:

$$\begin{cases} dp_1 = (\dfrac{\partial p_1}{\partial c_1} + \dfrac{\partial p_1}{\partial c_2}) dc = (1 - \dfrac{(m - b_1)(n - k)}{mn - k^2}) dc < dc \\ \\ dp_2 = (\dfrac{\partial p_2}{\partial c_1} + \dfrac{\partial p_2}{\partial c_2}) dc = (1 - \dfrac{(m - k)(n - b_2)}{mn - k^2}) dc < dc \end{cases} \tag{3.13}$$

This means when the two firms' input prices increase by an identical amount, neither firm will fully pass the cost increase to passengers. This result is consistent with the fact that both firms face negatively sloped demand curves as depicted in figure 3.1.

3.2.4 Analytical Results on Firms' Profits

It can also be shown that in general, the FSA's profit will be proportionally less harmed by an identical increase in input prices. To show this, the two firms' profit functions can be written as:

$$\begin{cases} \pi_1 = (p_1 - c_1) q_1 = \dfrac{m - b_1}{(mn - k^2)^2} [n(a_1 - c_1) - k(a_2 - c_2)]^2 \\ \\ \pi_2 = (p_2 - c_2) q_2 = \dfrac{n - b_2}{(mn - k^2)^2} [m(a_2 - c_2) - k(a_1 - c_1)]^2 \end{cases} \tag{3.14}$$

Therefore, an identical increase in input prices dc will change firms' profit by:

$$\begin{cases} d\pi_1 = (\dfrac{\partial \pi_1}{\partial c_1} + \dfrac{\partial \pi_1}{\partial c_2})dc = -2\dfrac{m-b_1}{(mn-k^2)^2}[n(a_1-c_1)-k(a_2-c_2)](n-k)dc \\ \\ d\pi_2 = (\dfrac{\partial \pi_2}{\partial c_1} + \dfrac{\partial \pi_2}{\partial c_2})dc = -2\dfrac{n-b_2}{(mn-k^2)^2}[m(a_2-c_2)-k(a_1-c_1)](m-k)dc \end{cases} \tag{3.15}$$

Like before, $(a_1 - c_1) > (a_2 - c_2)$ is a sufficient condition to ensure that the full service airline is proportionally less affected. However, as we have shown that firms' positive outputs imply equation (3.9), from which it immediately follows that $d\pi_1 < 0$ and $d\pi_2 < 0$ whenever $dc > 0$. That is, although FSA will be proportionally less harmed by such an identical input price increase, its profitability will always be reduced.[31] As such, unless the FSA is sure that such identical input price increase will drive the LCC out of the entire market, it is not in the FSA's interest to adopt the strategy of "Raising Rival's Cost", at least not in the form of encouraging an airport to raise the user charges it imposed on airlines (in such a way to increase marginal passenger costs of both airlines by an identical amount). This may explain why Qantas joined Virgin Blue's declaration application. Although a price increase by Sydney airport would harm Virgin Blue more than it does to Qantas (thus creating some competitive advantage for Qantas), it is unlikely that Virgin Blue will be forced to abandon all markets to/from Sydney airport.

Although these results are derived from the assumption that firms have constant marginal costs, our general conclusions are likely to hold because fixed costs at route level are likely to be small both for FSAs and LCCs. Note that these results derived from

[31] In theory, a cost increase may make firms better off, see for example, Seade(1985). Such profitable cost increase hasn't been reported in the air transport industry. Instead, when fuel price increases, or security charges are introduced, airlines' profits tend to decrease. We thus choose not to discuss such possibilities in this essay.

the route-level analysis may not hold at any company-wide or even at airport-level decisions.

3.2.5 Summary of Analytical Results:

From the duopoly model of FSA vs. LCC competition with product differentiation, we find that:

- An identical increase in input prices will harm an LCC more than an FSA as the former suffers proportionally more reduction of its output and profit than the latter;
- Neither the FSA nor the LCC can fully pass on such an external input price increase to consumers. Both firms are worse off.
- When the LCC behaves more competitively, an identical increase in input prices would lead the LCC to reduce its output quantity by a larger amount than the FSA, implying a more serious harm to LCC.

That is, an identical input price increase will proportionally harm the LCC more.[32] Although such an identical input price increase, such as per-passenger airport service charge, or government imposed per-passenger security charge is likely to only constitute a small proportion of the total unit costs, its impacts may be non-trivial. As most airlines are currently operating at barely breakeven level, such input price increase will further reduce these airlines' profitability, possibly forcing them to reduce service levels or cease

[32] In practice, many LCCs use secondary airports which typically charge lower prices. However, consumers may value such services less (smaller a_2, and possibly smaller b_2) and/or treat them as an inferior substitute to FSA services (smaller k). Although our general conclusions are likely to hold even in such cases, the extent of differential impact on LCC vs. FSA in such cases is really an empirical question which depends on demand and cost parameters of LCC and FSA as well as the existing pricing structures of the primary and the secondary airports.

operations on some routes altogether. Another important implication of such asymmetric impacts is that when an airport increases its service charge, LCCs will find them disadvantaged in the competition with FSAs in the routes out of this airport. This will further discourage LCC entry into those airports, which could cause negative effects to airline competition.

We have shown that in theory, although an FSA's outputs and profits will be less impacted negatively by an external factor leading to an identical increase in per-passenger marginal cost (input price) to both FSAs and LCCs (and thus, creating a competitive advantage over an LCC), an FSA will not adopt the "Raising Rival's Cost" strategy by encouraging airports to raise airside user charges unless it is sure that such cost increase will drive the LCC totally out of the market.

3.3 Numerical Simulation and Sensitivity Test

Many cases involving the competition between LCC and FSA pose special challenges for empirical analysis because of the often disequilibrium nature of market data. For example, an LCC enters the market with significantly lower prices than FSAs. In this situation, FSAs often respond to the challenge by allocating more seats to deep discount fare category and thereby lowering their average price. At the same time, FSAs lose their market shares (and often traffic volumes) as they reduce their average air fares progressively while the LCC keeps its initial low prices at the similar level for some time. The market data on Qantas and Virgin Blue revealed such disequilibrium nature of the market during our sample period. In other words, Qantas was losing passenger shares while it reduced air fares, but Virgin Blue was gaining passenger shares although it maintained similar (low) prices introduced at the time of entry. Therefore, it is impossible to estimate a sensible econometric model from such a short term data set. Therefore, we had to rely on numerical simulations in order to measure the differential effects of increasing airside service charges on Qantas and Virgin Blue as well as validating our analytical results.[33]

The parameter values used in this section mimic a realistic air transport market, but they don't represent any particular city pair market we studied because of the confidential nature of the route-specific data we received from Qantas and Virgin Blue. All parameters used in our model met the assumptions and constraints described in section 3.2, and reflect our best estimate based on our understanding of the air transport markets, in particular in the markets where an FSA and an LCC compete.

Assumptions:

We start with the likely values for some of the parameters so that the differentiated duopoly model described in section 3.2 can be calibrated. This base case provides some numerical results which enable one to appreciate the differential impacts of an identical increase in input prices on an LCC and an FSA. Sensitivity tests are used so that we are sure these results hold for any reasonable ranges of the parameter values. The assumptions we made for the base case are:

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[33] Even though FSAs and LCCs have been competing in U.S. airline markets for a long time, to our knowledge, few empirical industrial organization studies have been carried out on the differentiated product competition between LCCs and FSAs probably because of the fact that detailed airline and route specific cost data are often not accessible by researchers. The empirical analysis conducted in chapter 2 of this thesis provides strong evidence for product differentiation between FSAs and LCCs. The estimated parameters however can not be directly applied in this essay as they are obtained in oligopoly markets. As shown in chapter 2, an airline's competition strategy and firm specific elasticity change with its market position (market share). In addition, firm conducts were not explicitly treated in chapter 2.

- Conduct Parameters: We limit our analysis to non-collusive games, thus limiting ourselves to non-positive values for v_1 and v_2. The base values we choose are $v_1 = v_2 = -0.5$.

- b_1, b_2 and k: constraint (3.4) requires $b_1 > b_2 > k$. Parameter k measures how different the services provided by the two firms are. Let $k = t \cdot b_1$ $(0 < t < 1)$, then if $t = 0$ the two firms' services are not substitutes at all, while $t = 1$ indicates that the FSA and LCC produce homogenous services. Our base case assumes $t = 0.7$. We also assume $b_2 = \frac{b_1 + k}{2}$ so that constraint (3.4) is always satisfied.

- Market price elasticity for air travel: -1.4.[34]

- Each firm's equilibrium price: we assume FSA's price at $p_1 = \$100$ while the LCC's price is assumed to be 25% lower, i.e., $p_2 = \$75$.

- Each firm's equilibrium output: We assume that at equilibrium the FSA has a 60% market share carrying 60,000 passengers each month.

Base Case Model Results:

With the above assumptions, other parameters of the model can be derived as follows:

- Market output $Q = q_1 + q_2 = 100{,}000$ passengers per month.

[34] This price elasticity of -1.4 is used as what I considered as a medium value of elasticity estimation reported in the literature. Battersby and Oczkowski (2001) conduct an empirical analysis of domestic Australian markets. The markets have elasticities ranging of -1.68 and -1.63 for economy and -0.58 and -1.11 for business. The value used in this essay (-1.4 on average for all services) is also within the range of previous findings on air travel demand elasticity. The elasticity survey paper by Oum, Waters and Yong (1992) give an overview of previous elasticity studies. They report values for leisure travel ranging from -0.4 to -4.6. For business travelers, the values range from -0.65 to -1.15.

- Market price $P = \dfrac{p_1 q_1 + p_2 q_2}{Q} = \$90$

- b_1: When both firms experience an identical price change $dp_1 = dp_2 = dp$, or an equivalent market price change of $dP = dp$, from the demand equation in (3.1) the total change in market output can be obtained as $dQ = dq_1 + dq_2 = \dfrac{2k - b_1 - b_2}{b_1 b_2 - k^2} dp$. As market elasticity $e = \dfrac{dQ}{dP}\dfrac{P}{Q}$ is known, one can derive $b_1 = -\dfrac{3P}{e(2t+1)Q} = 0.0008$.

Table 3.1 reports the base case values of other parameters that we derived:

Table 3.1: Derived Parameter Values for Base Case

Parameters	b_2	c_1	c_2	a_1	a_2	e_{11}	e_{22}
Value	0.00068	68.7	58.9	170.7	136.1	-4.9	-6.48
Parameters	k	m	n	π_1	π_2	e_{12}	e_{21}
Value	0.00056	0.00133	0.00108	1,880,357	642,857	3.02	6.05

Note e_{ii} are firm's own price elasticity, while e_{ij} measures firm *i*'s cross elasticity with respect to firm *j*'s price. They have the correct signs and are within a reasonable range.[35] With all of the parameter values, it is straightforward to calculate the impact of an identical increase in input prices. The results are summarized in table 3.2 below.

[35] Few studies have empirically estimated firm specific elasticity for airlines. Oum, Zhang and Zhang (1993) reported that UA and AA's firm specific elasticities are significantly above market elasticity. In many leisure routes the two firms' firm specific elasticity were as high as around -10.

Table 3.2 Changes in Market Equilibrium Caused by Different Amounts of Increase in Airport Charge

Airport Charge Increase	$1	$2	$3	$5	$6
$\%\Delta q_1$	-0.8%	-1.6%	-2.3%	-3.9%	-4.7%
$\%\Delta q_2$	**-1.7%**	**-5.1%**	**-6.0%**	**-8.5%**	**-10.2%**
$\%\Delta p_1$	0.8%	1.5%	2.3%	3.8%	4.5%
$\%\Delta p_2$	**1.0%**	**1.9%**	**2.9%**	**4.8%**	**5.8%**
$\%\Delta \pi_1$	*-1.5%*	*-3.1%*	-4.6%	-7.6%	-9.1%
$\%\Delta \pi_2$	**-3.4%**	**-6.7%**	**-9.9%**	**-16.3%**	**-19.4%**
$\%\Delta P$	0.9%	1.8%	2.7%	4.5%	5.4%
$\%\Delta Q$	-1.1%	-2.3%	-3.4%	-5.7%	-6.9%

As expected, table 3.2 shows that the reductions in LCC's outputs and profits are larger than those of the FSA for all levels of increases in airport charges simulated, implying proportionally larger negative effects on the LCC. Although the market price elasticity in the base case is only assumed to be -1.4, the corresponding LCC's firm-specific price elasticity is much larger in absolute value ($e_{22} = -6.48$). Together with its low cost, it is not surprising that even a moderate increase in airport charge will reduce its profitability significantly. One should note that the LCC's price for the base case was assumed to be $75. The reduction in airline's profitability will be more moderate for longer distance (more costly) routes. In the base case, the FSA loses fewer passengers and passes on a greater proportion of the cost (airport charge) increase to passengers. These are, of course, entirely consist with our analytical results.

There are two major assumptions in our simulation: value of firms' conduct parameters, and parameter t (k) which measures the extent of product differentiation between LCC and FSA. Few studies estimated conduct parameters empirically using airline data on LCCs and FSAs. Haugh and Hazledine (1999) and Hazledine, Green and

Haugh (2001) are exceptions that we are aware. Although their studies found that the LCC does have lower conduct parameter in the trans-Tasman market, they obtained this result based on calibration of their models instead of estimating the model parameters empirically from the real data. Thus it is necessary for us to conduct a sensitivity test on a plausible range of conduct parameter values in order to test the sensitivity of our results.

First, we set firm 1's conduct parameter to -0.5 ($v_1 = -0.5$) and simulate market equilibrium as we change firm 2's conduct parameter v_2 from 0 to -1, with an interval of 0.1. We calculate all of the model parameters corresponding to each pair of the conduct parameters, and then simulate the effects of increasing marginal costs for both carriers by a \$1. Such tests are repeated for the t values of 0.5, 0.6, 0.7, 0.8 and 0.9 so that k takes values in the range of $[0.5b_1, 0.9b_1]$, respectively.

We plot curves for ratio of the two firms' passenger reduction percentage $y = (\frac{dq_2}{q_2})/(\frac{dq_1}{q_1}) = \frac{\%\Delta q_2}{\%\Delta q_1}$ in figure 3.3. All of the curves showing the ratio of percentages of the LCC-FSA output reduction are upward sloping, implying that when the LCC has lower conduct parameter, the more it behaves competitively, the larger its relative output reduction is from an identical increase in input prices. Figure 3.3 shows also that the curve for a higher value of t is steeper than the ones for lower t values at the higher absolute values of the conduct parameter. This indicates that competition becomes more important as products become closer substitutes. Let us consider the extreme case (not in the figure) where the goods are no longer substitutes (i.e. $t = 0$). In this case, the output reduction ratio curve in the figure would become a horizontal line, implying the absence of any effect of changing conduct parameter for LCC (v_2). This makes sense, since $t = 0$ implies that both firms are monopolists in their respective markets.

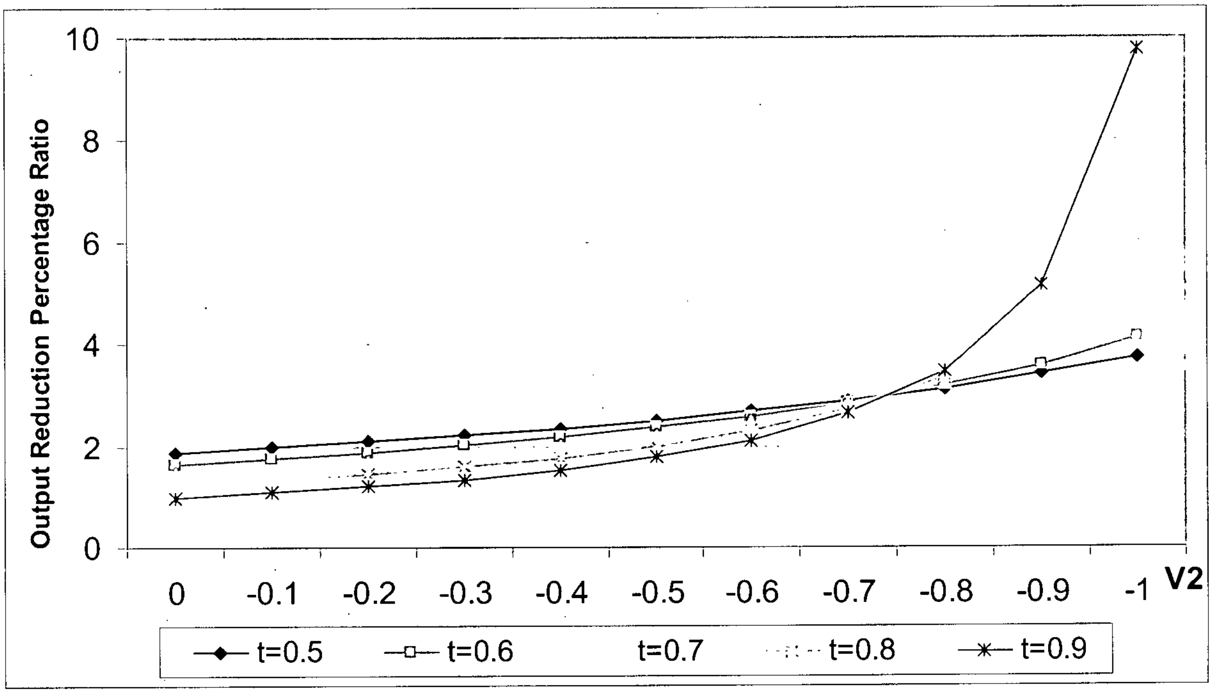

Figure 3.3. Output reduction ratio* (dc=$1)

(*The ration is defined as $y = \dfrac{\%\Delta q_2}{\%\Delta q_1}$, firm 2's conduct parameter v_2 changes while v_1 fixed as -0.5)

The corresponding differential changes in two firms' profits, $|\%\Delta\pi_2| - |\%\Delta\pi_1|$ are plotted as in figure 3.4. Note that since $\Delta\pi_i$ is negative for both firms, a positive differential number indicates that the LCC suffers more profit reduction proportionally.

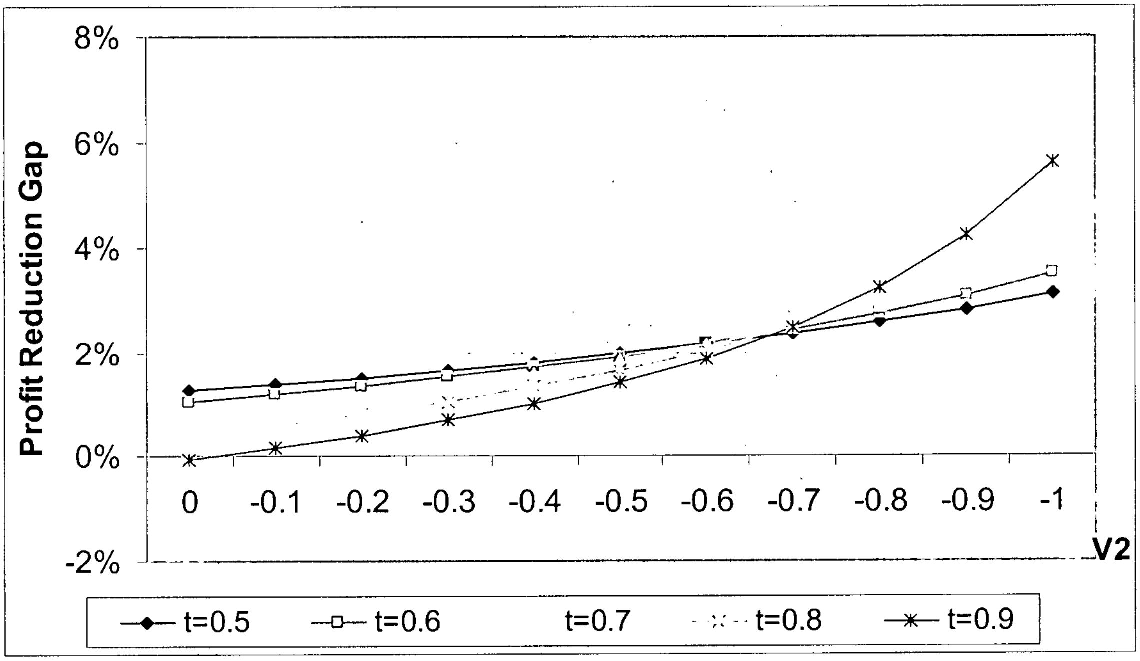

Figure 3.4 Profit reduction gap* (dc=$1)

(*The profit reduction gap is defined as $y = |\%\Delta\pi_2| - |\%\Delta\pi_1|$,

firm 2's conduct parameter v_2 changes while v_1 fixed as -0.5)

The profit reduction ratio curves are upward sloping, suggesting that the LCC's profit will be reduced more from an identical increase in input prices if it has a lower conduct parameter. Note that the curve for a high value of *t* is steeper than the ones for lower *t* values. This reflects again that competition becomes more important as products become closer substitutes. It can be seen from the graph that only in the unlikely case when two firms offer fairly close services (t = 0.9) while the FSA's conduct is more aggressive than the LCC ($v_1 = -0.5$, $v_2 = 0$), it is possible that the FSA loses profits proportionally more than the LCC.

Using the same numerical simulation assumptions but changing two firm's conduct parameters simultaneously, let us compare the proportional output reductions between LCC and FSA, as depicted in the surface graph figure 3.5. v_1 and v_2 represent values of conduct parameter for FSA and LCC, respectively, while Z axis corresponds to percentage of each firm's output reduction, $z = |\Delta q_i| / q_i$. The upper plane in figure 3.5 corresponds to LCC's proportional output reduction, while the lower plane corresponds to percentage reduction of FSA's output. It can be seen that LCC always loses proportionally more output except in the unlikely cases where FSA's conduct parameter is far lower than that of LCC (for example, $v_1 = -0.99$, $v_2 = 0$).

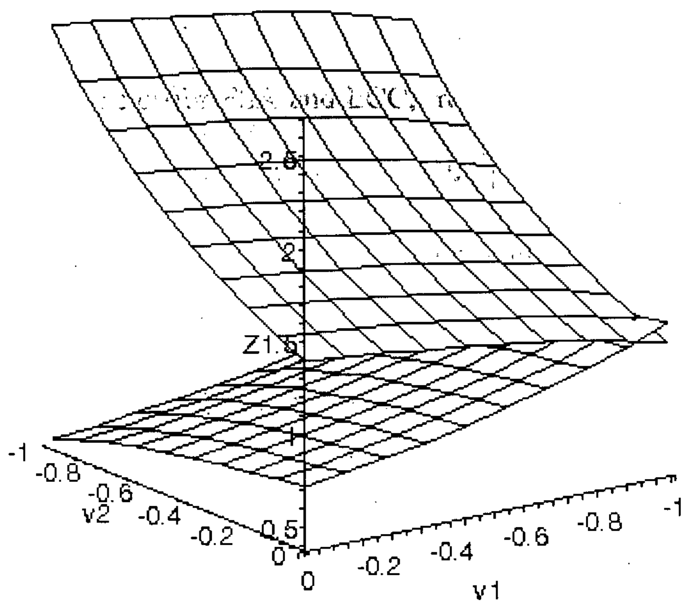

Figure 3.5 Output Reduction Proportions in Percentage (dc=$1)
(The output reduction percentage is defined as $z = |\Delta q_i| / q_i$)

In sum, our numerical simulation and sensitivity tests on key parameters of our duopoly model demonstrate the reliability of our analytical results within reasonable ranges of the key parameter values. More importantly, the numerical simulations also give the estimated values of the differential effects of an identical increase in input prices (e.g., due to increase in airport's airside service charges including landing fees) on an FSA and an LCC, and thus on the competition in downstream airline markets an airport serves.

3.4 Discussion and Conclusion

With the worldwide trend of airport privatization and commercialization, the extent and form of airport regulation are becoming an important issue for policy makers and regulators. The level of an airport's user charge affects not only air travel demand and social welfare, but also competition in the downstream airline markets to/from that airport. This latter aspect of the effect of airport user charges has been overlooked and thus, has not been incorporated in the analysis of airport pricing and regulation. This essay attempts to fill this void in the literature by showing that the level of competition in downstream airline markets may be reduced when an airport increases its airside service charges (e.g., aircraft landing fees) by the same amount to all airlines because such an increase would reduce equilibrium outputs and profits of LCCs proportionally more than those of FSAs.

In section 3.2, using duopoly models we have derived the following analytical results:

- When two airlines compete with differentiated products such as the case where an FSA and an LCC compete with each other, the LCC will lose its output and profits proportionally more than its FSA competitor. As a result, such increase in airport user charge could harm competition in the downstream airline markets to and from that airport.

- We have analyzed influences of the extent of product differentiation (substitutability), the extent of difference in unit cost levels and the difference in the two firms' conduct parameters on the equilibrium outcomes. In addition, although an increase in airport's airside fee can increase the competitive advantage of FSA vis-à-vis LCC, it is still not in the FSA's best interest to encourage airports to increase airside user charge in order to take advantage of its increasing competitive advantage.

Our numerical simulation and sensitivity tests on key parameters confirmed all of our analytical findings. The simulation experiments further indicated the following empirical results:

- The ratio of LCC's output reduction percentage relative to FSA's increases as LCC's conduct parameter (v_2) moves from zero towards -1. This implies that when the LCC's conduct becomes more competitive, for an identical increase in input prices, its output reduction relative to FSA will be higher;
- Competition becomes more important as the two firms (FSA and LCC) compete with closer substitutes;
- The differential in the percentage of profit reduction between LCC and FSA increases as the LCC's conduct parameter (v_2) moves from 0 towards -1.0. This implies that the LCC's profit reduction relative to FSA's profit reduction will increase as the LCC's conduct becomes more competitive.

Although in this essay we can not compare our simulation results explicitly with those of our work on the Virgin Blue vs. Sydney Airport case before the Australian

Competition Tribunal because of the confidential nature of the data and results, we are satisfied that our simulation results in this essay are consistent overall with the aggregate results we obtained using the real airline and airport data. In the Australian work, we obtained the results on the duopoly routes to and from Sydney. Our simulation results in this essay and our Australian work indicate clearly that an increase in an airport's user charge will harm LCCs significantly more than FSAs by reducing LCC's outputs and profits significantly more than those of FSAs. This may be a major reason why LCCs guard against airport user charge increases by seeking long term contracts on fees and charges with the airport. For example, in some cases Ryanair has very long contract arrangements with specific airports.

Our results indicate clearly that unregulated airside service pricing by a monopoly airport is likely to harm LCCs more, which reduces LCCs' ability to compete with FSAs, or even force LCCs to exit those marginally profitable markets. In addition, it may discourage LCC entry into those airports. This constitutes a negatively impact to the competition in the downstream air transport markets. Therefore, future analysis on airport pricing and price regulation should consider this aspect of additional welfare loss a monopolistic airport pricing may cause. It is noted, however, that our results were obtained under the assumption that the airport has a considerable monopoly power. In the case where there are strong competition among alternative airports for the majority of the traffic they handle, our results may need to be re-evaluated. For example, Starkie (2002) points out that when there are opportunities for substitution between airports (and other modes of transport) such as the case in western European cities, airports would have less incentives to exploit their market power. In addition, in markets where certain

LCCs achieved overwhelming market shares over their FSA competitors, such as some routes being served by Ryanair or Southwest, then there may be little or no loss in competition.

Some economists argue that since the incentives for generating non-aviation revenues including concession and car parking revenues would constrain airport management from charging monopolistic airside service charges, there is no need to impose any price regulation on privatized airports. However, recently Oum, Zhang and Zhang (2004) have shown that the airside service charges of an unregulated profit-maximizing airport are higher than those of a public airport under a breakeven budget constraint, even after the effect of concession profits is taken into account. In addition, because of the extremely low price elasticity of air travel demand with respect to airports' user charges,[36] any profit-maximizing airport management will have incentives to raise airside user charges at least several hundred percentage points beyond the current levels even after considering effect of the demand complementarity between aircraft landing and concession activities. Therefore, the governments should consider carefully whether or not they need to impose some sort of price regulation on privatized airports.

While we have argued the need for some sort of price regulation on privatized airports, we have not evaluated the types and extent of regulation. Instead, we pointed out that policy makers and regulators need to take into account of the effect of airport pricing on competition in the downstream airline market when decisions on price regulation or deregulation of privatized airports are considered. Obviously, further research, especially empirical research on this subject is needed.

[36] Gillen, Oum and Tretheway (1998) report the elasticity ranging between -0.01 and -0.1 depending on the aircraft size.

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Chapter 4

Effects of Airport Concession Revenue Sharing

4.1 Introduction

With the trend of airport commercialization and privatization in recent years, concession and other commercial operations (henceforth 'commercial operations') have become an increasingly important source for revenue and profit for major airports. These commercial operations refer to the non-aircraft related operations in terminals and on airport land, including activities such as running or leasing out shopping concessions of various kinds, car parking and rental, banking and catering, etc. Since these commercial operations at an airport depend greatly on passenger volume, there is a complementarity between demand for aviation services and demand for concession services. However, if airlines could not benefit from concession sale activities at airports, they would ignore such a positive demand externality in their decisions. In recent years, more and more airports are willing to share their concession revenues with airlines. For example, since several years ago Tampa International Airport has been sharing their concession revenue with airlines. In 2004, it paid $7 million out of a total budget of $30 million.[37] Ryanair has identified airport car parking as one of its business opportunities and cooperated with the leading airport parking company BCP (Ryanair, 2005, Davy Securities, 2006). In its negotiation with some airports, Ryanair asked for sharing parking revenue as a condition to initiate services to the airport.

Revenue sharing allows the airlines and airports to internalize the positive

[37] 2004 Annual Report of Tampa International Airport.

demand externality and thereby, to increase traffic volume (number of passengers). However, as airports provide an essential input to airlines, such airline-airport cooperation may raise anticompetitive concerns. In 2004, for instance, the European Commission ruled against the agreement between Charleroi airport and Ryanair, claiming that the favorable terms offered by the airport constitute an illegal state aid.[38] Also, FAA (U.S. Federal Aviation Administration) has shown its concern when an airport offers favorable terms to a particular airline because such a special treatment of one particular airline may harm competition in (downstream) airline markets.

Several papers have analyzed the potential economic impacts of airport concession revenue. Starkie (2001) concludes that *ex-ante* regulation for airports might be unnecessary on the ground that the airports are less likely to abuse their monopoly power due to their strong interest in increasing concession revenue. Countries such as Australia and New Zealand have moved towards a situation in which there is no formal price regulation but only price monitoring of privatized airports (Forsyth, 1997, 2002a, 2002b). Zhang and Zhang (2003) and Oum, Zhang and Zhang (2004) show that concession revenue does alleviate an airport's incentive to increase aeronautical service charges. However, an unregulated profit-maximizing airport would still charge a price higher than the socially optimal level, and even higher than the price a budget-constrained public airport would charge. Chapter 3 of this thesis also points out that because of the extremely low price elasticity of air travel demand with respect to airports' user charges,[39] any profit-maximizing airport will have an incentive to raise aeronautical charges even after taking into account of the positive externality effect of aviation

[38] Ryanair appealed to the case and the final decision has not been made at the point of writing this chapter.
[39] Gillen, Oum and Tretheway (1988) report the elasticity between -0.01 and -0.1 depending on aircraft size.

services on concession revenue.

While these studies have analyzed airports' pricing incentives when concession revenue is present, they have not examined implications on welfare and competition when a price-regulated airport cooperates with airlines using various agreements. This essay attempts to study such effects when an airport offers to share a certain proportion of its concession revenue for a fixed price with one or more airlines serving the airport. Our results show that such revenue sharing allows the airlines and airports to internalize the positive demand externality, and furthermore, such arrangements are likely to lead to welfare gains. However, in some cases such practice may strengthen the already dominant carrier at the airport. Airports do not necessarily prefer a competitive airline market, and there are cases where an airport can maximize its profit by strategically aligning with dominant airlines. In addition, an airport still has incentives to raise aviation user charges even after internalizing concession revenue. These observations suggest that the effects of revenue sharing may not be clear-cut as one expects, and thus, a full examination is warranted.

This essay is related but different from previous studies on revenue sharing, such as Cachon and Lariviere (2005) on general supply chain and Dana and Spier (2001) on video rental stores, where retailers (downstream firms) share a proportion of their revenue with the wholesaler or producer (the upstream firm). Wang, Jiang and Shen (2004) model a consignment contract where a manufacturer retains ownership of the product and sets retail price, but pays the retailer a percentage of the selling price as commission. In this essay, the airport, modeled as an upstream input provider, charges airlines a regulated service fee and shares its concession revenue with airlines for a fixed price. While Cachon and Lariviere (2005) and Dana and Spier (2001) allow the upstream firm to set the wholesale price freely, in this study revenue sharing is an airport's only instrument to influence market outcome since airport fees are regulated and fixed. A price regulated airport thus uses concession revenue sharing as a substitute measure for increasing aviation service charges. Wang, Jiang and Shen (2004) consider a pair of one producer and one retailer only. In contrast, we also consider the cases where multiple firms compete with differentiated products. In previous studies upstream and downstream firms derive revenue from the sale of the same products; consequently, the optimal inventory level is the main issue. Moreover, an airport receives concession revenue by exploiting the demand complementarity from another (passenger travel) market. Finally, unlike the above studies, competition and social welfare implications of concession revenue sharing are studied in this essay.

This chapter is organized as follows. Section 4.2 reviews relevant industrial background and sets up the basic model. Section 4.3 considers an oligopoly market with symmetric airlines, whereas Section 4.4 examines the case of asymmetric oligopoly airlines. Numerical simulations are conducted in Section 4.5. The last section summarizes and concludes the essay.

4. 2 The Basic Model

To make sure our analytical models are based on realistic assumptions and incorporate key features of the air transport industry, we first provide some further industrial background related to our study. Section 4.2.2 sets up the basic model and presents the results for the monopoly benchmark case.

4.2.1 Industrial Background

In recent years, airports have been under growing pressure to be more financially self-sufficient and less reliant on government support. Many airports around the world have been commercialized and/or privatized so that airports are operated more like a business (Carney and Mew 2003, IATA 1997). As aviation charges are usually regulated, airports rely increasingly on concession services to bring in more revenues. ATRS (2006) reports that most of the major airports around the world generates anywhere between 45% and 80% of their total revenues from non-aviation services, a major part of which is concession revenues. Jones et al. (1993) have shown that, in 1990–1991, the BAA's three London area airports as a group (Heathrow, Gatwick, and Stansted) generated approximately 60% of their total revenues from concession sales and achieved 64% operating margin on concession sales while suffering operating loss of −7% on their aviation service operations.

As concession services are derived demands from air travel, airlines and airports now cooperate to internalize the positive demand externality. There are cases where airports share their concession revenues with airlines via agreements, such as Tampa International Airport in the U.S. and Ryanair in Europe as mentioned above. In many other cases, revenue sharing is in effect when airlines hold shares in airports or directly control airport facilities. For example, terminal 2 of Munich airport is jointly invested by the airport operating company FMG (60%) and Lufthansa (40%), the airport's dominant airline. The terminal has a space of 18,000 square meters with about 110 stores and restaurants in the central market place. Profits generated from this terminal, including those from the lease of areas for catering and retail, are shared by FMG and Lufthansa

(Kuchinke and Sickmann 2005). Lufthansa has also been investing in Frankfurt airport, and holds 29% share of Shanghai Pudong International Airport Cargo Terminal Ltd (PACTL). Many other airlines control or own airport facilities, especially in their domestic hubs. Qantas owns terminals in both Sydney airport and Melbourne airport. LAPA Airways holds minority share in Aiport Aeropuertos Argentina, China Eastern Airlines holds share in Shanghai Pudong International Airport. In 1994, a consortium of four international airlines (Air France, Japan Airlines, Korean Air, and Lufthansa) invested in terminal 1 of JFK International Airport in New York. By 2006, Thai Airways has invested over US$400 million at the new Bangkok International Airport. Whilst the above cases deal with the airlines' investment in airports, an airport may also invest in airlines that serve the airport. One example is that Beijing airport has invested 24% in the all-cargo subsidiary of Air China, which is its home carrier.

Some other airline-airport agreements may be broadly classified as revenue sharing, in the sense that airports transfer some benefits to airlines via price discounting or favorable usage terms. Many airports now give preferential treatments to airlines serving new routes, or simply quantity discount for newly added flights. Such practices are often observed for low-cost carriers (LCCs) which usually boost airport traffic quickly with low airfares. For example, Belgium's Charleroi airport offered Ryanair very favorable conditions expecting that the airline would quickly expand its operation and bring in more traffic and concession revenue (Barbot 2006, European Commission 2004). On average, Ryanair paid much less airport charge than other European carriers (Barrett 2004).

As airports are input providers to airlines, there have been anti-trust concerns over airport-airline cooperations. For example, since many airports need airlines' service guarantee when securing long term loans, they often give major airlines "signatory airline" status. Such status gives airlines varying degrees of influence over airport operation including slot allocation, terminal usage, capacity expansion project, and exclusive or preferential facility usage in many cases. FAA believes this may harm airline competition and suggests airports to recover those exclusive facilities for public usage. Airports are allowed to levy Passenger Facility Charge (PFC) to finance non-exclusive facilities. In order to fully receive such revenue, large airports served by a "dominant" carrier must submit to the U.S. Department of Transportation (DOT) a plan on how they intend to promote airport access, entry, and competition (FAA 1999).[40] That is, regulators concerned about airport-airline cooperations, but have relied on airports to discipline their dominant carriers and ensure fair competition.

4.2.2 Basic Model and the Monopoly Case

We consider the case when a single airport provides aviation service to airlines. The airport maximizes its profit. The net airport aviation service charge per passenger is w, which is regulated and cannot be changed unilaterally by either the airport or airlines. Following Oum, Zhang and Zhang (2004) and Zhang and Zhang (1997), we define the per passenger demand for concession service as $x(u)$, where u is the price for concession services (goods) provided at the airport. Concession profit is maximized at u^*, at which

[40] The requirement of submitting competition plan was incorporated into the "the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century" legislated in 2000. According to this Act, large and medium airports that meet a certain threshold of concentration are required to submit competition plans.

the airport derives net concession revenue h ($h \equiv u^*$) from each passenger.[41] The consumer surplus derived from concession services is $CS_c = Q\int_{u^*}^{\infty} x(u)du$, where Q is market output (total number of passengers). We further require that $w \geq 0$, $h \geq 0$ and $dCS_c / dQ > 0$, i.e., the aviation service charge and concession revenue are non-negative, while the consumer surplus derived from concession services increases with number of passengers. Since price discrimination on aviation services is prohibited by the International Air Transport Association (IATA) rules, most airports charge all airlines the same aviation user price, w, regardless of whether or not they enter into concession revenue sharing agreement. The airport offers airlines the option to share proportion r_i ($0 \leq r_i \leq 1$ and $0 \leq \sum r_i \leq 1$) of its concession revenue in exchange for a fixed fee payment f_i. We assume that all airlines have equal access to such option.

The airport–airline behaviors are modeled as follows: In stage 1, the airport offers airlines the option to share its revenue and each airline decides to accept or reject the offer. In the second stage, airlines compete in Cournot fashion.

We first analyze the simplest (benchmark) case in which there is only one airline serving the airport with total cost function $c(q)$, where q is the airline's output (the number of passengers carried). The airline's demand is $p(q)$. With revenue sharing option (r, f), the airline's profit π_1 is

$$\pi_1 = p(q) \cdot q - c(q) - wq + rhq - f \tag{4.1}$$

[41] Our conclusions will still hold even if we assume fixed cost and constant marginal costs for the airport service and concession services. This assumption nevertheless simplifies our calculation and notation.

The airline sets quantity q to maximize its profit, and so the first order and second order conditions are, respectively:

$$\frac{d\pi_1}{dq} = p'(q) - c'(q) - w + rh = 0 \tag{4.2}$$

$$\frac{d^2\pi_1}{dq^2} < 0 \tag{4.3}$$

The two conditions jointly determine the airline's optimal output $q^*(r)$ for any revenue sharing ratio r. The airport's profit is:

$$\pi = wq + (1-r)hq + f \tag{4.4}$$

Intuitively, revenue sharing increases the airline's marginal revenue, thus should encourage the airline to expand output. This benefits travelers as well. Such intuition is formalized in Proposition 4.1.

Proposition 4.1. *When there is only one monopoly airline, revenue sharing allows airlines and airports to internalize positive demand externality, which leads to welfare gains and Pareto improvement.*

Proof: The airline and the airport will only participate in revenue sharing if their total profit $\prod = \pi_1(q^*(r), r) + \pi(q^*(r), r)$ increases. By (4.2) and (4.4) one has

$$\begin{aligned}
\frac{d\prod}{dr} &= \left[\frac{\partial \pi_1}{\partial q}\frac{dq^*(r)}{r} + \frac{\partial \pi_1}{\partial r}\right] + \left[\frac{\partial \pi}{\partial q}\frac{dq^*(r)}{dr} + \frac{\partial \pi}{\partial r}\right] \\
&= \frac{\partial \pi_1}{\partial r} + [w + (1-r)h]\frac{dq^*}{dr} + \frac{\partial \pi}{\partial r} \\
&= [w + (1-r)h]\frac{dq^*}{dr}
\end{aligned} \tag{4.5}$$

where the first order condition (4.2) is used. The airline's first order condition also implies that

$$\frac{\partial \pi_1(q^*(r), r)}{\partial q} \equiv 0 \tag{4.6}$$

Totally differentiate (4.6), and utilizing the fact that $\frac{\partial^2 \pi_1}{\partial q \partial r} = h > 0$, the sign of $\frac{dq^*}{dr}$ can be determined as

$$\frac{dq^*}{dr} = -\frac{\partial^2 \pi_1 / \partial q \partial r}{d^2 \pi_1 / dq^2} > 0 \tag{4.7}$$

With expression (4.5) we have

$$\frac{d\Pi}{dr} > 0 \quad \text{when } 0 \le r \le 1 \tag{4.8}$$

This implies that revenue sharing enhances the industry profit, or the combined profit of the airline and the airport. The airline and the airport split the increased profit, such that each firm's profit is at least as large as before. Since output is larger under revenue sharing than without revenue sharing, consumer surplus and social welfare would increase. This is a Pareto improvement. Q.E.D.

Equation (4.5) implies that the industry profit increases so long as $r < 1 + w/h$. That is, even after the concession revenues are fully internalized (r = 1), the industry profit and social welfare can be further improved by increasing r beyond the unity. This is due to the fact that revenue sharing allows the airport to practice two-part tariff, which also corrects the well-known double-marginalization problem. It can be shown that

$$\begin{aligned} \frac{d\Pi}{dr} &= \frac{dq^*(r)}{dr}\left[\frac{dp}{dq}q^*(r) + p - \frac{dc}{dq} + h\right] \\ &= \frac{dq^*(r)}{dr}\left[MR + h - MC\right] \end{aligned} \tag{4.9}$$

industry profit would be maximized if airport charge is $-h$, at which point the double marginalization effects are removed and concession revenue is fully internalized.

4.3 Oligopoly Airlines

In this section we consider an oligopoly airline market with n symmetric firms in the sense that all airlines have an identical constant marginal cost, c. These carriers produce horizontally differentiated services, and the inverse demand function for airline i is specified in (4.10). Those demand functions correspond to a representative consumer maximizing a concave utility function as in (4.11), where M is the numeraire good (money):

$$p_i = 1 - bq_i - k\sum_{j \neq i} q_j \quad \text{where } b \geq k > 0 \tag{4.10}$$

$$U(q_1, q_2, ..., q_n) = \sum_{i=1}^{n} q_i - \frac{1}{2}\sum_{i=1}^{n} bq_i^2 - k\sum_{i>j} q_i q_j + M \tag{4.11}$$

When $k = 0$ airlines provide totally differentiated service so that airlines don't compete with each others. This is essentially the benchmark case we studied thus we don't discuss further in this section. Positive outputs require $0 < c + w < 1$, such that the average cost curve (an airline's cost to carry a passenger, $c + w$) passes below the inverse demand curve. Without revenue sharing, or $r_i = 0$ and $f_i = 0$, it is straightforward to calculate each airline's equilibrium output, price and profit as follows:

$$q_i(0,...,0) = \frac{1-c-w}{2b+(n-1)k}$$

$$p_i(0,...,0) = 1 - \frac{b+(n-1)k}{2b+(n-1)k}(1-c-w) \tag{4.12}$$

$$\pi_i(0,...,0) = \frac{b(1-c-w)^2}{(2b+(n-1)k)^2}$$

where zeros in brackets denote zero revenue sharing for each airline. When airline i accepts revenue sharing contract (r_i, f_i), its profit also depends on revenue sharing arrangements of its competitors, where

$$\pi_i(r_1,...,r_n) = (p_i - c - w)q_i + r_i h(\sum_{i=1}^{n} q_i) - f_i \quad (4.13)$$

Two types of revenue sharing have been observed in the air transport industry. Tampa International Airport shares revenue with all airlines serving the airport, while the Charleroi airport and Munich airport only have agreements with one particular airline (Ryanair and Lufthansa, respectively). Since we consider symmetric airlines in this section, the following two types of revenue sharing are studied: the first corresponds to the situation when the airport shares an equal proportion of concession revenue with each airline. The second corresponds to the situation when the airport shares concession revenue with one airline only. These two types of revenue sharing are analytically solved in this section. Numerical simulations are conducted in section 4.5.

4.3.1 Equal Proportion of Revenue Sharing

We first consider the case when the airport shares an equal proportion of concession revenue with each airline (Equal Revenue Sharing) so that $r_i = r$, $f_i = f$. The following equilibrium results can be obtained under the assumption of symmetric airlines:

$$q_i(r,...,r) = \frac{1-c-w+rh}{2b+(n-1)k}$$

$$p_i(r,...,r) = 1 - \frac{b+(n-1)k}{2b+(n-1)k}(1-c-w+rh) \tag{4.14}$$

$$\pi_i(r,...,r) = \frac{rh\{(1-c-w+rh)[(2n-1)b+(n-1)^2 k]+b(1-c-w)\}}{[2b+(n-1)k]^2} + \frac{b(1-c-w)^2}{[2b+(n-1)k]^2} - f_i$$

For ease of notational expression, we define an airline's operating profit, or the profit before paying out the fixed amount f_i, as $\pi_i^0 = \pi_i + f_i$. By (4.14) we have $\pi_i(r,...,r) + f_i > \pi_i(0,...,0)$ and $d\pi_i^0(r,...,r)/dr > 0$. That is, *ceteris paribus*, an airline always prefers to share more concession revenue. As an increasing portion of concession revenue is shared, each airline's output increases while price gets lowered. Therefore, consumer surplus and social welfare always increase with r.

An airline is willing to accept a fixed price f_i up its "reservation price", the price at which this airline is indifferent between accepting the revenue-sharing contract or not. In this section, we consider an airline market in which symmetric carriers compete, and there is only one input provider, the airport. For the analysis of oligopoly airlines (Section 4.3) we assume for technical convenience that the airport is able to charge such reservation price for revenue sharing options, while an airline will accept the option when its reservation price is charged. Since airlines are symmetric, they have identical reservation price. This allows us to get the following Proposition 4.2:

Proposition 4.2 *Relative to the case without revenue sharing, the equal revenue sharing allows the airport to extract surplus from the airline market. Airport improves its own profit, while the profits of all airlines are reduced.*

Proof: We first show that an airline left out in revenue sharing is disadvantaged in the competition with other airlines. To see this, consider the case when only airline 1 does not participate.[42] The profits of airline 1 and airline j ($j \neq 1$) are, respectively:

$$\begin{aligned} &\pi_1(0,\bar{r}) = (p_1 - c - w)q_1 \\ &\pi_j(0,\bar{r}) = (p_j - c - w)q_j + rh(q_1 + \sum_{j \neq i} q_j) - f \end{aligned} \tag{4.15}$$

where the n-1 dimensional vector $\bar{r}$ is defined as $\bar{r} = (r,...,r)_{n-1}$. Imposing symmetry on the *(n-1)* airlines other than 1, the corresponding equilibrium outputs and profits can be derived as follows:

$$\begin{aligned} &q_1(0,\bar{r}) = \frac{(2b-k)(1-c-w)-(n-1)krh}{(2b-k)[2b+(n-1)k]} \\ &q_j(0,\bar{r}) = \frac{(2b-k)(1-c-w)+2brh}{(2b-k)[2b+(n-1)k]} \\ &\pi_1(0,\bar{r}) = \frac{b[(1-c-w)(2b-k)-krh(n-1)]^2}{(2b-k)^2[2b+(n-1)k]^2} \\ &\frac{dq_1(0,\bar{r})}{dr} < 0, \quad \frac{dp_1(0,\bar{r})}{dr} < 0, \quad \frac{d\pi_1(0,\bar{r})}{dr} < 0 \end{aligned} \tag{4.16}$$

Clearly airline 1 is worse off than the case when the airport does not offer the option to share concession revenue. All other airlines' outputs expand with r, forcing airline 1 to reduce its own output and price. This lowers profit for airline 1, which implies that an airline left out in concession revenue sharing is disadvantaged: it is unable to internalize concession revenue as other airlines do. In addition, any output expansion by this airline helps increase its competitors' income from concession revenue.

[42] We consider the case when firms decide whether to participate or not simultaneously. That is, even if a firm does not share airport's revenue, the airport can't allocate the unaccepted shares to other airlines.

Next, we show revenue sharing improves the airport's profit, while airlines are worse off regardless whether or not they share revenue or not. Note when reservation price $f(r,...,r)$ is charged, we have $\pi_1(r,...,r) = \pi_1(0,\bar{r})$. This defines $f(r,...,r)$ as follow:

$$f(r,...,r) = \frac{(1-c-w+rh)\{b(1-c-w)+rh[(2n-1)b+(n-1)^2k]\}}{(2b+(n-1)k)^2} - \frac{b[(1-c-w)(2b-k)-krh(n-1)]^2}{(2b-k)^2[2b+(n-1)k]^2} \tag{4.17}$$

The airport's profit can be calculated as follows:

$$\pi(r,...,r) = n \cdot f(r,...,r) + [(1-nr)h + w] \cdot n \cdot q_i(r,...,r) \tag{4.18}$$

Substituting (4.17) into (4.18), it can be shown (see Appendix A) that

$$\frac{\partial^2 \pi(r,...,r)}{\partial r \partial c} < 0, \qquad \frac{\partial^2 \pi(r,...,r)}{\partial r \partial w} > 0, \qquad \frac{\partial^2 \pi(r,...,r)}{\partial r^2} < 0 \tag{4.19}$$

Utilizing the results in (4.19), it can further be shown that when $r = 0$, $d\pi(r,...,r)/dr > 0$. Therefore, it is always profitable for the airport to engage in equal revenue sharing. Since $\pi_1(r,...,r) = \pi_1(0,\bar{r})$ when reserve price is charged, by (4.16) it is clear that airlines are always worse off regardless of whether or not they share concession revenue. In sum, an airline left out from the concession revenue sharing scheme is disadvantaged. Exploiting this fact, an airport can use revenue sharing option to extract surplus from airlines so that its own profit is enhanced. Q.E.D.

As shown in equation (4.19), when r increases, revenue sharing is less effective in enhancing the airport's profit ($\partial^2\pi(r,...,r)/\partial r^2 < 0$). That is, the airport's return on revenue sharing decreases with r. Therefore, an airport does not always fully share its concession revenue (to give 100% of its concession revenue to airline(s) in exchange for fixed payments). When a certain amount of concession revenue has been shared, it may be more profitable for the airport to simply keep the concession revenue to itself than to share it with airlines. To see this, note the sign of $d\pi(r,...,r)/dr$ can be negative. With the assumption of symmetric airlines, $r = 1/n$ when all concession revenue are shared. In such case, $d\pi(r,...,r)/dr$ can be negative. For example,

$$\frac{d\pi(r,...,r)}{dr} = \frac{h(n-1)[n(1-c-h)+2h]}{k(1+n)^2} < 0 \tag{4.20}$$

$$\text{when } w = 0,\ r = 1/n,\ b = k,\ c > 1 - \frac{(n-2)h}{n}$$

which implies that there are cases when an airport will choose to not fully share its concession revenue.

Finally we briefly discuss the effects of revenue sharing on airport pricing. Starkie (2001) conclude that airports are unlikely to abuse their market power due to the demand complementarity between concession services and aviation services. However, equation (4.19) suggests airport may derive some benefits from an aviation charge increase ($\partial^2\pi(r,...,r)/\partial r\partial w > 0$). As shown in Appendix C, an airport still has incentives to raise aviation user charges even after internalizing concession revenue.[43]

Since an airport does not always internalize all its concession revenue, and has incentive to raise service charge after internalizing concession revenue, government intervention may still be needed for the purpose of welfare maximization.

[43] This does not imply Starkie's (2001) conclusion is always unreasonable, as he implicitly considered the cities in Western Europe, where many closely located airports compete for airline business. This is different from the scenarios we modeled in this chapter.

4.3.2 Exclusive Revenue Sharing with One Airline

Instead of sharing an equal proportion of concession revenue with each airline, the airport has the option to exclusively share its revenue with one airline only (Exclusive Revenue Sharing). Without loss of generality, let us denote this carrier as airline 1. When it enters into revenue sharing agreement (r_1 , $f_1(r_1,\bar{0})$) with the airport, airline 1's profit is calculated as $\pi_1(r_1,\bar{0}) = (p_1 - c - w)q_1 + r_1 h(q_1 + \sum_{j \neq i} q_j) - f_1(r_1,\bar{0})$. Imposing symmetry for the remaining (*n-1*) carriers, the airlines' outputs and profits can be derived as in (4.21), where Q denotes total market output:

$$q_1(r_1,\bar{0}) = \frac{(2b-k)(1-c-w) + r_1 h[2b + (n-2)k]}{(2b-k)[2b + (n-1)k]}$$

$$q_j(r_1,\bar{0}) = \frac{(2b-k)(1-c-w) - r_1 hk}{(2b-k)[2b + (n-1)k]}$$

$$Q(r_1,\bar{0}) = q_1(r_1,\bar{0}) + \sum_{j \neq i}^{n} q_j(r_1,\bar{0}) = \frac{n(1-c-w) + r_1 h}{2b + (n-1)k} \qquad (4.21)$$

$$\pi_1(r_1,\bar{0}) = \frac{b(1-c-w)^2}{[2b + (n-1)k]^2} + r_1 h \frac{(1-c-w)n + r_1 h}{2b + (n-1)k} - f_1(r_1,\bar{0}) +$$
$$r_1 h \frac{(2b-k)(1-c-w)(n-1)k^2 - r_1 h[2b + (n-2)k][2b^2 + (n-2)bk - (n-1)k^2]}{(2b-k)^2[2b + (n-1)k]^2}$$

$$\pi_j(r_1,\bar{0}) = \frac{b[(1-c-w)(2b-k) - r_1 hk]^2}{(2b-k)^2[2b + (n-1)k]^2}$$

Similar to the Equal Revenue Sharing case, the carrier aligning with the airport (firm 1 in this case) expands its output, while all other carriers reduce their outputs when a proportion of concession revenue is shared, and thus, the positive demand externality is internalized. Airline 1 can accept a price for revenue sharing up to the point when it is indifferent between accepting the offer and passing it to another carrier, which implies $\pi_1(r_1,\bar{0}) = \pi_j(r_1,\bar{0})$. This condition defines airline 1's reservation price $f_1(r_1,\bar{0})$. As stated, we assume in Section 4.3 that the airport is able to charge an airline's reservation price. This allows us to get the following results:

Proposition 4.3 *Relative to the case without revenue sharing, the exclusive revenue sharing allows an airport to improve its profit by extracting surplus from the airlines. Airlines' profits are reduced, and their market shares and traffic volumes change with revenue sharing.*

Proof: With (4.21) and the condition $\pi_1(r_1,\bar{0}) = \pi_j(r_1,\bar{0})$, airline 1's reservation price $f_1(r_1,\bar{0})$ can be explicitly solved. This allows us to calculate the airport's profit:

$$\pi(r_1,\bar{0}) = [w + (1-r_1)h][q_1 + \sum_{j\neq i}^{n} q_j] + f_1(r_1,\bar{0}) \tag{4.22}$$

Furthermore, as shown in Appendix B, that $\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial w} > 0$. Therefore, when $r_1 = 0$, $d\pi(r_1,\bar{0})/dr_1$ takes the lowest value at $w = 0$, where

$$\frac{d\pi(r_1,\bar{0})}{dr_1} = \frac{h[h(2b-k)+k(1-c)]}{(2b-k)[2b+k(n-1)]} > 0 \tag{4.23}$$
$$\text{When } w = 0,\ r_1 = 0$$

This implies that an airport can improve its profit by doing exclusive revenue sharing. Using the definition of $f_1(r_1,\bar{0})$, it is easy to show that an airline is always worse off regardless of whether or not it is the partner for concession revenue sharing. That is, revenue sharing enhances the airport's profit by extracting surplus from airlines. In addition, we have shown with equation (4.21) that the carrier cooperating with the airport expands its output and market share at the expense of all other competitors. This means that airlines' market shares and traffic volumes (outputs) have changed with revenue sharing. Q.E.D.

The intuition behind Proposition 4.3 is as follows: When a price regulated airport engages in exclusive revenue sharing, its total profit / revenue comes from three sources: (1) total aviation service charge which increases with market output Q; (2) the fixed fee payment f, which is an airline's reservation price; (3) concession revenue not shared with airlines. Note an airline's reservation price is its profit difference between the two alternatives: sharing concession revenue and not sharing. When an airline internalizes concession revenue, its output and market share increase at the expense of its competitors. This makes the option of sharing concession revenue more attractive than the 'not sharing' option. This in turn allows the airport to charge a premium for the sharing option. This mechanism is similar to exclusive franchise contract. Although a franchisee is protected from competition with such arrangement, she is not necessarily better off since the franchisor can capture all of the surplus by charging a high franchise fee. In sum, the airport has a strategic interest to manipulate airline competition since this enables it to capture surplus from the downstream airline market. For convenience, hereafter we refer to such captured surplus as the "king maker's reward".

As shown in Appendix B, the following results hold:

$$\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial w} > 0, \quad \frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial c} < 0, \quad \frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1^2} < 0 \tag{4.24}$$

$$\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial n} < 0 \text{ when } 1-c-h>0$$

Using (4.24), one can again show that there are cases when the airport will not fully internalize concession revenue. The intuition behind this result is explained as follows: As shown in (4.24), the benefit of revenue sharing to the airport decreases with r_1 and n ($\partial^2\pi(r_1,\bar{0})/\partial r_1^2 < 0$ and $\partial^2\pi(r_1,\bar{0})/\partial r_1\partial n < 0$). Revenue sharing encourages an airline to expand output. However, marginal revenue declines so that the value of output expansion diminishes. In addition, output expansion will be less profitable when there is stronger competition (larger n). The diminishing return of output expansion implies that the value of revenue sharing also declines with r_1 and n. When these two parameters are sufficiently large, it is more profitable for the airport to keep its concession revenue than to share it with airlines. Similar results were obtained in the analysis of equal revenue sharing in the previous section. These facts suggest that an airport's profit does not always increase when there are more airlines (larger n) and a greater proportion of revenue is shared (larger r_1). Such intuition is further explored with numerical simulations in Section 4.5.

Now we examine the welfare implications of exclusive revenue sharing. Equation (4.21) shows that total market output increases with r. Since the airlines' services are differentiated, larger market output does not necessarily improve welfare. Social welfare can be calculated as follows:

$$\begin{aligned} Wel &= U(q_1,q_2,...,q_n) - c\sum_{i=1}^{n} q_i + (h\sum_{i=1}^{n} q_i + CS_c) \\ &= \sum_{i=1}^{n} q_i - \frac{1}{2}bq_1^2 - \frac{(n-1)b}{2}q_2^2 - k(n-1)q_1q_2 \\ &\qquad - k\frac{(n-1)(n-2)}{2}q_2^2 - c\sum_{i=1}^{n} q_i + \sum_{i=1}^{n} q_i(h + \int_{t}^{\infty} x(u)du) \end{aligned} \tag{4.25}$$

where q_1 and $q_2 = q_j$ ($j \neq 1$) are specified as in (4.21), while $CS_c = Q\int_{t}^{\infty} x(u)du$ is the consumer surplus derived from concession activities. It can be proven that

$$\frac{\partial^2 Wel}{\partial r_1^{\,2}} < 0 \qquad \frac{\partial^2 Wel}{\partial r_1 \partial w} > 0 \qquad \frac{\partial^2 Wel}{\partial r_1 \partial c} < 0 \qquad \frac{\partial^2 Wel}{\partial r_1 \partial n} < 0 \tag{4.26}$$

Utilizing (4.26), it can be shown that for the following special cases, $dWel/dr_1 > 0$, that is, welfare always increases when a larger proportion of concession revenue is shared.

- <u>Homogenous Airline Services</u>: this corresponds to the scenario when all the airlines produce homogenous services so $k = b$. In this case, social welfare only depends on market output, which always increases with revenue sharing.

- <u>Duopoly Airline Market:</u> When there are small number of firms (e.g., n = 2), social welfare always increases when a larger proportion of concession revenue is shared.

It is difficult, however, to derive welfare implications analytically for all general cases. When airline 1 (the firm sharing revenue) expands output, all other airlines reduce their outputs by a smaller amount. When firms are symmetric, marginal consumers purchasing more services from airline 1 have lower valuation of air travel compared to those lost consumers originally buying from other airlines. Intuitively, if n is very large then welfare may decrease in spite of the expansion of market output. Numerical simulations in section 4.5 confirm such intuition. However, the simulation results are obtained with not very realistic assumptions, and the relative welfare reductions are very limited. It appears that welfare reduction under output expansion is unlikely to be a serious concern in real transport markets.

4.4 Oligopoly Market with Asymmetric Airlines

Although the assumption of symmetric airline provides good approximation when one studies the competition among airlines of the same type, it is not very realistic for cases where some of the firms have clear competitive advantage. For example, Cathy Pacific and Singapore Airlines consistently provide superior service than other FSAs, while Southwest, Ryanair achieve sustainable cost advantage over many LCCs. Even if two airlines are alike overall, they may possess different market power or cost competitiveness in individual markets. For example, an airline usually has larger departure frequency and better network connection in its hub airports, which allows the carrier to reduce costs and/or charge a price premium. To incorporate such asymmetry between firms in our analysis, we model the case when an airline achieves substantial competitive advantage by having a lower marginal cost. For simplicity, we restrict to duopoly competition only and use the same demand function as in section 4.3. This leads to following restrictions:

$$0 < c_1 < c_2 < 1 \qquad \text{and} \qquad c_i + w < 1 \tag{4.27}$$

When an airport has revenue sharing agreements (r_1, f_{r1}) and (r_2, f_{r2}) with the two airlines respectively, profits of the airport and airlines are specified as follows, where f_{ri} is the fixed payment for sharing proportion r_i of the concession revenue:

$$\begin{aligned}
\pi_1(r_1, r_2) &= (p_1 - c_1 - w)q_1 + r_1 h(q_1 + q_2) - f_{r1} \\
\pi_2(r_1, r_2) &= (p_2 - c_2 - w)q_2 + r_2 h(q_1 + q_2) - f_{r2} \\
\pi(r_1, r_2) &= w(q_1 + q_2) + h(q_1 + q_2)(1 - r_1 - r_2) + f_{r1} + f_{r2}
\end{aligned} \tag{4.28}$$

Given the fixed payments f_{ri}, two airlines' equilibrium outputs and profits are derived as follows:

$$q_i(r_1,r_2)=\frac{2b(1-c_i-w)-k(1-c_j-w)}{(4b^2-k^2)}+\frac{h(2br_i-kr_j)}{(4b^2-k^2)} \tag{4.29}$$

$$\begin{aligned}\pi_i(r_1,r_2)=&\frac{b[2b(1-c_i-w)-k(1-c_j-w)]-h[(2b^2-k^2)r_i+kbr_j]}{4b^2-k^2}\times\\ &\left[\frac{2b(1-c_i-w)-k(1-c_j-w)}{(4b^2-k^2)}+\frac{h(2br_i-kr_j)}{(4b^2-k^2)}\right]+\\ &r_ih\frac{2-c_i-c_j-2w+h(r_i+r_j)}{2b+k}-f_{ri}\end{aligned} \tag{4.30}$$

With (4.29) it is easy to show that market output $Q(r_1,r_2)$ depends only on the total proportion of concession revenue shared $R=r_1+r_2$. This implies that when a given proportion of concession revenue is shared, an airport's profit solely depends on the airline's fixed payments f_{ri}. Unlike most two-part tariff problems, in our model a buyer's (airline) profit strategically depends on its rival's decision. This makes it difficult to solve the game analytically. Still, the following proposition can be proven:

Proposition 4.4 *When an airline enjoys a significant cost advantage over its competitor (in the case of $(c_2-c_1)>2h(b-k)/k$ in our model), the airport shares concession revenue with this competitive carrier only. This implies that the dominant airline's market power is further strengthened in terms of getting larger market share. In duopoly competition, this arrangement always increases social welfare.*

Proof: Consider the case when the airport plans to share proportion Δr of its concession revenue when it already shares r_i ($i = 1,2$) with airline i. Carrier 1's reservation price for Δr, denoted as $x_1(r_1, r_2)$, can be calculated as:

$$\begin{aligned} x_1(r_1,r_2) &= \pi_1(r_1+\Delta r, r_2) - \pi_1(r_1, r_2+\Delta r) \\ &= \{\pi_1(r_1+\Delta r, r_2) - \pi_1(r_1,r_2)\} - \{\pi_1(r_1, r_2+\Delta r) - \pi_1(r_1,r_2)\} \\ &= \Delta r\left(\frac{d\pi_1}{dr_1} - \frac{d\pi_1}{dr_2}\right) \end{aligned} \tag{4.31}$$

The reservation price of airline 2, $x_2(r_1, r_2)$, can be derived in a similar way. Thus we have the following result:

$$x_1(r_1,r_2) - x_2(r_1,r_2) = \frac{\Delta r h}{(2b-k)^2}[k(c_2 - c_1) - 2h(b-k)(r_1 - r_2)] \tag{4.32}$$

which means if $(c_2 - c_1) > 2h(b-k)/k$, $x_1(r_1,r_2) > x_2(r_1,r_2)$ holds for any (r_1, r_2). That is, when an airline has substantial cost advantage over its competitor, it is willing to pay a higher price for any given proportion of concession revenue. Thus a profit maximizing airport will work with this dominant airline only. The airport will demand a high fixed payment which effectively exclude carrier 2 without practicing price discrimination explicitly.[44]

In Section 4.3.2 we found $dWel/dr_1 > 0$ when $n = 2$. With this conclusion it is straightforward to show that in duopoly airline market when airport shares concession revenue with airline 1 only, social welfare always increases. Meanwhile, the dominant airline's market power is strengthened since it increases its market share with the concession revenue sharing. Q.E.D.

[44] Strictly, the proof for Proposition 4.4 corresponds exactly to the situation when the airport bids out the right to share concession revenue by percentages. It is a first order approximation for the case when the airport sells out the right to share certain proportion r in one shot.

The intuition behind Proposition 4.4 is explained as follows: when an airport's action can influence downstream airline competition, a dominant airline (modeled as having lower marginal cost in our analysis) is more likely to pay a premium for such action. When the airport cooperates with the more efficient airline, this airline achieves larger market share and larger absolute output than the other airlines. Thus the airport influences market shares towards the efficient direction and captures some of those benefits via the fixed payment.

To further demonstrate the above intuition, note an airline's operating profit[45] increases as the airport shares an increasing share of concession revenue with this airline:

$$\frac{d\pi_i^0(r_1,r_2)}{dr_i}>0, \quad \frac{d^2\pi_i^0(r_1,r_2)}{dr_i^2}>0, \quad \frac{d^2\pi_1^0(r_1,r_2)}{dr_1^2}=\frac{d^2\pi_2^0(r_1,r_2)}{dr_2^2} \tag{4.33}$$

Such "operating profit enhancing" effect is always greater for the dominant airline if it has substantial cost advantage over its competitor. To see this, note

$$\frac{d\pi_1^0(r_1,r_2)}{dr_1}-\frac{d\pi_2^0(r_1,r_2)}{dr_2}=\frac{kh}{(2b-k)^2(2b+k)}[k(c_2-c_1)-2h(b-k)(r_1-r_2)] \tag{4.34}$$

which implies that $d\pi_1^0(r_1,r_2)/dr_1 > d\pi_2^0(r_1,r_2)/dr_2$ if $(c_2-c_1)>2h(b-k)/k$. That is, the option to share concession revenue is always more valuable to airline 1 if it enjoys "substantial" cost advantage. When airline services are close substitute, the condition $(c_2-c_1)>2h(b-k)/k$ gets satisfied easily. Therefore, "substantial" cost advantage is not an unrealistic requirement.

[45] As defined in Section 4.3, operating profit is an airline's profit before paying out fixed payment f_i, or $\pi_i^0(r_1,r_2)=\pi_i(r_1,r_2)+f_{ri}$.

When the airport shares proportion r of its concession revenue ($0 \le r \le 1$) with airline 1 exclusively, the actual price paid, denoted as f, is within the interval of $[f_2, f_1]$, where f_i is airline i's reservation price as defined below:

$$f_1 = \pi_1^0(r,0) - \pi_1^0(0,r) \quad \text{and} \quad f_2 = \pi_2^0(0,r) - \pi_2^0(r,0) \tag{4.35}$$

Any $f \in [f_2, f_1]$ would be acceptable to both the airport and airline 1. For the airport, f_2 is the highest alternative payment it can get from airline 2. For airline 1, paying any price lower than f_1 would be a better choice than passing the revenue sharing option to its competitor airline 2. In addition, it can be shown that

$$\frac{df_1}{dc_1} < \frac{df_1}{dc_2} < 0 \quad \text{and} \quad \frac{df_2}{dc_2} < \frac{df_2}{dc_1} < 0 \tag{4.36}$$

implying when airline 2's cost efficiency improves, both f_1 and f_2 increase. That is, as airlines improve cost efficiency, the airport can extract an increasing surplus from the airlines.

4.5 Numerical Simulations

It is difficult to obtain analytical solutions in some cases because of the large number of factors modeled in our analysis, especially when comparison is made across different market structures. For example, two types of revenue sharing, namely equal revenue sharing and exclusive revenue sharing, are discussed in Section 4.3. We have not, however, discussed whether one type of revenue sharing is always preferred by the airport. Nor have we been able to analyze the effects of airline competition on an airport's profit and business strategy. Numerical simulations are conducted in this section to provide additional insights.

The main purpose of the numerical simulations is to complement our analytical modeling rather than to quantify actual effects. Therefore, different sets of demand/cost parameters are used in the simulations. The simulations don't represent an "average" route or airport. Based on my knowledge of the air transport industry I try to assign realistic values to following parameters used in the simulations. However, since there are great variations among the operations of airport and airlines, I eventually rely on the model's mathematical constraints to decide whether a parameter value is legitimate or not.

- *b*: Slope of the inverse demand function $p_i = 1 - bq_i - k\sum_{j \neq i} q_j$. Since we normalized the demand function's intercept to 1, the value of *b* determines the size of the market. We used $b = 0.00001$ in all simulations.
- *k*: This parameter measures product differentiation among airlines. We decided to simulate the cases when airlines produce close substitutes. Thus, we assumed $k = 0.9b$ and $k = 0.8b$ in the simulations
- *c*: airlines' marginal cost. Since there are large variations of airlines' marginal costs across routes and airlines, we rely on the model's mathematical constraints $0 < c + w < 1$ to decide whether a parameter value is legitimate or not.
- *w* and *h*: airport's net service charge and concession revenue. There are again large variations among airports with respect to their service charge and concession activities.[46] Since airport charges and concession revenues are usually smaller than an airline's marginal cost, we rely on following constraints in choosing the values: $0 < w < c$, $0 < h < c$, $0 < c + w < 1$.

We are not aware of any empirical study on the demand for airport concession services. This implies any numerical treatment of CS_C would be subjective. For

[46] In 2004, the share of concession revenue (excluding parking service) ranged from 9% for Toronto Pearson airport to 63.7% at Cairns Airport (Australia). The concession revenue per passenger (excluding parking) ranged from US$13.83 at Tokyo Narita to US$0.55 at Cincinnati /Northern Kentucky International Airport (ATRS, 2006). Airport service charges are usually low since they are regulated, but there are also complaints that service charges in certain airports have increased rapidly.

simplicity, we use a constant $X = \int_{u^*}^{\infty} x(u)du$ as the per passenger consumer surplus from concession services in such a way that $CS_C = Q \cdot X$. The change in CS_C is predictable (linear in Q). In order to focus more on the effects of other factors, we decide to use a conservative value for X, where $X = h/2$.[47]

We first consider the case of Equal Revenue Sharing as modeled in Section 4.3.1. To examine the effects of airline competition, we vary the number of competing airlines n in simulations, and calculate the corresponding airport profits, social welfare, market outcome, etc. The results are reported in Figure 4.1, with the parameter values: b = 0.00001, k = $0.9b$, c = 0.9, w = 0.001, h = 0.2. Because airlines are horizontally differentiated, a larger n implies both demand expansion and sharper competition.

[47] If the demand for concession service is linear and optimal concession price u^* is set right between the intercept and constant marginal cost, then consumer surplus is exactly half of concession profit.

- — Solid lines are the results with equal revenue sharing;
- ... Dotted lines are the results without revenue sharing.
- Horizontal axis corresponds to the number of firms, $n \in [2,40]$

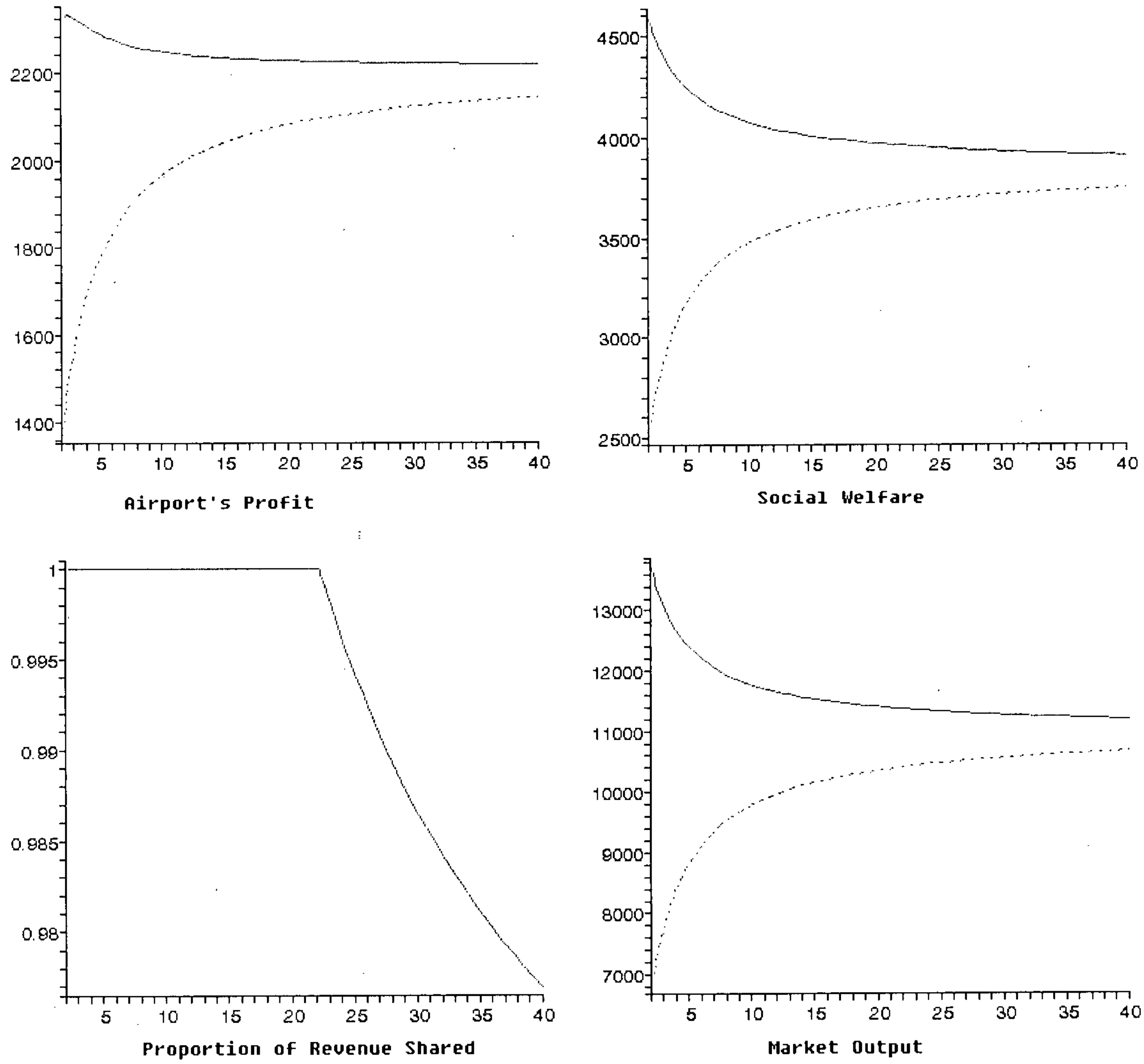


Figure 4.1 Equal Revenue Sharing When Airlines Are Symmetric -1
(Parameter Values: $b = 0.00001$, $k = 0.9b$, $c = 0.9$, $w = 0.001$, $h = 0.2$)

For the simulations used in Figure 4.1, we assumed that the concession service is very profitable (large h).[48] Note that when an airport shares its revenue fully so that $r = 1/n$, one can obtain the following from Equation (4.14),

[48] For the simulations in figure 4.1, concession revenue (h=0.2) is high relative to the airline's marginal cost (c=0.9). Ryanair is well known for getting "ancillary" revenue (which the airline used to refer to non-aviation revenues such as onboard food, parking revenue etc.). Even for Ryanair, in fiscal year 2006 its average fare is about €50, while the average "ancillary" revenue per passenger is €7.7. It appears that the h we used in the simulations is fairly high.

$$\frac{dQ(r,...,r)}{dn} = \frac{(2b-k)(1-c-w)-hk}{[2b+(n-1)k]^2} \tag{4.37}$$

where $Q(r,...,r) = \sum_{i=1}^{n} q_i(r,...,r)$ is the total market output.

It follows from (4.37) that $dQ(r,...,r)/dn < 0$ if concession service is very profitable (large h), so that market output and social welfare decrease with n, a somewhat surprising result. Intuitively, the adoption of revenue sharing increases airlines' outputs substantially if concession service is very profitable. Output expansion, however, is less profitable to airlines in competitive markets, thus output expansion effect declines quickly with n. Although competition alone could lead to larger output and welfare, as shown by the dotted lines in Figure 4.1, overall market output and social welfare do not necessarily increase with n since they depend also on the effects of revenue sharing.

In Figure 4.1, the airport reaches its maximum profits with revenue sharing around n = 2.5. When there is strong airline competition ($n \geq 23$), an airport would not choose to share its concession revenue fully. This result provides supporting evidence to our intuition that an airport does not always prefer stronger competition in the downstream airline market.

Although the above results are plausible in theory, it is not clear whether airport concession service could be this profitable in reality. Figure 4.2 reports a more realistic case, where the parameter values are set as: b = 0.00001, k = $0.9b$, c = 0.9, w = 0.05, h = 0.05. In this case, airports would prefer larger output and sharper airline competition. The results in Figure 4.1 and Figure 4.2 suggest that there may be more than one answer to airports' preferred level of airline competition, since it is influenced by many factors such as market structure, product differentiation, airlines' costs and concession profits etc.

Therefore, empirical investigation would be needed when regulators deal with actual policy issues involving a specific case.

- — Solid lines are the outcomes with revenue sharing;
- ... Dotted lines are the outcomes without revenue sharing.
- Horizontal axis corresponds to the number of firms, $n \in [2,40]$

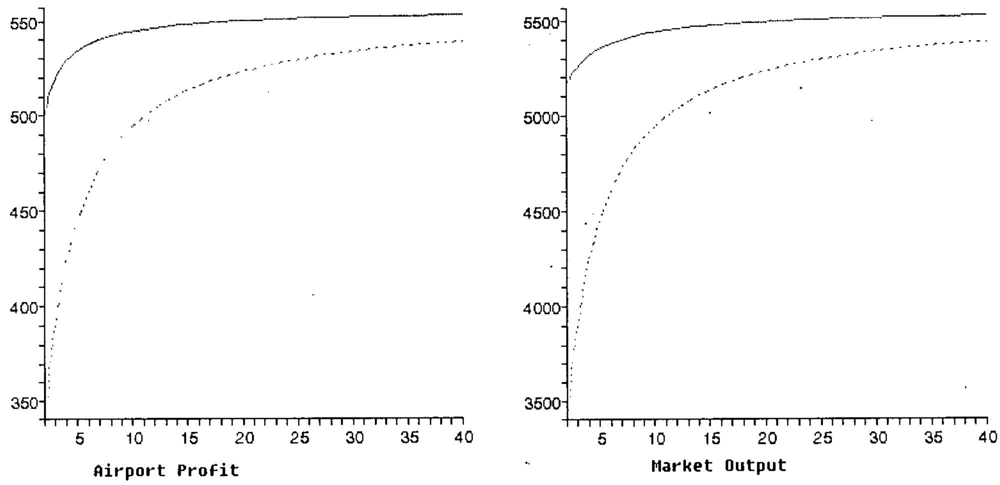


Figure 4.2 Equal Revenue Sharing When Airlines Are Symmetric - 2
(Parameter Values: $b = 0.00001$, $k = 0.9b$, $c = 0.9$, $w = 0.05$, $h = 0.05$)

In section 4.3.2 exclusive revenue sharing, we suspected that when the number of oligopoly airlines is large, social welfare may decrease in spite of the expansion of market output. Our simulation results show that this is indeed possible. Figure 4.3 reports the results on airports' profit and welfare improvement under exclusive revenue sharing. The results indicate that although an airport's profit would be higher with revenue sharing, social welfare could be reduced. However, the welfare loss would not likely to be a major concern in practice, as the relative welfare losses are very small (less than 0.1%), and would occur in the unrealistic cases when $n > 70$. After all, market output is larger with revenue sharing.

- In the graph for airport's profit,
  - — solid line is airport's profit with exclusive revenue sharing;
  - ... the dotted line represents the result without revenue sharing.
- Horizontal axis corresponds to the number of firms, $n \in [30,200]$

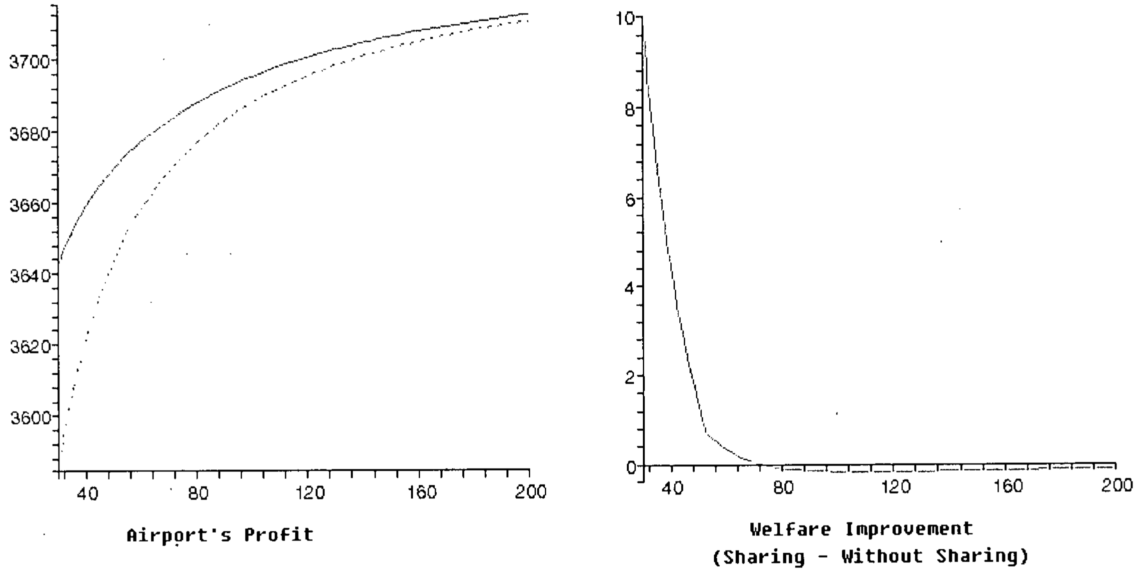
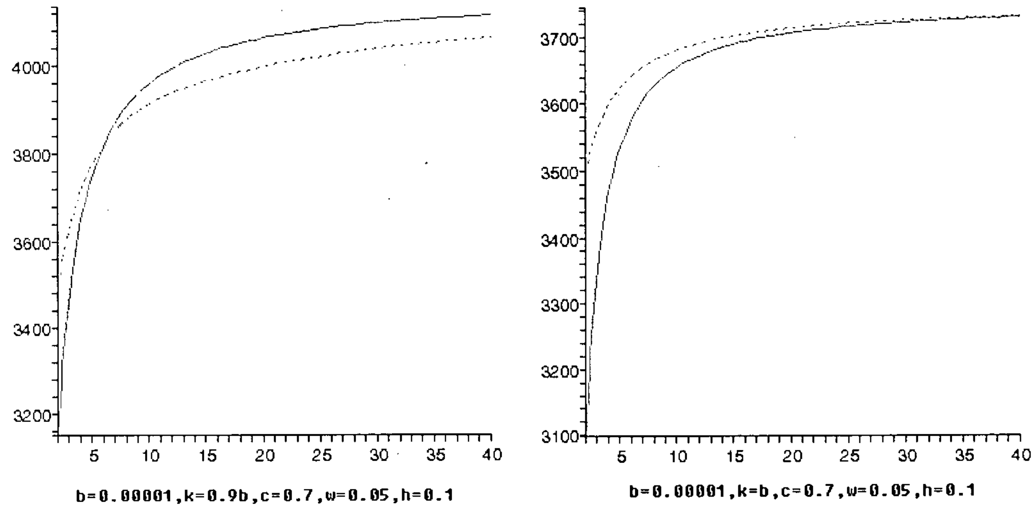


Figure 4.3 Exclusive Revenue Sharing When Airlines Are Symmetric
(Parameter Values: $b = 0.00001$, $k = 0.9b$, $c = 0.5$, $w = 0.05$, $h = 0.05$)

As discussed earlier, we consider two revenue sharing schemes in oligopoly airline market, namely equal revenue sharing and exclusive revenue sharing. When an airport consistently achieves higher profit with a certain revenue sharing scheme, it would offer this revenue sharing option only. Airport's profits under the two alternative revenue sharing schemes are compared in Figure 4.4. The comparison indicates that an airport could have different preferences over the two schemes depending on market structure (number of firms n) and product differentiation (k and b). This implies that both types of revenue sharing are possible.

- Horizontal axis corresponds to the number of firms, $n \in [2,40]$



Solid Line : Airport's profit with equal revenue sharing arrangement
Dotted Line: Airport's profit with exclusive revenue sharing arrangement

Figure 4.4 Comparison of Airport Profits Under Two Alternative Revenue Sharing Schemes

Figure 4.5 reports on the results in the duopoly case where both airlines produce positive outputs and airline 1 has "substantial" cost advantage ($(c_2 - c_1) > 2h(b-k)/k$). In this case, the airport would prefer to share its concession revenue with airline 1 only no matter what fixed price *f* is charged. ($f \in [f_2, f_1]$, where f_i is airline i's reservation price defined in (4.35)). For airport's profit, the blue point line depicts the case when the airport is able to charge f_1. The solid red line depicts airport's profit when f_2 is charged. In either case, the airport benefits from airline competition as implied by equation (4.36). When airline 2 is more efficient (smaller c_2), market concentration, as measured by HHI index, decreases, which allows the airport to achieve higher profit with revenue sharing. Revenue sharing, however, has negative effects on airline competition in the form of higher market concentration (solid line in the HHI index graph). This has mixed implications for regulators who rely on airports to discipline hub carriers: airports may indeed welcome airline competition; but they may still prefer to cooperate with dominant carriers, which would strengthen the dominant carrier's market power.

When airlines are symmetric and their reservation price is charged, our analysis of the oligopoly market shows that airlines are always worse off regardless of revenue sharing or not. The results in Figure 4.5 indicate that a carrier (airline 1 in this case) may be better off in terms of profit with revenue sharing if it has competitive advantage and is charged a price lower than its own reservation price. This means that an airport and its dominant carrier could both have strong incentive to collude. This finding is consistent with recent industry observations. For example, the Charlotte/Douglas airport authority believes that it benefited from enjoying a single dominant carrier (US Airways) that was regarded as a "partner" of the airport.[49]

The simulation results also show that the two most important goals of economic regulation, namely social welfare maximization and fair competition, are not always consistent. When an airport cooperates with the more efficient airline, that airline achieves larger market share and larger absolute output at the expense of its competitor(s). Consequently, the airport influences airline market shares in the efficient direction and captures some of the benefits via the fixed fee the airline pays. This improves welfare and strengthens dominant carrier's market power.

[49] FAA, however, expressed concern that US Airways exercised too much control over airport facility and operations such as landing slot allocation and passenger terminal usage. The mayor of Charlotte appointed a task force to address the issues of airline competition. Additionally, the Aviation Department, pursuant to a directive from the City's Advisory Committee, hired a consultant to evaluate the competitive situation at Charlotte and to develop strategies for improvement (FAA 1999)

- Horizontal axis corresponds to airline 2's marginal cost $c_2 \in [0.55, 0.7]$
- .....Red Dotted Line: Results without revenue sharing
- ° ° Blue Point Line: Results when airline 1 share revenue and its reservation price f_1 is charged.
- — Red Solid Line: Results when airline 1 shares revenue but f_2 is charged.
- f_1 and f_2 are two airlines' reservation prices defined in (4.35).

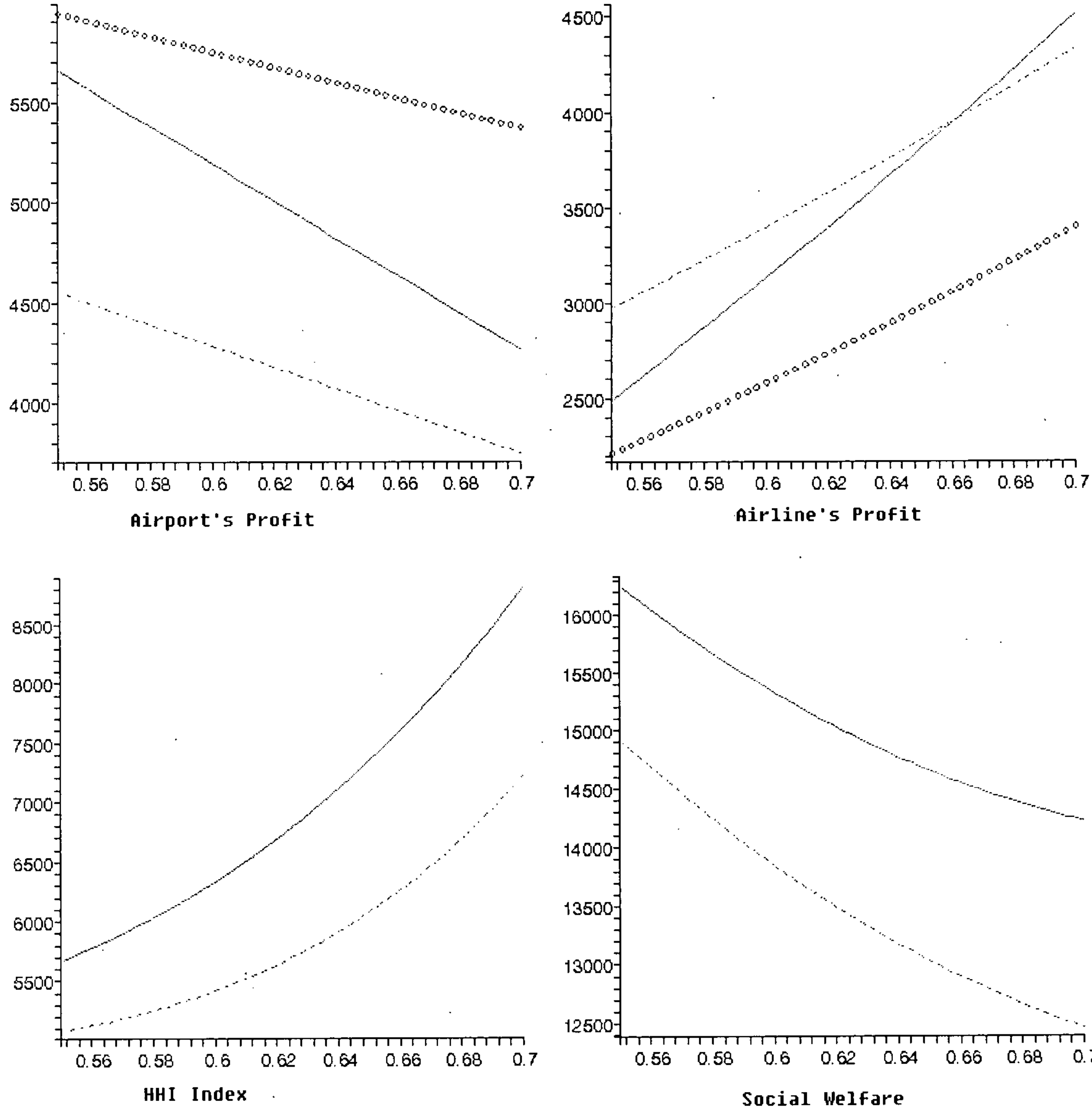


Figure 4.5 Duopoly Airlines When Firm 1 Enjoys Competitive Advantage
(Parameter Values: $b = 0.00001$, $k = 0.8b$, $c_1 = 0.5$, $w = 0.05$, $h = 0.1$)

4.6 Summary and Conclusion:

With the trend of airport commercialization and privatization in recent years, concession and other commercial operations have become an increasingly important source of revenue and profit for airports. As concession service is a derived demand from passenger travel, airports and airlines have an incentive to work together in order to internalize such positive demand externality. This chapter examines the competitive and welfare implications of revenue sharing. Three airline market structures have been modeled, namely: (1) a benchmark case where an airport is served by a monopoly airline; (2) an oligopoly airline market in which symmetric airlines serve horizontally differentiated demands; and (3) an oligopoly market with asymmetric airlines when one carrier enjoys a substantial cost advantage over the other. Although some results vary across the market structures, the following general conclusions are worth emphasizing:

- *Welfare Implications:* Concession revenue sharing allows for the airport and airlines to exploit the demand complementarity between aviation services and concession services. This leads to increased market outputs and higher social welfare in almost all market structures and revenue sharing options we considered. In certain circumstances, such as the case when an airport is served by a monopoly carrier, revenue sharing may lead to a Pareto improvement. Overall, our findings suggest that concession revenue sharing can be a major source for welfare improvement.
- *Airline Competition Effects:* Despite of its potential for welfare improvement, revenue sharing may have negative effects on downstream airline competition. With exclusive revenue sharing, an airport is able to capture surplus (the king

maker's reward) from the airline market by letting one carrier to achieve larger output and market share via revenue sharing. In addition, there are cases where the airport could cooperate with the dominant airline to maximize profit. This further strengthens the dominant firm's market power since its market share is larger after revenue sharing. Therefore, it is insufficient to rely on airports to discipline their dominant carriers and safeguard airline competition.

- *Implications on Airport Regulation:* Our results show that a profit maximizing airport has strategic interests in downstream airline competition. An airport may still have incentives and methods to collude with dominant carriers even if it satisfies all of the following three conditions: (a) aviation service price of the airport is regulated; (b) the airport has no ownership interest in airlines; (c) the airport is prohibited from price discrimination. We have also found cases where an airport does not want to fully internalize concession revenue, and prefers to increase aviation service charges. Therefore, government intervention or monitoring is needed to achieve welfare maximization.

The above conclusions may apply to other airline-airport agreements whenever an airport has ability and incentive to provide a particular airline with favorable terms. Favorable terms can be either superior service or preferential usage of key facilities (e.g. landing slots in peak hours, usage of checking counter, terminal gate and lounges etc. In the Munich airport case, terminal 2 is tailored to the customer needs and clearance processes of Lufthansa and other Star Alliance carriers). Any measure that affects airline competition would allow the airport to extract surplus from carriers. The surplus can be either payment as we have modeled, or non-monetary benefits such as loan guarantee, service commitment etc. The intuition is clear: whatever influences competition is valuable to airlines. Since such measures are usually more valuable to the dominant carrier, an airport is more likely to work with them. Our results thus imply a price regulated airport may still have strategic incentives to manipulate downstream airline competition.[50]

We have shown that the effects of concession revenue sharing, or other airport–airline cooperation, can be two-sided. Therefore, there may be a need for regulators to at least monitor airport–airline cooperations. Airports are often regarded as natural monopolies with substantial market power. Consequently, they are usually under direct price regulation, or threat of regulation. Hence, airports will find some measures to substitute price increase of its aviation services. Commercialization and privatization bring airport substantial pressure for profit / revenue growth. This has compelled airports to exploit "innovative" ways to improve their financial performance, such as concession revenue sharing studied in this essay.

Our conclusions are likely to hold wherever a monopoly firm who supplies one or more essential inputs to other firms, and has ability to influence the competition in the buyers' market. For example, many airports in North America allow only licensed taxi drivers to pick up passengers at their airports. For the case of the Greater Toronto Airport Authority (GTAA), taxi drivers without such license have to pay C$10 each time they enter a taxi queue in order to pick up passengers In Pearson International Airport. GTAA had issued such licenses to 360 taxicabs and 276 limousines by year 2005 (GTAA 2005). The last taxi plate sold cost C$465,000 (Legislative Assembly of Ontario 2005), a

[50] This is an extension of the results obtained in chapter 3 of this thesis, where an airport has no interests in airline competition *per se*.

remarkable price for a fairly competitive industry.[51] If unregulated, airports may exercise their market power on airlines with similar measures.

In this essay airports are treated as input monopolies. There are regions where adjacent airports compete for both airline services and air travelers, such as the case in many western European cities (Barrett, 2000) and in the U.S. (Basso and Zhang, 2006). If one plans to accommodate such reality, our analysis can be modified by assuming multiple airports compete for the service of one major airline. Such a study would be very valuable for assessing public policy alternatives on the airport-airline alliance cases similar to the Charleroi Airport-Ryanair case.

[51] It is my understanding that taxi licenses are normally issued by municipal governments instead of airport authorities. The Toronto municipal government issues taxi licenses, the municipal license holders are however banned from taking passengers out of the Toronto airport. On the other hand, taxi drivers holding a GTAA license can pick up passengers in Toronto. It is argued by some regulators and trade unions that such inconsistent policy has led to unfair competition.

Appendix A. Sketched proof for Equation (4.19)
For the first two equations, it can be derived that:

(A.1) $$\frac{\partial^2 \pi(r,\ldots,r)}{\partial r \partial c} = -\frac{(n-1)nhk^2}{(2b-k)[2b+(n-1)k]^2} < 0$$

(A.2) $$\frac{\partial^2 \pi(r,\ldots,r)}{\partial r \partial w} = \frac{2nh[(2b+kn)(b-k)+k^2]}{(2b-k)[2b+(n-1)k]^2} > 0$$

For the last equation, note

(A.3) $$\frac{\partial^2 \pi(r,\ldots,r)}{\partial r^2} = \frac{2nh^2 V_1}{(2b-k)^2[2b+(n-1)k]^2}$$

where $V_1 = 6nbk^2 + k^3 + 8b^2k - 6bk^2 - 4b^3 - nk^3 - n^2bk^2 - 4nb^2k$.

Clearly the sign of (A.3) depends on the sign of V_1 only. It can be calculated that $\frac{dV_1}{dn} = -k[k^2 + 2bk(n-1) + 4b(b-k)] < 0$. So that V_1 takes the largest value when n takes the lowest possible value 2. When n = 2, $V_1 = -2b(2b^2 - k^2) - k^3 < 0$. We thus know when $n \geq 2$, $V_1 < 0$ and $\frac{\partial^2 \pi(r,\ldots,r)}{\partial r^2} < 0$.

Appendix B. Sketched proof for Equation (4.24)
For first three equations, it can be derived that:

(B.1) $$\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial w} = \frac{2h(b-k)}{(2b-k)[2b+(n-1)k]} > 0$$

(B.2) $$\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial c} = -\frac{kh}{(2b-k)[2b+(n-1)k]} < 0$$

(B.3) $$\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1^2} = -\frac{2h^2[2(b-k)^2 + bk + kn(b-k)]}{(2b-k)^2[2b+(n-1)k]} < 0$$

For the last expression, note

(B.4) $$\frac{\partial^2 \pi(r_1,\bar{0})}{\partial r_1 \partial n} = \frac{khV_2}{(2b-k)^2[2b+(n-1)k]^2}$$

Where $V_2 = k^2(1-c-2w-h+2r_1h) - 2bk(1-c-3w-2h) - 4b^2(w+h)$

Clearly the sign of (B.4) depends on the sign of V_2 only. In addition, one has

(B.5) $\frac{dV_2}{dr_1} = 2k^2h > 0$, $\frac{dV_2}{dw} = -2(2b-k)(b-k) < 0$,

$$\frac{dV_2}{db} = -6w(b-k) - 2k(1-c) - 4h(2b-k) - 2bw < 0$$

thus when $w=0$, $r_1 = 1$, $b=k$ one has $Max(V_2) = -k^2(1-c-h) < 0$ so long as $1-c-h>0$. This is the same sufficient condition for $\partial^2\pi(r_1,\bar{0})/\partial r_1 \partial n < 0$.

Appendix C. Airport's incentive to raise service charge

We will show in the following that an airport can enhance its profits by levying a higher service charge even when the positive externality of concession revenue has been internalized by equal revenue sharing. To see this, define the airport's profit from concession activities as $\pi^C(r,...,r) = h(1-nr)\sum_{i=1}^{n} q_i + n \cdot f(r,...,r)$. It can be shown that

(C.1) $$\frac{d\pi(r,...,r)}{dw} > 0 \text{ when } 1-c-2w-h>0$$

(C.2) $$\frac{d\pi^C(r,...,r)}{dw} < 0$$

where $\pi(r,...,r)$ is the airport's profit when it shares an equal proportion of concession revenue with each airline. Positive airline output requires $c+w<1$. If the condition $1-c-2w-h>0$ does not hold, or $(c+w)+(w+h)>1$, then airlines will exit the market when there is a minor increase in their costs, say *(w+h)*. This may be possible in marginal routes but unlikely to hold in general. Therefore, $d\pi(r,...,r)/dw > 0$ hold in most cases. This means although higher airport charge does reduce the profitability of concession services (as implied by equation C.2), overall an airport's profit will increase with its aviation service charge *w*.

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Chapter 5

Conclusions

This dissertation examines two important issues in the air transport industry. The first issue is airline competition in the presence of major Low Cost Carriers (LCCs). The second issue is airports' role in downstream airline competition.

Essay One empirically examines airline competition in the presence of a major LCC when the initial LCC entry effects have stabilized. Using a panel data from the United States domestic markets, we are able to calculate carrier-specific demand equations and identify substitution possibilities between FSAs, as well as substitution between LCC and FSA carriers. Competition analysis is also carried out by estimating LCC and FSA's reduced form price equations. The key results of this essay are as follows: (1) There is strong evidence of product differentiation effect between services provided by FSAs (American and United in our sample data) and the LCC carrier (Southwest in our sample data); (2) After removing the data for the first two quarters after the entry of the major LCC carrier, the reduced form fare equations show that the average prices of incumbent FSAs become more sensitive to the number of FSAs in the market than the number of LCCs. This shows that competition between FSAs will continue to be important even with the presence of a major LCC; (3) Furthermore, the average price offered by the major LCC (Southwest) is much more responsive to the number of LCCs present in the market while being pretty insensitive to the number of FSAs; (4) Airlines with higher market shares (regardless of whether they are FSA or LCC) tend to charge higher prices, indicating the effect of market concentration on pricing; (5)

There is evidence that FSAs derive larger positive pricing benefit from an increase in their market shares of available seats, while LCCs obtain larger positive pricing benefits from an increase in their shares of flight frequency.

These results have the following policy implications: (a) importance of anti-trust scrutiny on mergers between FSAs even in markets where one or more LCCs are present, and (b) both carrier types (FSA and LCC) appear to exercise substantial market power, indicating the need for anti-competitive concern.

Essay One finds empirical evidence that FSAs and LCCs do provide differentiated services. This implies that a change of input price, such as the case when an airport increases its service charges, may have asymmetric impacts on the two types of carriers. In Essay Two this intuition is formalized in a duopoly airline competition model, where a monopoly airport levies an identical per-passenger service charge to an FSA and an LCC. The results of analytical and numerical investigations in this essay find existence of the asymmetric effects of an airport's monopoly pricing on LCC and FSA carriers. LCCs suffer more from an identical input price increase than FSAs and are, therefore, more vulnerable to an airport's monopolistic pricing. This may cause a reduction of competition in downstream airline markets. This reduction of airline competition constitutes a further detrimental effect on welfare over and above the first-order welfare loss caused by high airport charges above competitive level. Such results indicate that it is important for the governments to take into account of these asymmetric effects of increasing airport user charges on FSAs and LCCs when considering the form and extent of airport regulation or deregulation.

Essay Two points out an important issue which has been largely ignored by air transport economists, namely airports' role in downstream airline competition. However, the findings of this essay are obtained under the assumption that an FSA competes with an LCC using differentiated services. In addition, an airport's detrimental influences to airline competition come as a by-product of the airport's desire for higher service charge. An airport has no interests in airline competition *per se* in this study. In Essay Three, I relax such assumptions by considering a special form of airport – airline agreement, where an airport offers an option of sharing its concession revenue with airlines. It is found that revenue sharing allows airlines and airports to internalize positive demand externality, which could lead to substantial welfare gains. However, such practice may bring negative effects to airline competition. In fact, there are cases where an airport can maximize its profit by strategically aligning with dominant airlines. Such airport's strategy would, of course, further strengthen the dominant firm's market power since its market share is larger after revenue sharing. We show that a profit maximizing airport may still have incentives and methods to collude with dominant carriers even if it satisfies all of the following three conditions:

(a) aviation service price of the airport is regulated;

(b) the airport has no ownership interest in airlines;

(c) the airport is prohibited from price discrimination.

In addition, while sharing concession revenue with airlines an airport may still prefer to increase airport service charge. All of these results imply that the effects of airport revenue sharing may be two-sided and warrant close examination. The same conclusions may apply to other airline-airport agreements, and to the industries where a firm's action can affect competition in another market.

There are many possibilities for future research and extension, some already identified in previous chapters. Perhaps the most important extension to the essays is to consider competition among airports. An airport is usually regarded as a natural monopoly in most previous studies. However, for deregulated markets which are served by multiple airports, such as the cities in Western Europe, this assumption may be too restrictive. With empirical analysis similar to those used in Essay One, competition and product differentiation for airports may be identified and quantified. In addition, since competing airports are likely to possess less market power, models used in Essay Two and Essay Three may need some modification, which leads to additional insights in alternative scenarios. These future studies will be very valuable and necessary.