AIRPORT PRICES IN A TWO-SIDED MARKET SETTING: MAJOR US AIRPORTS

Marc IVALDI[*] Senay SOKULLU[†] Tuba TORU[‡]

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Abstract

This paper analyzes airport business model, showing that how the pricing rules are changed when the airports are considered as platforms where airlines and passengers are the two end-users. The analysis shows that the airports indeed should be considered as two sided markets because there exists two sided network externalities between the airlines and the passengers. A testing procedure to detect the real business model of airports is also provided in this paper, demonstrating that the airports in our data set do not internalize the externalities existing between airlines and passengers. Moreover, we find that airports set profit maximizing prices for passengers and Ramsey prices for airlines. Given these results, we conduct a welfare simulation and show that when an airport sets its prices under a two sided market setting, the impact on social welfare depends on the airport.

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[*] Toulouse School of Economics, marc.ivaldi@tse-fr.eu
[†] University of Bristol, senay.sokullu@bristol.ac.uk
[‡] Bahcesehir University, tuba.toru@bahcesehir.edu.tr

1 Introduction

In many countries, airports are under increasing pressure to become more financially self-sufficient and less reliant on government support for at least two reasons. (See Graham, 2009.) First, airlines, which face a fierce price competition since the liberalization in the air transport industry, seek to lower their operating costs that comprise landing fees and other costs linked to the aeronautical services. Second, the air traffic experiences a strong and sustainable growth that fosters the degree of congestion of airports and airspace, which in turn triggers delays and, as a consequence, involves further costs for airlines and for passengers.

Traditionally airports have been viewed as public service providers to airlines, and as such, have always been owned, managed or regulated by public authorities. Mainly based on the argument that public airports have not been able to rise to the challenge the increase in the air traffic and the need for efficient solutions to higher congestion costs and travel delays, a major movement has been initiated towards a higher involvement of the private sector in the operation of airports, as in the United Kingdom, Australia, New Zealand and Canada which have been pioneers in the process of airport privatization. In the United States and in many European countries, the debate on the privatization of airports remains high on the agenda.[4]

In this context, our objective is here to contribute to the design of efficient business models of airport management and to the debate on privatization of airports. Specifically, this paper is aimed at deciphering the economic behavior of airport managers, that is to say, at identifying their pricing rules and testing how they account for the interdependency of their clients, passengers and airlines. For this purpose, it is crucial to base the analysis on a correct model of airport behavior.

Nowadays airports are considered as complex infrastructure providing various services, both aeronautical and non-aeronautical, to airlines and passengers. Although the aeronautical activities are the original mission of airports, airports generate a significant amount of revenue from passengers through non-aeronautical activities. It is well understood that there is interdependence between airlines and passengers: Airlines prefer to operate at airports which are attractive to passengers and passengers enjoy airports where they can access more air links and destinations, as well as a wide range of shops and restaurants, and convenient parking and transportation facilities.

Based on this description, our conjecture is that airports can be considered as two-sided markets or platforms. Following the seminal article by Rochet and Tirole (2002), and subsequent articles by Rochet and Tirole (2003, 2006) and Armstrong (2006), Weyl (2010) and Filistrucchi *et al.* (2012) state that two-sided platforms have three main features. First, they are multi-product firms which serve distinct products to each side. Secondly, users' benefits from a platform depend on how well the platform performs on the other side of the market. Finally, platforms are price setters on both sides. It is straightforward to observe that airports satisfy these three conditions to be treated as two-sided platforms. Indeed, airports serve two distinct groups of users: passengers and airlines. On one side, passengers use non-aeronautical services of airports such as parking, shops and restaurants as well as its aeronautical services to travel. On the other side, airlines use aeronautical services of airports such as landing and take-off

[4] See Gillen (2009) for the ownership structure of airports.

facilities, or check-in areas. Airports negotiate prices with the airlines and charges them to use the aeronautical facilities at the airport and they charge the passengers via the prices of non-aeronautical facilities provided by the airport. In addition, the benefits of each side depend on the number of agents on the other side: An airport is more valuable to airlines if it is popular with the passengers, and passengers value the airport more when they can find a flight scheduled closer to their desired departure time or which is better in saving their travel time.

Note that Gillen (2009) has also suggested that airports could be considered as two-sided platforms after pointing out the increasing importance of commercial revenues of airports and in a companion piece, we provide some empirical evidence on the two-sidedness of airports using data on U.S. airports. (See Ivaldi *et al.*, 2012.). Here, we exhibit the structural ingredients of this two-sidedness and we take one step further in identifying the pricing strategies of airports using this two-sided market setting and in providing an estimate of welfare gains obtained by using a business model that fully recognized this economic structure of airports.

With this approach in mind, we consider an airport as a monopoly platform, and, in this setup, we derive the passengers' demand for air transport services by means of a logit-type specification and the airlines' pricing behavior under Bertrand competition. We then fit the whole model to a panel dataset of U.S. airports. The estimation confirms the significance of externality effects between the two sides of the market. We then discuss airports' business models. Given our data on U.S. airports, we compare three pricing schemes under either a two-sided or a one-sided structure: Pigouvian, profit maximization and Ramsey pricing. To do so, we apply a test statistic implemented through a bootstrap method to identify the pricing behaviour of airports that is the best approximation of the data generating process.

Our first conclusion states that, without any doubt, airports should be considered as two sided platforms. As such this paper is the first extensive empirical analysis of airports within the literature on the two-sided markets.[5] Furthermore, as a result of our testing procedure to detect the real business model of airports, we demonstrate two main facts. First, the airports in our data set do not account for the two-sidedness of their activity when deciding on the prices charged to passengers and airlines. In other words, they do not internalize the externalities existing between two sides. Second, they use different pricing schemes for each side. More precisely, we find empirical evidence of profit maximizing prices for passengers and Ramsey prices for airlines. Given this conclusion, we simulate the case where the monopolist profit maximizing airport is setting the prices under a two-sided market structure. We compute the social welfare under this scenario and compare it with the actual social welfare. We find that the results are airport dependent, for some airports this hypothetical pricing would increase the welfare while for others it would not.

Our paper differs from previous studies that look at the question of airport pricing from a theoretical point of view as in Basso (2008) and Basso and Zhang (2008) or from an empirical angle as in Gagnepain and Marin (2005, 2006), who consider the airport-airline-passenger relationship to be vertically integrated, taking passengers as final consumers. In other words, demand for airport services is a derived demand which comes from the necessity of the product

[5] The empirical literature on two-sided markets is mainly focused on the media industry. See Kaiser and Wright (2006), Argentesi and Ivaldi (2007), Argentesi and Filistrucchi (2007) and Sokullu (2012).

of airlines (air transport demand) so that they consider airlines as intermediaries. It is then not surprising that we differ in our evaluation of the sources of sub-optimality of airport pricing.

Our paper also sheds light on an important debate on different regulatory pricing policies, the so-called single-till or dual-till, applied to airports. In the single till approach, a price-cap formula includes revenues derived from both aeronautical and non-aeronautical activities while, in the dual till approach, only the revenues from aeronautical activities are taken into account. The advocates of the dual till system claim that regulation should concentrate on activities which are characterized by a natural monopoly; thus revenues from commercial activities should not be included in the formula. (See Beesly, 1999.) Several articles contribute to the debate on these two systems. Starkie and Yarrow (2009) point out the strong complementary between the aeronautical and non-aeronautical activities. Zhang and Zhang (2010) study the airport's decision on pricing and capacity both under the single-till and the dual-till approach and conclude that it will over-invest in capacity under both single-till and dual-till regulation. Currier (2008) looks at a price cap regulation of airports and proposes a price capping scheme which yields Pareto improvements compared to the status-quo regardless of single-till or dual-till regulation. Czerny (2006) points out that single-till regulation is more welfare enhancing at non-congested airports than dual-till. Here we do not investigate the impact of these regulations. However, by demonstrating the two-sidedness of airports and by identifying the true business model of airports under an appropriate economic structure, our paper provides key evidence for the design of an efficient pricing methodology.

The paper is structured as follows. *Section 2* describes the data and provides a descriptive analysis. *Section 3* explains the passengers' and airlines' behaviour. *Section 4* introduces the airport pricing schemes. *Section 5* presents the empirical specification and estimation results. *Section 6* describes the airport pricing and simulation results. Finally, we conclude in *Section 7*.

2 Data

Our data are drawn from the Airline Origin and Destination Survey (DB1B) and DOT 100 Domestic Segment (T100 databases) provided by the U.S. Bureau of Transport Statistics (BTS), and Airport Data published by Federal Aviation Administration (FAA). Moreover, some of the airport characteristics, such as the number of parking lots and the number of concession contracts, are gathered directly from the airports. The DB1B survey comprises a 10% sample of airline tickets from the US reporting carriers and gives detailed information on ticket fares, itinerary (origin, destination, and all connecting airports), the ticketing and operating carrier for each segment, and the number of passengers travelling on the route at a given fare. The T100 databases contain the frequency of flights for all routes in the US. Airport Data combined with information gathered directly from airports covers the aeronautical and commercial operations of airports as well as the facilities. To construct our working sample, we extracted from the original data set the records corresponding to the third quarter of 2006 during which, for the first time since 2000, the US airline industry experienced a positive aggregate net profit (ATA, 2012).[6]

To arrive at the final sample used for estimation, several restrictions are imposed on the original data set. These restrictions are chosen mostly to make our sample compatible with the model introduced in *Section 3*. First, we keep only round trip itineraries within the US territories. By considering itineraries within the US, we do not have to deal with any issues that may arise because of differences amongst countries. Besides, the US is geographically large enough so that we can still have lots of variation in destination specific features, such as miles flown and destination population. Moreover considering only round trips eliminates any effect that may stem from nonlinear pricing of single tickets. Second, the market is defined as a directional pair of an origin and a destination airport. This allows us to capture not only the origin airport and city characteristics but also the destination city characteristics in passenger demand, thus preventing any possible omitted variable bias that might be related to destination city. Third, we select markets which are served by at least two competing carriers to be consistent with the assumption of competing airlines in our model. In our sample around 20% of the routes are served by only one airline, so we did not lose many observations by this restriction. Fourth, we focus on direct flights with single ticketing and operating carriers, thus excluding code shared flights as well as impacts of connecting airports. Although the passengers are likely to consider the characteristics of connecting airports when they buy their tickets, our first attempt in this paper is to consider the two-sidedness of the market by using the origin airport. Hence, to eliminate any possible effect of connections (connecting airport characteristics, connection times, etc.) we consider direct flights only. In the code-shared flights the passenger's decision may also be affected by the code-sharing partner, thus exclusion of this information may cause an endogeneity problem. By considering the observations with single ticketing and operating carriers we also try to eliminate this endogeneity. Finally, as we make the assumption of monopoly airport, we consider the US hub airports as origins. These hubs are more likely to have a monopoly position since they are much larger and offer more facilities to airlines and passengers. In addition, hub airports are busier than other airports thus they may allow us to capture congestion effects better. After contacting airports, we obtained concession and parking data from 9 U.S. hub airports. The sum of revenue passenger of these 9 airports represents 42.1% of the total passenger traffic at the 31 largest US hub airports. (See Table 1.)

After applying the above restrictions, our data contain several observations of a given airline-itinerary combination (namely product) that are distinguished by the prices paid and the number of passengers paying each of those prices. Therefore, the data are then transformed by taking the weighted average of the price and aggregating the number of passengers purchasing the same product.

Finally, we use demographic data obtained from the U.S. Census Bureau in order to control for market characteristics. Population and median per capita personal income in the metropolitan area where airports are located, are included in the demographic data. The market size is measured by the population in the metropolitan area where the origin airport is located.

The resulting sample used in our estimation has 377 products (airline-itinerary combination), covers 165 markets (origin-destination) and 9 origin airports. The complete list of airlines and the total number of products provided by them can be found in Table 2. As

[6] \$3.04 billion excluding restructuring and bankruptcy costs.

shown in Table 3, airports in our sample generate, on average, 40% of their revenue from non-aeronautical (e.g. commercial) activities and the rest from aeronautical (e.g. landing-departure) activities.

Table 4 reports the summary statistics of our main variables. Average ticket fare (price of product) is $97.85 with a minimum at $3.73 and a maximum at $259.24. An airline has in average 401 flights per product in one quarter.

3 Modelling Passenger and Airline Behavior

In this section, we present our model of passenger and airline behavior. First, we derive the transport demand equation for passengers, then the pricing and frequency equations that define the airlines' strategies.

3.1 Passenger Side

A passenger i, $i = 1, \dots, I$, has to decide between travelling to a given destination d, $d = 1, \dots, D$, from an airport a and "not travelling" or "using other transport modes" which is her outside option referred by the index 0. Under the option of travelling by air, the passenger has to choose an airline j among the set of available airlines $j = 1, \dots, J_{ad}$ for the given origin-destination ad, and J_{ad} is the total number of airlines operating from airport a to destination d. Moreover, each passenger consumes a positive amount of commercial good at the airport while non-fliers cannot consume any. To represent the behavior of passengers, we adopt a nested logit model.[7] The indirect utility level achieved by passenger i from choosing airline j for the given origin-destination, ad, is:

$$U_{adj}^{i} = V_{adj} + \varepsilon_{adj}^{i} \tag{1}$$

where V_{adj} is the mean utility level of using airline j at ad and ε_{adj}^{i} is a consumer specific unobservable effect. We specify ε_{adj}^{i} as follows:

$$\varepsilon_{\mathrm{adj}}^{\mathrm{i}} = \nu_{\mathrm{ad}}^{\mathrm{i}} + (1-\sigma)\nu_{\mathrm{adj}}^{\mathrm{i}} \quad \forall \mathrm{i} = 1, \dots, \mathrm{I} \tag{2}$$

The error term ν_{ad}^{i} captures passenger i's preference for travelling by air, and ν_{adj}^{i} captures passenger preference for a specific airline operating at ad. We assume that ν_{adj}^{i} is distributed Type I Extreme Value and ν_{ad}^{i} is distributed such that ε_{adj}^{i} is also distributed Type I Extreme Value. Under this specification, the parameter σ shows the within group correlation of unobserved utility and it is restricted to lie between 0 and 1. In other words, σ is the substitutability of airlines operating in ad. Note that, higher σ means greater substitutability across airlines and more intense competition.

[7] Note that, including first the choice of using an airport or not using it, allows us to extend the model to competing platforms easily. Indeed, to do so, one can introduce the competing airports to the first nest of the choice tree.

The mean utility level of using airline j, V_{adj} is specified as:

$$V_{adj} = X'_{adj}\beta + \beta^j \frac{1}{\sqrt{f_{adj}}} + \beta^a f_a + \beta^c p_c - \alpha p_{adj} + \xi_{adj} \tag{3}$$

where X_{adj} is a vector of observable characteristics of the airport, destination and airline. The term f_{adj} is the frequency with which airline j flies from airport a to destination d and $1/\sqrt{f_{adj}}$ measures the passenger's cost of schedule delay, i.e., the difference between the passengers' preferred departure time and the actual departure time. A passenger's schedule delay is inversely proportional to the frequency, assuming that desired departure times are uniformly distributed and an airline groups some of its departure times. (See Richard, 2003.) The airport capacity, f_a is the sum of flight frequencies of all airlines operating at the airport, i.e., $f_a = \sum_d \sum_j f_{adj}$. p_c is the price of commercial goods at the airport and p_{adj} is the ticket price of airline j.

Finally, ξ_{adj} is the error term capturing airport, destination and airline characteristics which are unobservable to the econometrician such as the number of check-in desks at the origin airport, the number of baggage belts at the destination airport and departure time. Note that the β's and α are parameters to be estimated.

Let s_{adj} be the market share of airline j in the origin-destination ad, $s_{j|ad}$ be the market share of airline j within the nest "travelling by an airline from airport a to destination d, and s_0 be the market share of the outside option. Moreover, let us normalize the mean utility of the outside option to 0, i.e. $V_0 = 0$. Following Berry (1994), the share of passengers using airline j in a given origin destination ad, s_{adj}, is given by

$$s_{adj} = e^{V_{adj}} s_0 s_{j|ad}^{\sigma} \tag{4}$$

which leads to the following estimation equation:

$$\begin{aligned} \ln s_{adj} - \ln s_0 = {} & X'_{adj}\beta + \beta^j \frac{1}{\sqrt{f_{adj}}} + \beta^a f_a + \beta^c p_c - \alpha p_{adj} \\ & + \sigma \ln s_{j|ad} + \xi_{adj} \end{aligned} \tag{5}$$

The market shares are measured as:

$$s_{adj} = \frac{q_{adj}}{M} \tag{6}$$

$$s_{jad} = \frac{q_{adj}}{\sum_{j \in J_{ad}} q_{adj}} \tag{7}$$

where q_{adj} is the total number of passengers travelling from origin airport a to destination d by airline j and M is the total market size.

If airports are two-sided platforms, the airport should be able to affect the demand of passengers for the airlines through its pricing scheme. Thus, we expect β^c in Equation 5 to be significantly different than zero. Moreover, in this two-sided platform the passenger's benefit, hence their demand, should also depend on the total number of products (flights) they can access. So we also expect β^a to be statistically significant.

3.2 Airline Side

Each airline j, $j = 1, \dots, J_{ad}$ sets its fare, p_{adj}, and frequency, f_{adj}, which maximizes its profit π_{adj} on each market. The profit maximization problem of airline j is written as:

$$\max_{p_{adj}, f_{adj}} \pi_{adj} = \left(p_{adj} - c_{adj}^{q}\right) q_{adj} - p_a f_{adj} - F_{adj} \quad s.t.\ \ \pi_{adj} \geq 0 \tag{8}$$

where F_{adj} is the airline j's route specific fixed cost, p_a is the aeronautical fee charged by the airport a per flight (departure) and c_{adj}^{q} is the marginal cost per passenger of airline j for route ad. Since we do not observe this marginal cost, we posit that

$$c_{adj}^{q} = Z_{adj}'\lambda + u_{adj} \tag{9}$$

where Z_{adj}' is a vector of cost shifters that includes airline, destination and airport specific variables, and u_{adj} is an error term. Then, the optimal levels of price and frequency obtained from equation (8) are given by:

$$p_{adj}^{*} = c_{adj}^{q} + \frac{1}{\alpha\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma} s_{j|ad} - s_{adj}\right)} \tag{10}$$

$$f_{adj}^{*} = \left[\frac{2}{\beta^{j}}\left(\beta^{a} - \frac{\alpha p_a}{q_{adj}}\right)\right]^{-2/3} \tag{11}$$

Note that the price of product adj is equal to the marginal cost of product adj plus a mark-up term. The latter decreases in the substitutability among the products in a given origin-destination. Moreover, Equation (10) shows that higher market shares lead to higher prices This relation is in line with the finding of Borenstein (1989) that an airline with a dominant position at an airport can use its market power to charge higher prices. Equation (11) shows that the optimal level of frequency depends on the number of passengers and the aeronautical fee charged by the airport, as well as on the parameters σ, the marginal utility of income, β^j, the consumers' valuation of waiting time, and β^a, consumers' valuation of total frequency at airport (in other words, the cost of congestion). Put it differently, the demand of airlines for the airport does not only depend on the aeronautical fee p_a but also on the number of passengers, q_{adj}. In this case, as a two-sided platform, the airport can effect this demand either by changing the aeronautical fee which will affect the demand directly or by changing the commercial fee p_c which will affect the passenger demand q_{adj} and then the airline demand f_{adj} via the two-sided network effects.

4 Estimating Passenger and Airline Behavior

In this section we specify the model according to the data set and explain the estimation method. Then, we present the estimation results of the passenger demand Equation (5) and the airline pricing Equation (10).

4.1 Model Specification

The econometric model includes three groups of explanatory variables: origin airport characteristics, market characteristics and product/airline characteristics.

The origin airport characteristics we include are the total flight frequency at the airport, the distance to the closest business district, the average shopping area and the daily parking fee. The daily parking fee, which can be considered as an access fee to the airport, is used as a proxy for commercial fees charged by the airport to passengers. Since our data set only contains direct flights, each passenger using the origin airport has to bear a transport cost. So the parking fee captures this transport cost guaranteeing our assumption that each passenger consumes a positive amount of commercial good. The observed market characteristics are population and median per capita personal income at the origin and destination metropolitan areas as well as the distance between the origin and destination airports (in terms of miles flown). Regarding product/airline characteristics we consider price, number of passengers, flight frequency, number of destinations (the number of destinations operated from origin airport by an airline) and the total distance flown from origin airport by each airline.

The factors affecting the passenger demand are then the following: ticket fare, average shopping area, number of destinations, population at destination, consumer's cost of schedule delay, total flight frequency at the airport, distance, distance squared, daily parking fee, distance to the closest business district, total distance flown from origin by each airline, and airline dummies.[8] As well as the common origin airport specific variables like distance to the closest business district and total flight frequency, we include average shopping area in the passenger demand equation in the interest of showing whether passengers gain from the presence of large shopping areas at an airport.

When considering the daily parking fee in the estimation process, we multiply it with a

[8] We include American Airlines (baseline dummy), JetBlue Airways, Continental Airlines, Delta Airlines, Northwest Airlines, United Airlines, US Airways, Southwest Airlines and a dummy for the rest.

destination specific coefficient which is the weight of destination in terms of passenger traffic at the origin airport in the previous period (i.e., the second quarter of the year 2006) to capture the heterogeneity of destinations in commercial revenue generation.

We have both distance and distance squared variables to capture the shape of demand. In general, air travel demand is U-shaped in distance. Whence, passenger demand for air transport initially grows with distance because of the decrease in substitution between air and other modes of transportation (e.g., trains and cars), then decreases as the distance increases further since the trip becomes less pleasant. Air travel demand initially grows with distance since the competition with other modes of transportation decreases. There is inter-modal competition between airlines and other modes of transportation (e.g. trains, cars) at a short distance. (See Ivaldi and Vibes, 2008.) Berry and Jia (2010) find that demand starts to decrease as distance increases further and conclude that travel becomes less pleasant. Similarly Bilotkach *et al.* (2010) show also that flight frequency decreases after a certain distance since the competition from other modes of transportation decreases.

As mentioned in *Section 3*, the consumer's cost of schedule delay is the value of the time difference between the consumer's desired departure time and the closest scheduled departure time of an airline. This difference is specified as inversely proportional to the airline's flight frequency on a given market (origin-destination). (See Richard, 2003.)

Moreover, we include two network measures for airlines in the passenger demand equation: The number of destinations and total distance flown from the origin airport by an airline. The former is the number of destinations from the origin airport operated by an airline and the latter is the logarithm of the sum of distances of all destinations from the origin airport provided by an airline. We also look at the interaction effect of these two network variables.

In Equation (5) the marginal utility of income, α, is assumed to vary across origin cities. More precisely, as in Foncel and Ivaldi (2005), it is a function of the income at the origin city[9]:

$$\alpha = \alpha_0 + \alpha_1 INCOME_a \tag{12}$$

where α_0 and α_1 are parameters to be estimated. This specification allows us to capture the wealth effect. Assuming that income is a proxy for wealth, we expect α_1 to be negative and α_0 to be positive. Then, the overall effect should be positive.

The marginal cost defined by Equation (9), which enters the optimal price equation of each airline (Equation 10) contains distance, distance squared, number of passengers, flight frequency, number of destinations, an origin-destination hub dummy which is equal to one if either the origin or the destination airport is a hub for the airline, carrier dummies and airport dummies.[10] The reason we include both distance and distance squared in the marginal cost equation is that the sign and size of the coefficients of distance and distance squared suggest the pattern of marginal cost. Moreover, the number of passengers, q_{adj}, and the flight frequency,

[9]Median per capita personal income is used for income.

[10]We include airport dummies for MSP (baseline dummy), ATL, JFK, SFO, ORD and a dummy for the rest of the airports (BWI, IAD, IAH and SLC).

f_{adj}, are introduced to identify their impact on marginal cost separately.

The airline demand (Equation 11) links the optimal frequency to the equilibrium number of passengers, up to a stochastic disturbance term which represents measurement errors. We have tried to estimate the system of these three equations (5, 10 and 11) together, but faced some difficulties due to data availability. Particularly, carriers use different types of aircraft on a given origin destination, therefore we need information on the type of aircraft used and the flight schedule in order to model carriers' choices of flight frequencies together with pricing decisions.[11] Given that we do not have such detailed data, the flight frequency is not estimated but treated as endogenous and is instrumented in our econometric model.

In the model demand, price and frequency are determined simultaneously. As a result, in the passenger demand (Equation 5), price (i.e., ticket fare) and frequencies (i.e., an airline's flight frequency and total flight frequency at the airport) are endogenous. Likewise, there are two endogenous variables in the marginal cost equation (Equation 9): number of passengers and flight frequency.

4.2 Instruments

The econometric problem that we face is the endogeneity of market shares, prices and frequency. The classical solution to this problem is to estimate two equations jointly by using instruments which are orthogonal to the unobservables in both equations. So, we estimate the system of equations simultaneously using Generalized Method of Moments (Hansen, 1982). For each equation, we define instruments which satisfy the moment conditions

$$E\begin{bmatrix}\xi|W_q\\ u|W_p\end{bmatrix}=0 \tag{13}$$

where W_q is the vector of instruments for the demand equation and W_p is the vector of instruments for the pricing equation. Since the number of exogeneous variables of our system is not enough to instrument all endogeneous variables, we construct some additional instruments.

On the passenger demand side, we construct five instruments: 1) the number of other airlines operating in the same market (i.e., the number of rival airlines); 2) the average number of passengers carried by rivals in the same market; 3) the average flight frequency of rivals in the same market; 4) a dummy indicating whether the origin airport is a hub for the airline; 5) a dummy indicating whether the destination airport is a hub for the airline. The number of other airlines operating in the same market (origin-destination) affects the level of competition in the market; hence it seems natural to use the number of competitors to instrument price (ticket fare). (See Berry *et al.*, 1995.) In the sample, the average number of passengers carried by rivals predicts the market shares and the frequency very well. In practice, the average flight frequency of rivals on the same market predicts the flight frequency of a carrier, so it turns out to be a good instrument for the frequency. We believe that using a hub has an effect on airlines' cost and reflects the strategy of airlines hence the two dummy variables indicating whether the origin airport is a hub for the airline and whether the destination airport is a hub are good instruments

[11] A similar type of problem is also encountered by Berry and Jia (2010).

for price and frequency. Besides these five instruments, we use airport dummies and nonlinear transformations of some instruments.

On the cost side, we built two instruments: 1) the average number of passengers carried by rivals on the same market; 2) the average flight frequency of rivals on the same market. We assume that the average number of passengers carried by the rivals on the same market can predict q_{adj} in the cost function, but it will be independent of the unobserved cost shocks of the particular airline. Using the same type of argument, we assume that the average frequency of the other airlines is correlated with the frequency of the given airline because they share the same market characteristics, however it will be uncorrelated with the unobserved cost shocks of that particular airline.[12]

As mentioned above, the exogenous variables that directly enter the passenger demand Equation (5) and the marginal cost Equation (9) are also used as instruments for the equations. As a result, there are more moment conditions than parameters to estimate in our system. We therefore test for the over-identifying restrictions.

4.3 Estimation Results

The parameters estimated from the passenger demand and airline pricing equations are presented first. Then, we discuss the estimated marginal cost and margin of airlines. Table 5 presents the parameter estimates for the two-equation system. In the upper panel, we report the parameters of the passenger demand equation and in the lower panel, the parameters of the marginal cost equation are shown. We also report the Hansen J-test of over-identifying restrictions. It does not reject the joint null hypothesis that the instruments are valid, i.e., uncorrelated with the error term.

4.3.1 Demand Parameters

As discussed in *Section 4.1*, passenger demand is affected by ticket fare, average shopping area, number of destinations, population at destination, consumer's cost of schedule delay, total flight frequency at airport, distance, distance squared, daily parking fee, distance to closest business district, total distance flown from origin by each airline, and airline dummies. All the estimated parameters have the expected signs and most of them are significant.

To begin with, the price coefficient, α, is positive hence the effect of price on passenger demand is always negative at each airport. In other words, any increase in ticket fare leads to a decrease in passenger demand. Moreover, α is assumed to vary across origin airports. (See Equation 12.) By specifying the price coefficient as in Equation (12), we introduce origin airport dependent effects of price on passenger demand. As expected, α_1 is estimated to be negative and significant. Thus, passengers flying from an airport located at a richer origin are expected to be less sensitive to ticket fare.

In a nested logit model, the coefficient σ measures the within group substitutability. The within group products are perfect substitutes when σ is equal to one. Note that, σ is

[12]A same type of identification strategy is also used in Kaiser and Wright (2006).

estimated to be 0.55, we can conclude that the airlines flying to the same destination from a given origin are substitutable. Moreover, the estimated value is large enough to ensure that the nested logit model is informative. In other words, there exists a moderate correlation among products provided in the same market (origin-destination).

As explained in *Section 4.1*, air travel demand is expected to be U-shaped in distance. However, the estimated parameters for distance and distance squared variables in our model do not show a U-shaped behavior. While the estimated coefficient of distance is positive and significant, the coefficient of the squared distance is not significant. Hence, we can only say that passenger demand for air transport increases with distance.

Note that the frequency and the network size variables are also included in the demand function. The effect of the airline network on the passenger demand equation is in two directions. Passenger demand grows if an airline increases its number of destinations. That is, the more destinations an airline offers from the origin airport (platform), the larger the passenger demand will be. However, the passenger demand decreases with the total distance flown by an airline. We also look at the interaction effect of two network variables and find out that it is negative and significant. Thus we can conclude that passengers prefer airlines to operate many destinations rather than to operate longer destinations.

Concerning the platform specific (i.e., origin airport specific) variables, discussed in *Section 3.1*, they are all statistically significant. First, the average shopping area is estimated to be positive, showing that passengers gain benefit from the presence of large shopping area at an airport. Second, we find that passenger demand decreases with the distance between the airport and the closest business district. Third, the coefficient on total flight frequency at airport, β^a, is found to be negative, which captures congestion at airport. Accordingly, passengers do not prefer to fly from a congested airport. It can be claimed that passengers do care about the platform (origin airport) properties when they make their travel decisions.

As discussed in *Section 4.1*, daily parking fee is considered to be the price of non-aeronautical (or commercial) services paid by each passenger to have access to the airport (i.e., join platform). The coefficient of daily parking fee, β^c, is found to be negative and significant so passengers fly more if the price of the representative commercial product goes down. That is to say, the airport can affect the transaction between airlines and passengers by changing its pricing structure. This result is in line with the two-sidedness definition of Rochet and Tirole (2003). They state that the volume of transactions changes due to the network externalities if the price structure (relative prices between two end users) changes. The passenger demand in our model exhibits the cross relationship between the two end users, passengers and airlines.

The two variables, namely the airline frequency, f_{adj}, and the total frequency at the airport, f_a, capture the two-sided network externality in the passenger demand. Note that, we specify the cost of schedule delay as inversely proportional to an airline's flight frequency on a given market. Table 5, on the one hand, shows that the coefficient on the cost of schedule delay, β^j, is negative and significant. Passenger demand decreases if the cost of delay increases. In other words, the passengers prefer to fly with a carrier with more frequent departures because it means that they could catch a flight as close as possible to their desired departure time. This is the positive network externality between passengers and airlines. On the other hand, we have mentioned that the coefficient on total flight frequency, β^a, is negative. Although the passengers benefit from an increase in the frequency of the airline that they choose, an increase in total frequency has a negative effect which captures congestion at the airport. Hence, there is also a negative externality between the two end users. Airports can affect airline demand, f_{adj}, by changing the price of departures. This change will be reflected in passenger demand through β^j and β^a which will have a further impact on airline demand for aeronautical services via Equation 11.

As a result, airports satisfy the two main features of two-sided markets: the existence of network externalities between the two sides and the internalization of these externalities during pricing decision. Thus, one can conclude that airports are two-sided platforms which connect passengers and airlines in a way that they cannot interact without the platform and that the airports recognize the interdependency of the two demands. Moreover, airports can choose a pricing scheme for both sides by internalizing these indirect network externalities to maximize their profits. So an airport can exploit the externalities between the two sides, i.e., the more the two sides benefit by interacting with each other the more the airport can exploit these interdependent benefits to increase its profits.

4.3.2 Cost Parameters

We specify the marginal cost Equation (9), which enters the optimal price equation of each airline (10), as a function of distance, distance squared, number of passengers, flight frequency, number of destinations, an origin-destination hub dummy, carrier dummies and airport dummies. Most of the estimated parameters have an expected sign and are significant.

For the marginal cost parameter estimates, there are a couple of points worth noting. The coefficients on number of passengers, q_{adj}, and flight frequency, f_{adj},capture the long-run effects. The coefficient on q_{adj} is estimated to be negative, which means the marginal cost of an airline decreases in q_{adj}. Precisely, by increasing the number of passengers, carriers can increase the load factor, thus spread out costs with more passengers. The sign of the coefficient on f_{adj} is positive as expected. The positive sign implies that an increase in flight frequency leads to a rise in the marginal cost of airlines. An extra flight in a market would increase marginal cost since the airline may fly with less full aircraft so costs are higher. However, we cannot fully support this conclusion since the coefficient is insignificant.

Regarding the other variables, we find that marginal cost is increasing in distance, a long route may imply more fuel consumption. Moreover, the coefficient on the dummy indicating whether the origin or destination is a hub is estimated to be positive and significant. Note that we are only considering direct flights in this study. It is true that hub utilization decreases the cost of airlines in connecting flights but it is not valid for the direct flights. Finally, the coefficients on the airport dummies are broadly consistent with the reports on the landing and take-off charges of airports. For example, the estimated coefficient for JFK is positive, which charges the highest landing/departure fee among airports.

4.3.3 Marginal Cost and Margins of Airlines

More than 87% of marginal costs of airlines are estimated to be positive, which is a sign of the robustness of our estimated model. The estimated marginal cost and the margin of a representative airline at the airport level are presented in Table 6. The marginal cost is on average $52 while the margin is around 44%, which is quite close to the one found in the previous literature. Note that JFK and SFO charge the highest aeronautical fee among our sample, as expected the products originated from JFK and SFO airports have the highest marginal cost.[13] Table 7 presents the estimated marginal cost and margins of different airlines. The low cost carriers have lower marginal costs and larger margins than the rest of the airlines.

To sum up, our estimation results provide empirical evidence of two-sidedness in airport business models. One aspect is that passengers do care about airport facilities such as the average shopping area and airports are able to choose a price structure and not only a price level for their services. Another aspect is that both the flight frequency of the airline and the total frequency at the airport are significant in passenger demand. If an airline raises its frequency on a given route, it results in an increase in passenger demand through decreasing waiting cost. In addition to this, an increase in total frequency at an airport would reduce passenger demand via congestion effects. Consequently, a change in aeronautical fees would not only lead to a change in airlines' demand but also to passenger demand. Similarly, a change in concession fees would affect passengers and then airlines through network effects.

5 Identifying Airport Pricing

5.1 Theoretical Equations

We consider a multi-product monopoly airport which provides aeronautical services to airlines and commercial services to passengers. The airport decides on an aeronautical charge p_a and a concession price p_c. In this section, we assess Pigouvian, profit-maximizing and Ramsey pricing under a two-sided market structure and a one-sided market structure.

Pricing under a two-sided market structure implies that the airport considers the revenues or welfare from both sides when it is deciding on the price of one side. In other words, it internalizes the network externalities between the two sides. On the contrary, under a one-sided market structure, the airport considers revenues and/or welfare from each side separately.

[13] As can be seen in Table 11, the aeronautical fee of JFK and SFO is much higher than that of other airports. We constructed the aeronautical fee as, p_a= landing revenues/no. of departures, however in reality the landing fees are composed of a fixed fee and a per 1000 lbs. variable fee. Since JFK and SFO receive more international flights than the other airports in our sample (33% and 14 % respectively) and the international flights are done by larger aircrafts, this makes the approximated fee per landing higher in these airports.

5.2 Pricing under a two-sided platform setting

Pigouvian Pricing

Pigouvian pricing requires that the marginal benefit of an activity equals the marginal cost of that activity. A Pigouvian airport (platform) maximizes total social value which is equal to the sum of benefits of users on the two sides of the market minus its costs. Thus, the problem of the airport is given by (Weyl, 2010)

$$\max_{p_a, p_c} \sum_d CS_d + \sum_d \sum_j \pi_{adj} - c_a f_a - c_c q_c \tag{14}$$

where CS_d is the consumer surplus on route ad, π_{adj} is the profit of airline j on route ad, c_a is the marginal cost of producing aeronautical services and c_c is the marginal cost of producing commercial services. Moreover f_a is the total number of flights from airport a and q_c is the total number of commercial good buyers. Roy's identity gives $q_c = -\frac{\beta^c}{\alpha} q_a$ where $q_a = \sum_d \sum_j q_{adj}$ is the total number of passengers flying from airport a.

Note that consumer surplus has two components: The first component comes from using air transport and the second comes from using commercial services at the airport. Given the demand specification in equation (5), the surplus of passenger i from using air transport is given by:

$$CS^a = \frac{1}{\alpha} \ln \left[1 + \left[\sum_{j \in J_{ad}} e^{\frac{V_{adj}}{1-\sigma}} \right]^{1-\sigma} \right] \tag{15}$$

and the surplus of passenger i from using commercial services at the airport is:

$$CS^c = -\frac{1}{\beta^c} \ln \left[1 + \left[\sum_{j \in J_{ad}} e^{\frac{V_{adj}}{1-\sigma}} \right]^{1-\sigma} \right] \tag{16}$$

From the solution of the optimization problem in Equation (14), it is clear that the Pigouvian platform internalizes network externalities such that the social planner (airport) chooses the prices of its services on each side by considering the marginal benefit on both sides and the network externality between the two end users. Since the demand of passengers depends on frequency, a change in the aeronautical price, which affects frequency, also has an effect on the demand of the passengers. Similarly, a change in the price of commercial activities affects not only the demand of passengers but also that of airlines (frequency).

Profit-maximizing Pricing

We now consider a profit-maximizing monopoly airport. As a profit maximizing platform, the airport solves the following problem:

$$\max_{p_a, p_c} \Pi = (p_a - c_a)f_a + (p_c - c_c)q_c - K \tag{17}$$

where Π is the profit of airport and K is the fixed cost. The first order conditions lead to the following mark-up equations:

$$\frac{p_a - c_a}{p_a} = -\frac{1}{\eta_a} - (p_c - c_c)\frac{\partial q_c / \partial p_a}{\frac{\partial f_a / \partial p_a}{p_a}} \tag{18}$$

$$\frac{p_c - c_c}{p_c} = -\frac{1}{\eta_c} - (p_a - c_a)\frac{\partial f_a / \partial p_c}{\frac{\partial q_c / \partial p_c}{p_c}} \tag{19}$$

where η_a is the price elasticity of airlines' demand and η_c is the price elasticity of passengers' demand. Since the airport considers the market under a two-sided structure, the mark-up for the aeronautical fee (commercial fee) is equal to the inverse elasticity of demand for aeronautical (commercial) activities plus an additional term. This additional term on the right hand side captures the effect of the number of passengers on frequency (number of flights on passenger demand) which may lead to prices below marginal cost.

Ramsey Pricing

In some cases the social welfare maximizing process may be infeasible in the sense that it may require a huge amount of subsidies. Ramsey pricing is a quasi-optimum or second best pricing scheme designed for a multiproduct monopolist airport since it reduces the deficit incurred in the operation of the airport. To get over this problem, the airport may choose to maximize the social welfare subject to the constraint that its profit is nonnegative. In other words, the idea of Ramsey pricing is to choose the price to maximize social welfare, i.e. consumer surplus and airlines' profit, subject to meeting a revenue requirement for the airport. The problem of the airport is given by

$$\max_{p_a, p_c} \sum_d CS_d + \sum_d \sum_j \pi_{adj} - c_a f_a - c_c q_c \quad s.t. \;\; \Pi \geq 0 \tag{20}$$

A Lagrange multiplier, μ, is used to include the revenue constraint explicitly in the above objective. Note that when the constraint is not binding, then the Lagrange multiplier is zero and we obtain Pigouvian prices. Moreover, we get closer to profit maximizing prices when the targeted profit is higher. As pointed out by Weyl (2010), Ramsey prices are weighted averages of Pigouvian and profit maximizing prices.

The solution to the problem in Equation (20) provides a pricing scheme which takes into account the externalities arising from the two-sidedness of the market. As in Oum and Tretheway (1988), our Ramsey pricing can be used to determine the quasi-optimal user charges for the airport and we extend the analysis to a two-sided market setting.

5.3 Pricing under a separated platform setting

The airport can also decide on the prices to be charged by considering each side separately. Under this scenario, the maximization problems of the airport are given by the following:

Pigouvian Pricing

A public airport which considers one-sided markets would choose prices by considering the surplus of the related sides. More precisely, it would choose a price for aeronautical services which equalizes its marginal cost to the marginal benefit of the airlines.

$$\max_{p_a} \sum_d \sum_j \pi_{adj} - c_a f_a \tag{21}$$

$$\max_{p_c} \sum_d CS_d - c_c q_c \tag{22}$$

The price for commercial services is chosen at the level where the marginal cost of providing the service is equal to its marginal benefits for passengers. In this case, the airport does not take into account the network externalities which exist between passengers and airlines and the prices may be below or above the socially optimal levels when the two-sided network externalities are taken into account.

Profit-maximizing Pricing

A profit maximizing airport, which considers one-sided markets, does not take into account the externalities exist between the airlines and passengers, and solves two separate maximization problem to choose its optimal price levels.

$$\max_{p_a} \Pi_a = (p_a - c_a) f_a - K_a \tag{23}$$

$$\max_{p_c} \Pi_c = (p_c - c_c) q_c - K_c \tag{24}$$

where Π_a is the profit from aeronautical services, Π_c is the profit from commercial services, K_a is the fixed cost of providing aeronautical services and K_c is the fixed cost of providing commercial services. These maximization problems bring about the usual mark-ups which are equal to the inverse elasticity of demand on each side. The solutions to the maximization problems in Equation (23) and (24) are given by

$$\frac{p_a - c_a}{p_a} = -\frac{1}{\eta_a} \tag{25}$$

$$\frac{p_c - c_c}{p_c} = -\frac{1}{\eta_c} \tag{26}$$

Ramsey Pricing

Under a Ramsey pricing scheme, the airport chooses the aeronautical fee which maximizes the social net benefits on the aeronautical side subject to the constraint that the profits on the same side are non-negative:

$$\max_{p_a} \sum_d \sum_j \pi_{adj} - c_a f_a \quad s.t. \;\; \Pi_a \geq 0 \tag{27}$$

The fee for commercial activities is given by the maximization of the net benefit from commercial activities subject to a non-negative profit constraint.

$$\max_{p_c} \sum_d CS_d - c_c q_c \quad s.t. \;\; \Pi_c \geq 0 \tag{28}$$

In the next section, we show what our data suggest about the pricing scheme of airports and we provide a test to identify the business model of airports by bootstrap methods.

5.4 Simulations

As explained in Section 5.1, we model an airport as a multi product monopoly platform which provides aeronautical services to airlines and commercial services to passengers. The airport decides on the price of aeronautical services, p_a, and the price of commercial goods, p_c. Moreover, we present the airport's decision problem with different pricing schemes under a two-sided and one-sided market structure. If we model the demand side, i.e. the passenger and airline behaviors (Equations 5, 10 and 11) correctly, and given the parameter estimates in Table 5, the marginal costs of airports implied by the airport's pricing problem should not be negative. In other words, the correct specification of the industry on both the demand and the supply side (airport) should result in a positive marginal cost. Hence, to identify the business models of airports we use the following strategy: We compute the marginal costs for aeronautical (c_a) and non-aeronautical (c_c) activities of each airport under different pricing scheme using our parameter estimates. We obtain a proxy for the aeronautical fee, p_a, by dividing the landing revenues of the airports by the number of departures. As already mentioned, the daily parking fee is used as a proxy for the price of commercial goods, p_c. Then, we check if the relevant constraints are satisfied with these estimated marginal costs (nonnegative profits for airports under profit maximizing and Ramsey pricing schemes). After controlling for these non-negative profit constraints, we test if these marginal cost estimates are significantly greater than zero using bootstrap methods. More broadly, we perform 1000 bootstrap replications of our original data set to obtain the standard errors of the marginal costs and the critical values for the t-test. The results are presented in Tables 8-10.

Three main remarks can be made on these results. First, none of the pricing schemes under a two-sided market structure fits our model, i.e., the implied marginal costs are not both positive, see Table 10. We can conclude that the airports in our data set do not internalize the two-sided network externalities existing in the market when deciding on their prices. Second, we find statistical evidence of non-negative marginal costs obtained from separate maximization problems. Indeed the airports consider the market as one-sided, i.e. airports maximize their profits separately in each side without considering the interdependency between the two sides. Third, airports are using different pricing schemes for passengers and airlines. The results are presented in Table 8 and Table 9.

On one side of the market, we find that the marginal cost of commercial services obtained under profit maximization are statistically significantly greater than zero, hence we can say that the prices for commercial services are profit maximizing prices. On the other side of the market, the profit maximizing prices give a positive marginal cost and these marginal costs range from \$28 for ATL to \$1312 for JFK. The result shows that the marginal costs of airports are varying widely among airports. Besides, we know that US airports are not allowed to freely set prices for aeronautical services because they are perceived as the natural monopolies. Almost all airports in the U.S. are government owned but effectively privately operated and even the private airports are subject to legal controls in the pricing of aeronautical services. Thus, we believe that the sample airports, which are all public, are implementing either Pigouvian or Ramsey pricing. While the Pigou prices do not satisfy the revenue constraints, the aeronautical marginal costs calculated under the Ramsey pricing scheme are statistically significantly greater than zero.

As explained in Section 4, the Ramsey prices are calculated at different weights. Let us define the weight $\lambda = \mu/(1+\mu)$ where μ is the Lagrange multiplier of the constrained social welfare maximization problem in Equation (20). The weights airports are using in their Ramsey pricing schemes are given in Table (9). There are a few points worth noting. First, marginal costs are statistically significantly greater than zero for a weight $\lambda = 0.5$ for 7 out of 9 airports. Similarly, Salt Lake City International (SLC) Airport's marginal cost for the aeronautical side is found to be positive under a Ramsey pricing scheme with $\lambda = 0.55$. Finally, Atlanta International Airport (ATL) is known to be one of the most efficient airports, i.e. with the lowest cost. (See ATA, 2012.) We find that it puts the highest weight, $0.6 \leq \lambda \leq 0.7$, on the profit maximizing price. Since ATL airport has lower marginal costs, it has a higher ability to put more weight on profit maximizing prices. Thus, we conclude that ATL is implementing Ramsey prices on the aeronautical side although we are not able to obtain a unique weight without further information.

In the US most airports are publicly owned, thus the airports have no incentive to set unfair prices. Although the Federal Aviation Administration is allowed to regulate the airports, no regulation has been needed. (See Gillen, 2011.) The airports‘ business models as implied by our empirical model are in line with what the industry does in the real world. Thus, our tools can be used to evaluate the situation in other countries. In the regulation of private airports, the debate over single-till vs. dual till price-cap regulation is a hot issue. Although, there are some theoretical and empirical papers looking at this topic, such as Zhang and Zhang (2010), Czerny (2006) and Bilotkach *et al.* (2012), none of them considers the two-sided structure of the market. To draw reasonable conclusions on this topic the market as well as the actions of players should be defined correctly. When considered under a two-sided market structure, the conclusions obtained in these papers may not hold any more. In the next section we present a welfare simulation where we assume that the monopolist airport maximizes its profit under a two-sided market structure. We believe that the methodology and findings we present here will shed light on the pricing and regulation of airports.

5.5 A Welfare Analysis

In the previous section, we have concluded that the airports in our dataset are pricing passengers and airlines under a separated platform setting and they are using different pricing schemes for each side. While doing this we have also computed the marginal costs of airports. In this section, we simulate the model where the airport is a private monopolist who is maximizing its profits under a two-sided market setting. More precisely, given the parameters we have estimated as well as the implied marginal cost of airports we have computed, for each airport in our sample, we solve the system of simultaneous equations below to get the optimal airport prices, p_a and p_c, and optimal ticket prices for each airline on each route, p_{adj}, and the implied passenger demand, q_{adj}:

$$\ln s_{adj} - \ln s_0 = X'_{adj}\beta + \beta^j \frac{1}{\sqrt{f_{adj}}} + \beta^a f_a + \beta^c p_c - \alpha p_{adj} + \sigma \ln s_{j|ad} + \xi_{adj} \quad for \;\; j = 1, \dots, J_{ad} \tag{29}$$

$$p^*_{adj} = c^q_{adj} + \frac{1}{\alpha\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma} s_{j|ad} - s_{adj}\right)} \quad for \;\; j = 1, \dots, J_{ad} \tag{30}$$

$$\frac{p_a - c_a}{p_a} = -\frac{1}{\eta_a} - (p_c - c_c)\frac{\partial q_c/\partial p_a}{\frac{\partial f_a/\partial p_a}{p_a}} \tag{31}$$

$$\frac{p_c - c_c}{p_c} = -\frac{1}{\eta_c} - (p_a - c_a)\frac{\partial f_a/\partial p_c}{\frac{\partial q_c/\partial p_c}{p_c}} \tag{32}$$

After obtaining these optimal values, we have computed the consumer surplus, profits of the airlines and the airports and the social welfare. The results are presented in Table 12. Moreover Table 11 presents these values under the current pricing regime. Our results show that the welfare effect of privatization of the airports is different for each airport. For example for ATL, a private profit maximizing airport would lead to a social welfare increase of more than 200% while for SLC, this would result in a social welfare decrease of more than 50%. The effect of privatization on the number of total passengers using air transport is also airport dependent. The number of passengers originating from ATL, JFK and SFO would increase while for all other airports, this number would decrease. The mean ticket price the airlines charge would be higher at each airport although the aeronautical fee they would pay would not be higher at all airports. Flying from SFO would be cheaper under a private profit maximizing airport model whilst flying from ATL would be more expensive for the airlines. Finally, our most remarkable result is on the optimal price for commercial activities, p_c. Under the scenario of private profit maximizing airport p_c would increase drastically making it much more expensive for passengers to travel. Given the fact that the airports in our model are monopolists and that the we find that the passengers benefit from having more flights at the airports as well as using their services the private airport would exploit this benefit of passengers to increase its profits under a two-sided market pricing scheme. Though, note that despite the increasing p_c, at some airports total number of passengers travelling would still be higher.

The simulation results for Hartsfield-Jackson Atlanta International Airport (ATL) worth analyzing a bit more. Note that under the scenario of private profit maximizing airport under a two-sided market setting, the mean ticket price of airlines, aeronautical fee and the price of commercial services, they are all higher for ATL. At the same time, total quantity of passengers choosing air transport in Atlanta is also higher whilst the total CS is lower. Moreover, when we consider the social welfare, it would be more than 200% higher than the current state. To better understand the mechanism behind these results, we examined the ticket prices individually. Indeed, although the mean ticket price increases, for some of the routes it decreases which leads to huge increases in demand resulting in higher total quantity of passengers choosing air transport in Atlanta. Table 12 shows the routes from ATL which would have lower ticket prices. For example, the Delta Airlines flight from ATL to Myrtle Beach, SC (MYR) would be \$0.33 cheaper though with the increase in p_c, the demand of passenger would decrease from 119 to 20. On the other hand, a \$60 decrease in the price of Delta Airlines flight from ATL to Philadelphia (PHL) even with the increase in p_c, would result in 6282 more passengers travelling on this route.

Our simulation results have important implications for policy analysis. First of all, as can be seen from Table 12, the effect of privatization on SW would be airport (origin city) specific; for some airports it would be SW enhancing while for some other airports it would not. Secondly, such a case would lead the airports charge passenger much higher prices, which may necessitate regulation. Third, under the current situation of the industry, with a one-sided Ramsey pricing scheme, some airports, such as JFK or SFO set the aeronautical fee too high most probably as a result of not accounting for the two-sided network effects. Finally, it should be noted that we cannot included structure of the fleet of the airlines in our model. hence in the simulations, we assume that the capacity of aircrafts landing in the different airports are not modified. Indeed one could imagine that the change of landing fees due to a change in the regulation could lead airlines to change the structure of their fleet.

6 Conclusion

This paper analyses airport pricing under a two-sided market structure. In particular, we are able to show the interdependency between the two demands by identifying the network externalities between passengers and airlines and the ability of airports to set prices on each side of the market to affect demand. Using a data set from the US, we estimate the demand equation of passengers and the pricing equation of airlines. We also derive the pricing equations of airports under not only a two-sided market structure but also a one-sided market structure. Moreover, for each market structure we derive the mark-ups of the airports under three different pricing schemes: Pigouvian pricing, profit-maximizing pricing and Ramsey pricing. Using our estimation results we then compute the implied marginal costs for each pricing scenario. Finally, with the obtained marginal costs we performed a welfare simulation to see the effect of two-sided profit maximizing prices on the social welfare.

We obtain four main results. First of all, we find evidence of two-sidedness in the industry (i.e. airports are two-sided platforms) and that there are network externalities between the passengers and the airlines. Second, our results imply that airports in the U.S. do not internalize the externalities between the two sides when choosing their prices. They instead adopt one-sided pricing schemes in which they do not consider the interdependency between the two demands. Third, airports use different pricing schemes for each side. We find evidence of profit-maximizing prices for passengers and Ramsey prices for airlines. Fourth, the effect of two-sided profit maximizing prices on the welfare would depend on the airport under consideration. For instance, for ATL, BWI, JFK and SFO, the two-sided pricing scheme would increase the welfare whereas for other airports in our sample it would decrease the social welfare.

The main contribution of the paper is the empirical analysis of airports under a two-sided market structure which has not been done before. Moreover, to the best of our knowledge, this paper is the first one to consider the business model of airports under two-sided market structure. Combining these two facts, we believe that the paper as a whole contributes to the literature on the regulation of airports since it presents the methodology to define the structure of the market and behavior of the players. More precisely, the fact that airports are two-sided platforms changes the relevant economic market definition for competition analysis of airports.

The topic is very fruitful for future work. Our model can easily be extended to the case of competition between airports. Moreover, airports can also be examined for the optimal platform design, which in turn can increase profits by pricing the commercial services optimally. Besides all these, the debate of single-till versus dual-till can be reconsidered under the structure provided in this paper.

7 Appendix

Table 1: Airports by Size

Airport	Code	City	State	No. Of Departures	Revenue Passenger (million)
Hartsfield-Jackson Atlanta International	ATL	Atlanta	GA	467101	40.78
Chicago O'Hare International	ORD	Chicago	IL	441231	34.53
George Bush Intercontinental	IAH	Houston	TX	281339	19.83
Minneapolis-St.Paul International	MSP	Minneapolis	MN	214283	17.13
John F.Kennedy International	JFK	New York	NY	147685	15.04
San Francisco International	SFO	San Francisco	CA	145234	13.91
Salt Lake City International	SLC	Salt Lake City	UT	156878	10.28
Baltimore/Washington International	BWI	Baltimore	MD	120734	10.08
Dulles International	IAD	Washington	DC	145262	9.72
Top 31 Hub airports					511.13
United States all airports					736.36

Source: U.S. Department of Transportation, Bureau of Transportation Statistics

Table 2: Number of Observations by Airlines

Airline	Code	No. of Products
American Airlines	AA	56
Alaska Airlines	AS	1
JetBlue Airways	B6	14
Continental Airlines	CO	18
Delta Airlines	DL	70
Frontier Airlines	F9	6
AirTran Airways	FL	47
America West Airlines	HP	16
Spirit Airlines	NK	3
Northwest Airlines	NW	31
Sky West Airlines	SY	14
United Airlines	UA	72
US Airways	US	6
Southwest Airline	WN	21
Midwest Airlines	YX	2
Total		377

Table 3: Revenue Decomposition of Airports

Airport	Aeronautical Revenue (million dollars)	Share	Non-aeronautical Revenue (million dollars)	Share
ATL	53.17	0.25	158.02	0.75
ORD	340.26	0.69	155.23	0.31
IAH	230.73	0.74	81.74	0.26
MSP	87.42	0.58	62.08	0.42
JFK	553.78	0.78	155.79	0.22
SFO	259.01	0.65	141.18	0.35
SLC	41.70	0.51	39.80	0.49
BWI	69.66	0.58	50.77	0.42
IAD	137.45	0.70	56.86	0.30
Average Airport	197.02	0.60	100.16	0.40

Table 4: Variable Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Ticket Fare, (in dollars), p_{adj}	97.85	46.46	3.73	259.24
Number of Passenger, q_{adj}	2174.31	1811.21	1	11975
Number of Passenger on O-D, q_{ad}	5269.9	3587.56	16	19575
Flight Frequency, f_{adj}	401.81	273.88	9	1554
Flight Frequency at Origin, f_a	71123.12	35183.83	30819	113417
Daily Parking Fee (in dollars)	21.05	6.58	12	31
Landing Fee (in dollars)	310.85	322.69	28.87	1312.19
Average Shopping Area (in acres)	48.46	34.7	20.44	139.79
Number of Destinations	19.72	16.44	1	43
Population in Destination	4144403.42	3987904.35	27512	18825633
Distance (in miles)	1135.02	691.71	215	4243
Income in Origin (in dollars)	44162.94	6584.97	36210	59440
Distance to Business District (in miles)	10.09	4.52	3	20
Distance Squared	1765459.73	2154905.16	46225	18003049
Parking Coefficient	76949.97	211838.84	21.85	1809871.8
$\ln(Total\ Distance\ Flown)$	9.38	1.25	5.69	10.78
Population in Origin	5684085.9	4434666.74	585419	18825633
Origin Destination Hub	0.71	0.46	0	1
JetBlue Airways	0.037	0.19	0	1
Continental Airlines	0.05	0.21	0	1
Delta Airlines	0.19	0.39	0	1
Northwest Airlines	0.08	0.28	0	1
United Airlines	0.19	0.39	0	1
US Airways	0.02	0.13	0	1
Southwest Airlines	0.06	0.23	0	1
Other airlines	0.14	0.35	0	1
ATL	0.21	0.41	0	1
JFK	0.08	0.27	0	1
SFO	0.09	0.28	0	1
ORD	0.23	0.42	0	1
Other airports	0.28	0.45	0	1

Table 5: Parameter Estimates of the Two-Equation System

Demand Variables	**Parameter**	**Estimate**	**Std. Error**
Price	α_0	0.032^{**}	0.007
Price*Income	α_1	$2.11 * 10^{-7*}$	$1.18 * 10^{-7}$
ln $s_{j\|ad}$	σ	0.55^{**}	0.21
Cost of Schedule Delay	β^j	-22.04^{**}	4.25
Total Flight Frequency at Origin	β^a	$-5.83 * 10^{-6*}$	$3.32 * 10^{-6}$
Daily Parking Fee	β^c	$-1.07 * 10^{-6*}$	$6.04 * 10^{-9}$
Constant	β_0	-2.19^{**}	0.79
Average Shopping Area	β_1	0.019^{**}	0.002
Number of Destinations	β_2	0.23^{**}	0.11
Population at Destination	β_3	$4.5 * 10^{-8*}$	$6.55 * 10^{-9}$
Distance	β_4	0.0006^{**}	0.0001
Distance Squared	β_5	$7.08 * 10^{-8}$	$6.5 * 10^{-8}$
Distance to Business District	β_6	-0.03^{**}	0.01
$\ln(Total\ Distance\ Flown)$	β_7	-0.2^{*}	0.106
$\ln(Total\ Distance\ Flown) * (Number\ of\ \ destinations)$	β_8	-0.02^{**}	0.009
JetBlue Airways	β_9	-1.83^{**}	0.42
Continental Airlines	β_{10}	-0.26	0.3
Delta Airlines	β_{11}	-0.1	0.1
Northwest Airlines	β_{12}	0.03	0.16
United Airlines	β_{13}	0.28	0.17
US Airways	β_{14}	0.06	0.28
Southwest Airlines	β_{15}	-1.02^{**}	0.31
Other airlines	β_{16}	-0.5^{**}	0.16
Cost Variables	**Parameter**	**Estimate**	**Std. Error**
Constant	λ_0	23.08	16.96
Distance	λ_1	0.005	0.008
Origin Destination Hub	λ_2	15.28^{**}	6.03
Distance Squared	λ_3	$8.12 * 10^{-6**}$	$2 * 10^{-6}$
Number of Passengers	λ_4	-0.011^{**}	0.04
Flight Frequency	λ_5	0.007	0.23
Number of Destinations	λ_6	-0.09	0.18
JetBlue Airways	λ_7	-62.41^{**}	12.66
Continental Airlines	λ_8	20.09	12.45
Delta Airlines	λ_9	6.04	6.17
Northwest Airlines	λ_{10}	3.25	6.63
United Airlines	λ_{11}	16.64^{**}	7.25
Southwest Airlines	λ_{12}	-28.88^{**}	8.39
Other airlines	λ_{13}	-26.44^{**}	5.86
ATL	λ_{14}	17.7^{**}	7.33
JFK	λ_{15}	24.61^{*}	12.69
SFO	λ_{16}	17.39^{**}	8.15
ORD	λ_{17}	12.68^{*}	7.67
Other airports	λ_{18}	8.46	7.36
GMM Test Statistics			
Number of observation	377	**Objective**	0.0206
Test	**DF**	**Statistics**	**P-value**
Hansen J (Over-identification	11	7.78	0.73

Note: Other airlines are Alaska Airlines, Frontier Airlines, AirTran Airways, America West Airlines, Spirit Airlines, Sky West Airlines and Midwest Airlines. Other airports are BWI, IAD, IAH and SLC. Two stars (**) identify parameters that are significant at the 5% level, and one star (*) identifies parameters that are significant at the 10% level.

Table 6: Marginal Cost and Margin of Airlines (by airport)

Airport	Ticket Fare (dollars)	Marginal Cost (dollars)	Margin (%)
ATL	57.46	33.15	49.01
BWI	60.22	34.52	50.11
IAD	83.18	54.36	49.52
IAH	85.26	58.99	39.55
JFK	98.53	73.34	36.23
MSP	58.43	33.02	54.22
ORD	71.93	46.69	43.98
SFO	106.81	75.54	35.63
SLC	81.59	58.25	37.01
Average	78.16	51.99	43.91

Table 7: Marginal Cost and Margin of Airlines (by airline)

Airline	Ticket Fare (dollars)	Marginal Cost (dollars)	Margin (%)
AA	79.39	53.76	39.56
AS	83.97	62.13	26.01
B6	36.89	11.21	70.88
CO	83.63	54.11	47.39
DL	77.62	52.14	40.12
F9	50.01	27.48	47.81
FL	42.70	19.08	59.14
HP	77.47	54.11	38.33
NK	47.22	23.91	53.42
NW	68.85	40.12	48.31
SY	32.41	8.77	75.12
UA	94.59	68.41	36.95
US	71.06	44.65	41.91
WN	50.77	23.03	62.35
YX	46.98	22.94	52.44

Table 8. Profit Maximizing Pricing under a One-Sided Market Setting

Airports	c_a	Std. Dev.	$t^*_{0.05}$	t	c_c	Std. Dev.	$t^*_{0.05}$	t
ATL	28.87**	0.003823	2.13104	7550.711	15.9842**	0.004623	0.787733	3457.365
BWI	264.11**	0.002897	2.15538	91177.24	11.9994**	0.000528	0.421352	22705
IAD	272.2**	0.009945	2.11786	27371.25	16.9997**	0.000261	0.449791	65186.7
IAH	292.26**	0.001035	2.09882	282430	16.9999**	0.000103	0.409228	164680.5
JFK	1312.19**	0.008882	2.11808	147738.3	17.9999**	0.00005	0.383185	347251.1
MSP	186.91**	0.003631	2.13749	51482.66	17.9992**	0.000653	0.41453	27564.46
ORD	352.87**	0.005712	2.05379	61776.14	30.9997**	0.000287	0.397127	108015.7
SFO	483.99**	0.002939	2.14055	164684	19.9998**	0.000185	0.456119	108301.2
SLC	74.45**	0.002903	2.08422	25647.83	27.9974**	0.001666	0.526749	16807.71

Note: Profit constraint in profit maximizing pricing is satisfied in grey highlighted lines. Two stars (**) identify values that are significant at the 5% level, and one star (*) identifies values that are significant at the 10% level.

Table 9: Ramsey Pricing for Aeronautical Services under One-Sided Market Setting

$\lambda = 0.5$					$\lambda = 0.55$				
Airports	**Mean**	**Std. Dev.**	$t^*_{0.05}$	**t**	**Airports**	**Mean**	**Std. Dev.**	$t^*_{0.05}$	**t**
ATL	43.822	87.3550	0.1861	0.5017	**ATL**	35.98	75.816	0.1803	0.4746
BWI	89.384**	169.9740	0.2053	0.5259	**BWI**	-63.24	178.85	0.4167	-0.3536
IAD	120.582**	205.9850	0.2612	0.5854	**IAD**	-165.01	252.632	0.5133	-0.6532
IAH	51.661**	97.7480	0.2081	0.5285	**IAH**	-846.74	388.462	0.6819	-2.1797
JFK	128.999**	225.3140	0.2497	0.5725	**JFK**	-1665.55	811.47	0.6990	-2.0525
MSP	103.015**	193.7290	0.2156	0.5317	**MSP**	-19.24	189.66	0.3335	-0.1014
ORD	62.328**	119.6910	0.2064	0.5207	**ORD**	-211.59	174.249	0.5530	-1.2143
SFO	107.488**	162.7670	0.3211	0.6604	**SFO**	-274.59	260.278	0.6453	-1.0550
SLC	80.6790	166.9440	0.1829	0.4833	**SLC**	42.23**	150.631	0.2056	0.2804
$\lambda = 0.6$					$\lambda = 0.65$				
Airports	**Mean**	**Std. Dev.**	$t^*_{0.05}$	**T**	**Airports**	**Mean**	**Std. Dev.**	$t^*_{0.05}$	**t**
ATL	28.15	179.53	-0.0099	0.1568	**ATL**	20.31**	100.0100	0.1066	0.2031
BWI	-215.86	936.61	0.0557	-0.2305	**BWI**	-368.49	476.04	0.3424	-0.7741
IAD	-450.6	474.75	0.3703	-0.9491	**IAD**	-736.19	837.4	0.3611	-0.8791
IAH	-1745.14	699.29	0.6126	-2.4956	**IAH**	-2643.55	2231.11	0.3614	-1.1849
JFK	-3460.1	1351.93	0.7529	-2.5594	**JFK**	-5254.65	5105.34	0.3491	-1.0292
MSP	-141.49	1332.45	0.0074	-0.1062	**MSP**	-263.75	435.03	0.2911	-0.6063
ORD	-485.5	482.89	0.2500	-1.0054	**ORD**	-759.42	809.27	0.3340	-0.9384
SFO	-656.67	11815.38	0.0610	-0.0556	**SFO**	-1038.75	1158.35	0.3861	-0.8967
SLC	3.77	355	0.0209	0.0106	**SLC**	-34.68	218.75	0.1921	-0.1585
$\lambda = 0.7$									
Airports	**Mean**	**Std. Dev.**	$t^*_{0.05}$	**t**					
ATL	12.47**	160	0.0401	0.0779					
BWI	-521.11	864.18	0.2053	-0.6030					
IAD	-1021.79	1319.3	0.2729	-0.7745					
IAH	-3541.95	3360.44	0.3063	-1.0540					
JFK	-7049.19	7027.13	0.3231	-1.0031					
MSP	-386	896.7	0.1377	-0.4305					
ORD	-1033.33	1258.01	0.2540	-0.8214					
SFO	-1420.83	1719.77	0.3045	-0.8262					
SLC	-73.13	343.36	0.1193	-0.2130					

Note: Profit constraint in Ramsey pricing is satisfied in grey highlighted lines. Two stars (**) identify values that are significant at the 5% level, and one star (*) identifies values that are significant at the 10% level.

Table 10: Pricing under a Two-Sided Market Setting

	Pigouvian		Profit Maximization		$\lambda = 0.1$		$\lambda = 0.2$	
Airports	c_a	c_c	c_a	c_c	c_a	c_c	c_a	c_c
ATL	-947.78	263995.3	189383.4	-55228.4	-879.71	232073	-811.64	200150.6
BWI	7788.77	-4070728	-6272276	425900.1	6755.07	-3621066	5721.36	-3171403
IAD	9945.27	-92273.8	-549527	43683.86	8187.36	-78678	6429.45	-65082.3
IAH	13661.89	-271098	-3318812	270935.8	10983.4	-216895	8304.92	-162691
JFK	22543.05	-15690.7	-779081	16129.43	18065.75	-12508.7	13588.46	-9326.64
MSP	10801.46	-131215	-1020591	102661.8	8947.86	-107827	7094.26	-84439.4
ORD	4345.14	-287290	-4405241	244986.6	3545.39	-234062	2745.63	-180835
SFO	8062.14	-369902	-4997266	284813.5	6657.94	-304431	5253.74	-238959
SLC	-1027302	$1.81 * 10^{10}$	$1.24 * 10^{8}$	$-2.2 * 10^{7}$	-924082	$1.63 * 10^{10}$	-820862	$1.45 * 10^{10}$

	$\lambda = 0.3$		$\lambda = 0.4$		$\lambda = 0.5$		$\lambda = 0.6$	
Airports	c_a	c_c	c_a	c_c	c_a	c_c	c_a	c_c
ATL	-743.57	168228.2	-675.5	136305.8	-607.43	104383.5	-539.36	72461.09
BWI	4687.66	-2721740	3653.95	-2272077	2620.24	-1822414	1586.54	-1372751
IAD	4671.54	-51486.5	2913.63	-37890.7	1155.72	-24295	-602.19	-10699.2
IAH	5626.43	-108488	2947.94	-54284.5	269.46	-81.12	-2409.03	54122.26
JFK	9111.16	-6144.63	4633.86	-2962.63	1533.47	-14276.4	-320.13	9111.23
MSP	5240.66	-61051.7	3387.06	-37664.1	156.56	219.38	-4320.74	3401.39
ORD	1945.88	-127607	1146.12	-74379.4	346.36	-21151.7	-453.39	32075.96
SFO	3849.55	-173488	2445.35	-108016	1041.16	-42544.4	-363.04	22927.19
SLC	-717643	$1.27 * 10^{10}$	-614423	$1.08 * 10^{10}$	-511203	$9.3 * 10^{9}$	-407983	$7.22 * 10^{9}$

	$\lambda = 0.7$		$\lambda = 0.8$		$\lambda = 0.9$	
Airports	c_a	c_c	c_a	c_c	c_a	c_c
ATL	-471.29	40538.71	-403.22	8616.34	-335.15	-23306
BWI	552.83	-923088	-480.88	-473426	-1514.58	-23762.8
IAD	-2360.1	2896.57	-4118.01	16492.33	-5875.92	30088.1
IAH	-5087.52	108325.7	-7766	162529	-10444.5	216732.4
JFK	-8798.03	6583.4	-13275.3	9765.41	-17752.6	12947.42
MSP	-2173.73	32498.87	-4027.33	55886.52	-5880.93	79274.17
ORD	-1253.15	85303.63	-2052.9	138531.3	-2852.66	191759
SFO	-1767.24	88398.77	-3171.43	153870.3	-4575.63	219341.9
SLC	-304763	$5.41 * 10^{9}$	-201544	$3.6 * 10^{9}$	-98323.9	$1.79 * 10^{9}$

Table 11: State of the Industry under the Current Prices

	Passengers		Airlines		Airport		
Airports	**Q**	**CS**	**P**	**Profits**	**Pa**	**Pc**	**Profits**
ATL	0.1213	0.0068	57.15	2.1084	28.87	16	0.818
BWI	0.0420	0.0302	41.91	0.8867	264	12	5.5713
IAD	0.0187	0.0015	68.93	0.4328	272.20	17	5.1198
IAH	0.0180	0.0007	85.27	0.4592	292.26	17	14.989
JFK	0.0275	0.0001	72.63	-0.1451	1312	18	3.8150
MSP	0.0450	0.0011	55.80	0.9394	186.91	18	4.3403
ORD	0.136	0.010	69.47	1.967	352.86	31	30.679
SFO	0.0541	0.0055	98.90	1.5301	483.99	20	13.218
SLC	0.0288	0.1734	60.35	0.6606	74.45	28	1.2939

Notes: Total number of passengers (Q), total consumer surplus (CS) and total airline and airport profits are in millions.

Table12: Values under A Private Profit Maximizing Airport's Prices

	Passengers		Airlines		Airport			SW
Airports	**Q**	**CS**	**P**	**Profits**	**Pa**	**Pc**	**Profits**	**Change**
ATL	0.1296	0.0067	65.88	4.4516	201.16	623.28	19.623	217%
BWI	0.0417	0.0214	51.92	1.6705	207	1050	3.8126	47%
IAD	0.0106	0.0011	82.23	0.3580	246.68	425.28	4.2580	-2.1%
IAH	0.0040	0.0002	100.12	0.1287	430	8798	23.598	-12%
JFK	0.1012	0.0001	74.80	4.5488	272.18	578.06	4.6172	109%
MSP	0.0263	0.0007	69.88	0.8793	268	1108	8.5361	-1.4%
ORD								
SFO	0.0571	0.0062	108.96	2.6262	210	1272	3.6302	49%
SLC	0.0069	0.1507	73.40	0.2024	157	2874	4.6380	-55%

Notes: Total number of passengers (Q), total consumer surplus (CS) and total airline and airport profits are in millions.

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