Airport Prices in a Two-Sided Market Setting

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To analyze the rationale of airports' business models, we first provide evidence that they should be considered two-sided markets. Second, we apply tests supporting the hypothesis that the major U.S. airports set profit-maximizing prices for the non-aeronautical services to passengers and Ramsey prices for the aeronautical services to airlines. We then conduct a welfare analysis to evaluate the impact of implementing profit-maximizing prices when an airport fully accounts for the two-sidedness of its activities. As changes in social welfare are airport-specific, the results indicate that privatization does not fit all airports.

I. Introduction

In many countries, airports are under increasing pressure to become financially self-sufficient and less reliant on government support for at least two reasons. First, airlines, which face fierce price competition because of the liberalization in the air transport industry, seek to lower their operating costs that comprise landing fees and other costs linked to aeronautical services. Second, air traffic has experienced strong and sustainable growth that has fostered 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. (See Graham, 2009.)

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 of the increase in air traffic and the need for efficient solutions to larger congestion costs and travel delays, a major

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movement has been initiated toward the greater 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.[1]

In this context, our objective here is to contribute to the design of efficient business models of airport management and to the debate on the privatization of airports. Specifically, this article is aimed at deciphering the economic behavior of airport managers, that is, 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.

Currently, airports are considered as complex infrastructure providing various services, both aeronautical and non-aeronautical, to airlines and passengers. Although the aeronautical activities belong to the original mission of airports, airports generate a significant amount of revenue from passengers through non-aeronautical activities.[2] It is well understood that there is interdependence between airlines and passengers: Airlines prefer to operate at airports that are attractive to passengers, and passengers enjoy airports where they can obtain access to 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 that serve distinct products to each side. Second, users' benefits on one

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[1] See Gillen (2009) for a discussion on the ownership structure of airports.

[2] In 2014, airport and ancillary fees represented revenue of €1,251 million for Paris Airport, while retail, car parks and other services have amounted to €705 million.

side of the platform depend on how well the latter performs on the other side. Finally, platforms are price setters on both sides. It is straightforward to observe that airports satisfy these three conditions and consequently should 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 takeoff facilities, or check-in areas. Airports negotiate prices with the airlines and charge them for the use of the aeronautical facilities at the airport, and they charge the passengers through 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 that is better in saving their travel time.

Already, Gillen (2009) has suggested that airports could be considered two-sided platforms after noting the increasing importance of commercial revenues of airports. In a companion piece, we have also provided some empirical evidence on the two-sidedness of airports using data on U.S. airports. (See Ivaldi *et al.*, 2012.) Here, we first exhibit the structural ingredients of this feature of airports, and second, we take it one step further by identifying their pricing strategies under this setting and by providing an estimate of welfare gains obtained when their business model fully recognizes this specific economic structure.

With this perspective in mind and considering an airport as a monopoly platform, 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 entire 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 attempt to uncover the airports' business models.

Using 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 by means of a bootstrap method to identify the pricing behavior of airports that is the best approximation of the data generating process.

Our first conclusion states that, without a doubt, airports should be considered two-sided platforms. As such, this article is the first extensive empirical analysis of airports within the literature on two-sided markets.[3] Furthermore, as a result of our testing procedure to detect the real business model of airports, we exhibit two main facts. First, the airports in our dataset 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 the two sides. Second, they use different pricing schemes for each side. More precisely, we find empirical evidence of profit-maximizing prices for passengers' services and Ramsey prices for airlines' services. 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. This allows us to conclude that privatization does not seem to fit all airports.

Our article 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 these articles, the demand for airport services appears as a derived demand that comes from the necessity of the product of airlines (air transport demand) so that they consider airlines as intermediaries. It

[3] 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 (2016`1).

is then not surprising that we differ in our evaluation of the sources of sub-optimality of airport pricing.

Our article also contributes to 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, whereas in the dual till approach, only the revenues from aeronautical activities are considered. The advocates of the dual till system claim that regulation should concentrate on activities that are characterized by a natural monopoly; thus, revenues from commercial activities should not be included in the formula. (See Beesly, 1999.) Several articles deal with these two systems. Starkie and Yarrow (2009) note the strong complementarity between the aeronautical and non-aeronautical activities. Zhang and Zhang (2010) study airports' decisions 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) notes that single till regulation is more welfare enhancing at non-congested airports than is 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 article provides key evidence for the design of an efficient pricing methodology.

The article is structured as follows. *Section 2* describes the data and provides a descriptive analysis. *Section 3* explains the passengers' and airlines' behavior. *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*.

II. 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 from Airport Data published by the Federal Aviation Administration (FAA). Moreover, some of the airport characteristics, such as the number of parking lots and the number of concession contracts, have been gathered directly from the airports. The DB1B survey consists of a 10% sample of airline tickets from the U.S. reporting carriers and gives detailed information on ticket fares, itinerary (origin, destination, and all connecting airports), the ticketing and operating carrier(s) for each segment, and the number of passengers travelling on the route at a given fare. The T100 databases provide the frequency of flights for all routes in the U.S. Combined with the information gathered directly from airports, Airport Data informs us on the aeronautical and commercial operations of airports as well as the facilities. To construct our working sample, we extracted from DB1B and T100 the records corresponding to the third quarter of 2006 during which, for the first time since 2000, the U.S. airline industry experienced a positive aggregate net profit of 3.04 billion USD excluding restructuring and bankruptcy costs. (See ATRS, 2012.) The final working dataset satisfies the following constraints.

First, in our empirical model below, we define a product as an airline-itinerary combination, i.e., a route between an origin and a destination performed by an airline. After combining the different data sources, we consider the products with the following characteristics. First, we only hold round trip itineraries within the U.S. territory, thus avoiding any issues that may arise from international flights because of differences among countries. Note that as the U.S. is geographically large, we can still profit from the large heterogeneity among the 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. Then, 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.

Second, we also assume that each airport is a monopoly, i.e., there are no competitors. Thus, we need to select airports that can be considered monopolies. To do so, we restrict attention to flights originating from the main U.S. hub airports. These hubs are more likely to be in a monopoly position because they are much larger and offer more facilities to airlines and passengers. In addition, as hub airports are busier than other airports, they may allow us to capture congestion effects better. Table A1 in the Appendix provides the list of selected airports that also results from a practical reason. Airport Data of the FAA provides information such as financial statements, land area, and distance to the closest business district for all airports in the USA; however, it does not have information on the number of parking lots and number of concessions. To obtain these latter data, we directly contacted the thirty-one largest hub airports, and the needed information was provided by only nine hubs that constitute our dataset. Note that the total number of passengers using these nine hub airports represents 42.1% of the total passenger traffic of the thirty-one largest U.S. main airports. (See Table A1.)

Third, as the passengers are likely to consider the characteristics of connecting airports when they buy their tickets, data on airports are needed. Albeit, we had the connecting flights and connecting airports in the dataset, much information about the connecting airports (concession and parking) and connection such as layover time were missing. Hence, we focus on direct flights only.[4] In addition to direct flights, we eliminate code-shared products by keeping the direct flights with single ticketing and operating carriers. For the code-shared

[4] Note that selection of direct flights may only cause a potential selection bias if the idiosyncratic demand shocks are correlated with the choice of direct versus connected flights. Hence, in the model, we assume that a passenger chooses between the airlines given her choice of direct route.

flights, the passengers' decisions may also be affected by the code-sharing partners; thus, exclusion of this information may cause an endogeneity problem. By considering the observations with single ticketing and operating carriers, we reduce the effect of this endogeneity. At last, we select markets that are served by at least two competing carriers to be consistent with the assumption of competition among airlines in the same markets that we consider in our model. Among the direct flights in our sample, as the share on monopoly markets was approximately 20% of the data, we did not lose many observations by applying this selection.

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

Restricting attention to the main U.S. hub airports to support the monopoly assumption is worthwhile discussing in more detail. Two main issues can be raised against this choice. First, one may argue that the airports in our sample have competitors. For example, JFK would be possibly competing with La Guardia and Newark. Second, because the airports in our sample are hubs, it may also be the case that they are in competition with each other. For instance, someone who wants to fly from New York to Los Angeles can do it either via Atlanta or via Chicago, which makes Atlanta and Chicago competitors. Regarding the first point, because Atlanta, Minneapolis and Salt Lake City airports, which belong to our list of selected airports, are alone in their metropolitan area, they do not have competitors. For Chicago, Houston and New York City, there is more than one airport in their metropolitan area. However, they are all managed by the same local port authority. In that case, they are cooperating and sharing the market, which is compatible with our monopoly airport assumption. Concerning Baltimore International and Dulles International, which serve the same metropolitan area and are owned by two different local port authorities, we observe that, in our final data, there are five routes that originate from both of these airports and only three of them are served by the same airline. Hence, we believe that the monopoly assumption should not have significant effects on our results. Finally, there are three airports in the San Francisco Bay Area, and we only have San Francisco International in our sample. Given the FAA ranking and the total number of destinations at each airport, it is clear that the scales of these airports are very different from each other, and for most of the routes, San Francisco International is a monopoly. Regarding the second issue that can be raised, i.e., hub airports are in competition with each other, even if this is the case, it should not cause a bias in our analysis, as we consider direct flights only. Note that when we select the data for the nine hubs from the DB1B database, 63% of observations are direct flights. Hence, selecting direct flights and considering hub airports are de facto two complementary ingredients of the monopoly assumption.

[Insert TABLE 1]

The resulting sample used in our estimation has 377 products (airline-itinerary combination) and covers 165 markets (origin-destination) and 9 origin airports. Table 1 shows revenue decomposition of the airports in our sample for the year 2006. As seen from Table 1, the airports in our sample generate, on average, 40% of their revenue from non-aeronautical activities, with the rest coming from aeronautical activities. Note, however, the large share of non-aeronautical revenues for Atlanta. The reason for this large share stems from the fact that aeronautical revenues of Atlanta are very low compared to similar size airports in our data such as Chicago and George Bush airports. For instance, the aeronautical revenue of Chicago airport was $340.2 million, whereas its non-aeronautical revenue was $155.2 million in 2006. When we look at the same figures for Atlanta airport, although it had $158 million in non-aeronautical revenue, its aeronautical revenue was only \$53.1 million. ATRS Global Airport Benchmarking Report shows that Atlanta has the lowest landing fee among North American airports, which is explained by Atlanta airport's high efficiency due to its outsourcing strategy. (See ATRS, 2006.)

For each airline-itinerary combination (that we define as a product), there is a set of data that are distinguished by the prices paid and the number of passengers paying each of those prices. Therefore, we transform them by taking the weighted average of prices, and we aggregate the number of passengers purchasing the same product. To each product, then, is associated one price and one volume of passengers.

Table 2 reports the summary statistics of our main variables. The overall average ticket fare (i.e., the price of a product) is \$65.73, and an airline carries on average 2209 passengers in an origin-destination per quarter. The mean number of flights operated by an airline in an origin-destination is 401, and the average number of flights originating from an airport is approximately 71,000. Considering airport-related variables, the average number of destinations originated form an airport is 20 and the average landing fee is \$311 per aircraft.

[Insert TABLE 2]

III. Modeling 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 and then the pricing and frequency equations that define the airlines' strategies.

A. Passenger Side

A passenger i, $i = 1, \ldots, I$, has to decide between traveling to a given destination airport d, $d = 1, \ldots, D$, from an origin airport o and her outside option referred by the index

0, which includes the alternatives "not traveling" or "using other transport modes." Under the option of traveling by air, the passenger has to choose an airline j among the set of available airlines $j = 1, \dots, J_{od}$ for the given origin-destination od, and J_{od} is the total number of airlines operating from origin airport o to destination airport d. Moreover, each passenger consumes a positive amount of commercial goods at the airport, whereas non-fliers cannot consume any. To represent the behavior of passengers, we adopt a nested logit model.[5] The indirect utility level achieved by passenger i from choosing airline j for the given origin-destination, od, is:

(1) $$U^i_{odj} = V_{odj} + \varepsilon^i_{odj},$$

where V_{odj} is the mean utility level of using airline j at od and ε^i_{odj} is a consumer-specific unobservable effect. We specify ε^i_{odj} as follows:

(2) $$\varepsilon^i_{odj} = \nu^i_{od} + (1-\sigma)\nu^i_{odj} \quad \forall i = 1, \dots, I.$$

The error term ν^i_{od} captures passenger i's preference for traveling by air, and ν^i_{odj} captures the passenger preference for a specific airline operating at od. We assume that ν^i_{odj} has a Type I Extreme Value distribution and that ν^i_{od} is distributed such that ε^i_{odj} also has a Type I Extreme Value distribution. 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 measures the substitutability of airlines operating in od. Note that a higher σ means greater substitutability across airlines and more intense competition.

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

(3) $$V_{odj} = X'_{odj}\beta + \beta^j \frac{1}{\sqrt{f_{odj}}} + \beta^o f_o + \beta^c p^c_o - \alpha p_{odj} + \xi_{odj},$$

where X_{odj} is a vector of observable characteristics of the origin airport, destination and airline; p^c_o is the price of commercial goods at the origin airport o; and p_{odj} is the ticket price

[5] Note that including first the choice of whether to use an airport 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.

of the airline. The term f_{odj} is the frequency with which airline j flies from origin airport o to destination airport d. Let $1/\sqrt{f_{odj}}$ denote the flight accessibility of an airline j. Indeed, Richard (2003) interprets $1/\sqrt{f_{\mathrm{odj}}}$ as the passenger's cost of schedule delay, i.e., the difference between the passengers' preferred departure time and the actual departure time. Given that 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, we expect demand increases as the frequency increases, that is, we expect a negative estimate for β^j, which captures the preference for the flight accessibility. The airport capacity, f_o, is the sum of flight frequencies of all airlines operating at the airport, i.e., $f_o = \sum_d \sum_j f_{odj}$. This can be considered as the cost of delay referring to congestion in general at an airport.

Finally, ξ_{odj} is the error term capturing airport, destination and airline characteristics that 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 the departure time. Note that the β's and α are parameters to be estimated.

Let s_{odj} be the market share of airline j in the origin-destination od, $s_{j|od}$ be the market share of airline j within the nest "traveling by an airline from origin airport o 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 od, s_{odj}, is given by:

(4)
$$s_{odj} = e^{V_{odj}} s_0 s_{j|od}^{\sigma},$$

which leads to the following estimation equation:

(5)
$$\ln s_{odj} - \ln s_0 = X'_{odj}\beta - \beta^j \frac{1}{\sqrt{f_{odj}}} + \beta^o f_o + \beta^c p_o^c - \alpha p_{odj} + \sigma \ln s_{j|od} + \xi_{odj}.$$

The market shares are measured as:

(6) $$s_{odj} = \frac{q_{odj}}{M} \text{ and } s_{jod} = \frac{q_{odj}}{\sum_{j \in J_{od}} q_{odj}},$$

where q_{odj} is the total number of passengers travelling from origin airport o to destination airport 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 from zero. Moreover, in this two-sided platform setting, the passengers' benefits, and hence their demand, should also depend on the total number of products (flight frequencies) they can access. Therefore, we also expect β^o to be statistically significant from zero.

B. Airline Side

Each airline j, $j = 1, \dots, J_{od}$ sets its fare, p_{odj}, and frequency, f_{odj}, which maximizes its profit π_{odj} on each market. Let $C_{odj}(q_{odj}, f_{odj})$ be the total cost of airline j in the market od, and let $c_{odj}(q_{odj}, f_{odj})$ be its marginal costs. Note that it is not constant. The profit maximization problem of airline j is written as:

(7) $$\max_{p_{odj}, f_{odj}} \pi_{odj} = p_{odj} q_{odj} - C_{odj}(q_{odj}, f_{odj}) - p_o^a f_{odj} - F_{odj}$$
$$s.t. \;\; \pi_{odj} \geq 0,$$

where F_{odj} is airline j's route-specific fixed cost and p_o^a is the aeronautical fee charged by the origin airport o per flight (departure). Then, the optimal levels of price and frequency obtained from Equation (7) are given by:

(8) $$p_{odj}^* = c_{odj}^q + \frac{1}{\alpha\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma} s_{j|od} - s_{odj}\right)},$$

(9) $$f_{odj}^* = \left[\frac{2}{\beta^j}\left(\beta^o - \frac{\alpha p_o^a}{q_{odj}}\right)\right]^{-2/3}.$$

Because we do not observe this marginal cost, we posit that

(10) $$c_{odj}^q = Z_{odj}' \lambda + \lambda_q q_{odj} + \lambda_f f_{odj} + u_{odj},$$

where Z'_{odj} is a vector of cost shifters that includes airline, destination and origin airport-specific variables and u_{odj} is an error term. According to Equation (8), the price of product odj is equal to the marginal cost of product odj plus a mark-up term. The latter decreases in the substitutability among the products in a given origin-destination. Moreover, Equation (8) shows that higher market shares lead to higher prices. This relationship 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 (9) sets 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, α, the marginal utility of income, β^j, the consumers' valuation of waiting time, and β^o, consumers' valuation of total frequency at origin airport (in other words, the cost of congestion). Putting it differently, the demand of airlines for the airport not only depends on the aeronautical fee p_o^a but also on the number of passengers, q_{odj}. In this case, as a two-sided platform, the airport can affect this demand either by changing the aeronautical fee, which affects the demand directly, or by changing the commercial fee p_o^c, which affects the passenger demand q_{odj} and then the airline demand f_{odj} through the two-sided network effects.

IV. Estimating Passenger and Airline Behavior

In this section, we specify the model according to the dataset and explain the estimation method. Then, we present the estimation results of the passenger demand Equation (5) and the airline pricing Equation (8).

A. Model Specification

Some variables need to be defined to complete the specification of the model.

Factors affecting the passenger demand, that is, the variables that compose the vector X_{odj} in Equation (3), are the following: average shopping area, number of destinations, population at destination, distance, distance squared, distance to the closest business district, total distance flown from origin by each airline, and airline dummies.[6] Along with the common origin airport-specific variables such as distance to the closest business district and total flight frequency, we include average shopping area in the passenger demand equation in the interest of testing whether passengers gain from the presence of large shopping areas at an airport. At the same time, this variable can be considered the level of information the passengers have about the retail services at the airport. (See Flores-Fillol *et al.*, 2015.) If the parameter on this variable is significantly different than zero, it means that the passengers are not totally myopic about the non-aeronautical services at the airport.

The daily parking fee, which can be considered as an access fee to the airport, is used as a proxy for commercial (non-aeronautical) fees charged by the airport to passengers. As our dataset contains only direct flights, each passenger using the origin airport has to bear a transport cost. Thus, the parking fee captures this transport cost guaranteeing our assumption that each passenger consumes a positive amount of commercial goods. When considering the daily parking fee in the estimation process, we multiply it by a destination-specific coefficient, which is the share of the destination in terms of passenger traffic at the origin airport in the previous period (i.e., the second quarter of the year 2006) weighted by the population of the destination. Doing so, we capture the heterogeneity of destinations in commercial revenue generation.

We introduce both distance and distance squared variables to capture the shape of demand in distance. In general, air travel demand is expected to be U-shaped in distance. That is, air travel demand initially grows with distance and then decreases. The substitution between air travel and other modes of transportation (e.g., trains, cars) is higher at relatively short

[6] 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.

distances as discussed by Ivaldi and Vibes (2008). As distance increases, the competition with other modes of transportation weakens, and thus, demand for air travel increases. However, as the distance increases farther, the travel becomes less pleasant and the demand starts to decrease; see Berry and Jia (2010). Moreover, Bilotkach *et al.* (2010) find that flight frequency decreases with distance in long-haul routes where other alternatives such as driving become less substitutive. Moreover, we include two network measures for airlines in the passenger demand equation: The number of destinations from the origin airport operated by an airline and the logarithm of the sum of distances of all destinations from the origin airport provided by an airline. We also consider 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, following Foncel and Ivaldi (2005), we assume that it is a function of the income at the city where the origin airport is located:[7]

$$\alpha = \alpha_0 + \alpha_1 INCOME_o, \tag{11}$$

where α_0 and α_1 are parameters to be estimated. With this specification, we attempt to capture a wealth effect. Assuming that income is a proxy for wealth, we expect α_1 to be negative and α_0 to be positive. However, the overall effect α should remain positive.

Finally, according to Equation (10), the marginal cost, which enters in the optimal price equation of each airline (Equation 8), depends, in addition to the number of passengers, q_{odj}, and flight frequency, f_{odj}, on the vector Z_{odj} containing the following variables: 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.[8] The reason to include both the distance and the distance squared in the marginal cost equation is that the sign and size

[7] More precisely, the median per capita personal income is used to measure the income.

[8] 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).

of the coefficients associated with these variables suggest the pattern of marginal cost (whether marginal cost increases with distance up to some distance but declines in distance thereafter).

B. Instruments

We introduce a model of air travel demand, which is composed of three equations: passenger demand (Equation 5), airline's pricing equation (Equation 8) and airline demand (Equation 9). The airline demand (Equation 9) links the optimal frequency to the equilibrium number of passengers, up to a stochastic disturbance term, which represents measurement errors. Estimation of these three equations (5, 8 and 9) together entails convergence problems due to data availability. Specifically, as carriers use different types of aircraft on a given origin-destination market, we need information on the type of aircraft used and the flight schedule to model carriers' choices of flight frequencies together with pricing decisions.[9] 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 10): Number of passengers and flight frequency. Hence, the econometric problem that we face is the endogeneity of market shares, prices and frequency. The classical solution is to estimate the econometric model by using instruments that are orthogonal to the unobservable variables in all of the equations. Here, we estimate the system of Equations (5) and (8) simultaneously by means of the Generalized Method of Moments; see Hansen (1982). For each equation, we define instruments that satisfy the moment conditions, i.e.,

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

$$E\begin{bmatrix}\xi|W_q\\u|W_p\end{bmatrix}=0, \tag{12}$$

where W_q is the vector of instruments for the demand equation (Equation 5) and W_p is the vector of instruments for the pricing equation (Equation 9).

As the number of exogenous variables of our system is not enough to instrument all endogenous variables, we construct some additional instruments. On the passenger demand side, we build two instruments: 1) the number of other airlines operating in the same market (i.e., the number of rival airlines); and 2) the average number of destinations flown from the same origin by the rivals. 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.) Using rival product attributes as instruments in the demand equation is a common strategy in the empirical models of differentiated products. We use the average number of destinations flown by the rivals from the same origin, i.e., the average network size of the rivals from the same origin. The rivals with similar sizes provide closer substitutes; hence, the average network size of the rivals seems to be a good instrument for the market shares. In addition to these two instruments, we use airport dummies and nonlinear transformations of some instruments as well as interactions of exogenous variables of the model such as the area of the airport and its parking capacity. These characteristics of the airports are predetermined and cannot be adjusted in the short run. Hence, we believe that they predict well the market shares while being independent of the demand shocks for the particular airline.

On the cost side, we use the exogenous variables of demand equations that do not enter the cost equation, such as the distance of airport to the closest business district, the number of destinations and the total distance flown from origin by each airline, as well as their interactions. We also use exogenous airport characteristics such as the number of shops at the airport. As already explained, these airport characteristics cannot be adjusted in the short run, so they are uncorrelated with the contemporaneous shocks in the cost equation and are expected to predict well market shares and frequency.

In Table 3, we report the Hansen J-test of over-identifying restrictions. It does not reject the null hypothesis that the instruments are valid, i.e., uncorrelated with the error term.

C. Estimation Results

Table 3 presents the parameter estimates for the two-equation system made of the passenger demand and airline pricing equations. 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.

Demand Parameters

According to its specification, the 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 of 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. By specifying the price coefficient as in Equation (11), 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. As σ is estimated to be $0.47,$ 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, a moderate correlation exists among products provided in the same market (origin-destination), and this correlation is higher than between any products and the outside goods.

As explained in *Section IV.A*, 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 fully support this U-shaped behavior. Indeed, while the estimated coefficient of distance is positive and significant, the coefficient of the squared distance is not significant.

The effect of network size on the passenger demand equation is twofold. 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 the two network variables and find that it is negative and significant. Thus, we can conclude that passengers prefer airlines to operate many more destinations rather than to operate destinations at longer distances.

Concerning the platform-specific (i.e., origin airport-specific) variables, discussed in *Section IV.A*, they are all statistically significant. First, the average shopping area is estimated to be positive, showing that passengers gain benefit from the presence of a large shopping area at an airport. Putting it differently, following Flores-Fillol *et al*. (2015), we can say that the passengers are not myopic and that they have information about the non-aeronautical services at the airport. As Flores-Fillol *et al*. (2015) show, in such a case, it is optimal for the airport to be competitive in the non-aeronautical side and charge higher prices on the aeronautical side. 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 the airport, β^o, is found to be negative, which captures congestion at the origin 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 IV.A*, the daily parking fee is considered to be a proxy for measuring the price of non-aeronautical (or commercial) services paid by each passenger to have access to the airport (i.e., join platform). As the coefficient of the daily parking fee, β^c, is found to be negative and significant, it means that passengers fly more if the price of the representative commercial product decreases. In other words, through this price, the airport can affect the transaction between airlines and passengers. This result is in line with the two-sidedness definition of Rochet and Tirole (2003), who 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.

Although the estimate of β^c might seem much smaller than that of α, if we look at the elasticities given in Table A2 in the Appendix, it can be seen that the effect of the price of commercial services at the airport on demand is non-negligible. For instance, at JFK Airport, a 1% increase in daily parking fee decreases the demand by 0.44%, while a 1% increase in ticket price decreases the demand by 2%. Roughly speaking, increasing the daily parking fee from $18 to $19 at JFK would decrease the passenger demand more than increasing the ticket price by 1%. Salt Lake City airport can be given as a counter-example. The price elasticity of commercial services at Salt Lake City airport is 0.0002, and the price elasticity for air travel demand is 1.83. Hence, the effect of doubling the daily parking fee (from $28 to $56) on passenger demand is lower than raising the ticket price from $60.35 to $61.00.

[Insert TABLE 3]

The two variables, namely the airline frequency, f_{odj}, and the total frequency at the airport, f_o, capture the two-sided network externality in the passenger demand, Equation (5). Note that we specify the cost of schedule delay of airline j on a given market as inversely proportional to an airline's flight frequency on that market. Table 3, 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 schedule delay rises, meaning that the frequency of airline j and the time to access to flight are lessened. 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^o, is negative and significant. 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 origin airport. Hence, there is also a negative externality between the two end users. Airports can affect airline demand, f_{odj}, by changing the price of departures. This change will be reflected in passenger demand through β^j and β^o, which will have a further impact on airline demand for aeronautical services through Equation (9).

We conduct a test of specification where the network effect parameters β^j and β^o are assumed to be equal to zero in the restricted model. The χ^2 statistic is equal to 37.84 with an associated p-value of less than 0.0001; hence, we reject the restricted model. We can then conclude that two-sided network effects are needed to be considered when we model air travel demand.

To sum up, 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 the pricing decision. Thus, one can conclude that airports are two-sided platforms that connect passengers and airlines because they could not interact without these platforms and because 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. Therefore, 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.

Cost Parameters

We specify the marginal cost Equation (10), which enters the optimal price equation of each airline (8), 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_{odj}, and flight frequency, f_{odj}, capture the long-run effects. The coefficient on q_{odj} is estimated to be negative, which means the marginal cost of an airline decreases in q_{odj}. Precisely, by increasing the number of passengers, carriers can increase the load factor, thus spreading out costs with more passengers. The sign of the coefficient on f_{odj} 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 because the airline may fly with less full aircraft so costs are higher. However, we cannot fully support this conclusion as the coefficient is insignificant.

Regarding the other variables, we find that marginal cost is increasing in distance, as 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 direct flights. Finally, the coefficients on the airport dummies are broadly consistent with the reports on the landing and takeoff charges of airports. For example, the estimated coefficient for Chicago Airport is positive, which charges higher landing/departure fees than does Minneapolis-St. Paul Airport as well as most other airports.

Given the cost parameters' estimates, we calculate the marginal costs 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 A4. The marginal cost is, on average, $52, while the margin is approximately 44%, which is quite close to the one found in the previous literature. Note that JFK and SFO charge the highest aeronautical fees among our sample; as expected, the products originating from JFK and SFO airports have the highest marginal costs.[10] Table A5 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 costs. In addition, an increase in total frequency at an airport would reduce passenger demand through congestion effects. Consequently, a change in aeronautical fees would not

[10] As seen in Table 6, the aeronautical fees of JFK and San Francisco airport are much higher than those of other airports. We constructed the aeronautical fee as p_o^a = landing revenues/no. of departures; however, in reality, the landing fees are composed of a fixed fee and a per 1,000 lbs. variable fee. Because JFK and SFO receive more international flights than the other airports in our sample (33% and 14%, respectively) and the international flights are flown by larger aircrafts, this makes the approximated fee per landing higher in these airports.

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 two-sided network effects.

V. Identifying Airport Pricing

A. *Theoretical Equations*

We consider a multi-product monopoly airport that provides aeronautical services to airlines and commercial services to passengers. The airport decides on an aeronautical charge p_o^a and a concession price p_o^c. In this section, we assess which, among Pigouvian, profit-maximizing and Ramsey pricing models under a two-sided market structure and a one-sided market structure, is the best to represent the actual decisions of airports in our sample.

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.

Pricing under a two-sided platform setting

Pigouvian Pricing

Pigouvian pricing requires that the marginal benefit of an activity equals its marginal cost. A Pigouvian airport (platform) maximizes the total social value, which is equal to the sum of benefits of users on the two sides of the market minus its costs.[11] Thus, the problem of the airport is given by

[11] It should be noted that our simulation results depend on the included components of our welfare function. Missing components due to the presence of other interest groups such as green lobbyists who force airports to limit landing capacities could change the outcomes of our simulations.

(13)
$$\max_{p_o^a, p_o^c} \sum_d CS_d + \sum_d \sum_j \pi_{odj} - c_o^a f_o - c_o^c q_c$$

where CS_d is the consumer surplus on route od, π_{odj} is the profit of airline j on route od, and c_o^a and c_o^c are the marginal costs for producing aeronautical and non-aeronautical services, respectively. (See Weyl, 2010.) Moreover, f_o is the total number of flights from airport o, and q_c is the total number of passenger buying non-aeronautical services. Roy's identity gives $q_c = -\frac{\beta^c}{\alpha} q_o$, where $q_o = \sum_d \sum_j q_{odj}$ is the total number of passengers flying from airport o.

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:

(14)
$$CS^a = \frac{1}{\alpha} \ln \left[1 + \left[\sum_{j \in J_{od}} e^{\frac{V_{odj}}{1-\sigma}} \right]^{1-\sigma} \right],$$

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

(15)
$$CS^c = -\frac{1}{\beta^c} \ln \left[1 + \left[\sum_{j \in J_{od}} e^{\frac{V_{odj}}{1-\sigma}} \right]^{1-\sigma} \right].$$

When solving the optimization problem in Equation (13), the Pigouvian platform internalizes network externalities to choose 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. As the demand of passengers depends on frequency, a change in the price of aeronautical services, which affects frequency, also has an effect on the demand of 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 at origin solves the following problem:

$$\max_{p_o^a, p_o^c} \Pi_o = (p_o^a - c_o^a) f_o + (p_o^c - c_o^c) q_c - K_o \tag{16}$$

where Π_o is its profit and K is the fixed cost. The first order conditions lead to price levels determined by the Lerner formula:

$$\frac{p_o^a - \left[c_o^a - (p_o^c - c_o^c)\dfrac{\partial q_c / \partial p_o^a}{\partial f_a / \partial p_o^a}\right]}{p_o^a} = -\frac{1}{\eta_o^a}, \tag{17}$$

$$\frac{p_o^c - \left[c_o^c - (p_o^a - c_o^a)\dfrac{\partial f_a / \partial p_o^c}{\partial q_c / \partial p_o^c}\right]}{p_o^c} = -\frac{1}{\eta_o^c}, \tag{18}$$

where η_o^a is the price elasticity of airlines' demand and η_o^c is the price elasticity of passengers' demand at the origin airport o. Similar to Rochet and Tirole (2006), due to the two-sidedness, the marginal cost has been reduced by the cost of externality generated by the other side compared to the standard Lerner formula in Equations (17) and (18). As the airport considers the market under a two-sided structure, the airport's profit per new user on one side pays a part of the cost per user on the other side of the platform. This term deducted from the cost on the left-hand side captures the effect of the number of passengers on frequency and the 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 because it reduces the deficit incurred in the operation of the airport. To surmount this problem, the regulator may force the airport to choose to maximize the social welfare subject to the constraint that its profit is nonnegative. In other words, Ramsey pricing corresponds to the price that results from solving this program:

$$\max_{p_o^a, p_o^c} \sum_d CS_d + \sum_d \sum_j \pi_{odj} - c_o^a f_o - c_o^c q_c \quad s.t. \ \Pi_o \geq 0 \tag{19}$$

A Lagrange multiplier, μ, is used to include the revenue constraint explicitly in the above objective. Note that when the constraint is not binding, 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 noted by Weyl (2010), Ramsey prices are weighted averages of Pigouvian and profit-maximizing prices.

The solution to the problem defined in Equation (19) provides a pricing scheme that considers the externalities arising from the two-sidedness of the market. In other words, we extend the quasi-optimal user charges for the airport proposed by Oum and Tretheway (1988) to a two-sided market setting.

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 can be obtained as follows.

Pigouvian Pricing

A public airport that considers one-sided markets would choose prices by considering the surplus of each side separately. More precisely, it would choose a price for aeronautical services that equalizes its marginal cost to the marginal benefit of the airlines by solving:

$$\max_{p_o^a} \sum_d \sum_j \pi_{odj} - c_o^a f_o. \tag{20}$$

Then, 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 the passengers by solving:

(21) $$\max_{p_o^c} \sum_d CS_d - c_o^c q_c.$$

In this case, the airport does not consider the network externalities that exist between passengers and airlines, and the prices may be below or above the socially optimal levels compared to the case when the two-sided network externalities are considered.

Profit-maximizing Pricing

A profit-maximizing airport that considers one-sided markets solves two separate maximization problems to choose its optimal price levels according to:

(22) $$\max_{p_o^a} \Pi_o^a = (p_o^a - c_o^a) f_o - K_o^a$$

and

(23) $$\max_{p_o^c} \Pi_o^c = (p_o^c - c_o^c) q_c - K_o^c,$$

where Π_o^a is the profit from aeronautical services, Π_o^c is the profit from commercial services, K_o^a is the fixed cost of providing aeronautical services, and K_o^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.

Ramsey Pricing

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

(24) $$\max_{p_o^a} \sum_d \sum_j \pi_{odj} - c_o^a f_o \qquad s.t. \;\; \Pi_o^a \geq 0$$

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

(25) $$\max_{p_o^c} \sum_d CS_d - c_o^c q_c \qquad s.t. \;\; \Pi_o^c \geq 0$$

A monopolist airport that uses one-sided Ramsey prices will not be able to cross-subsidize between the two sides, and hence, satisfying the positive profit constraint may become even harder.

B. Simulations

As explained in *Section V.A*, we model an airport as a multi-product monopoly platform that provides aeronautical services to airlines and commercial services to passengers. The airport decides on the price of aeronautical services, p_o^a and the price of commercial goods, p_c. Moreover, we propose different pricing schemes under a two-sided and one-sided market structure to represent the airport's decision problem.

Given our estimates in Table 3 of the demand sides for the passengers and the airlines (Equations 5, 8 and 9), the marginal costs of services provided by an airport should not be negative if the implied airport's pricing problem is correct. In other words, the correct specification of the industry on both the demand and the supply side should result in positive marginal costs. Hence, to identify the business models of airports, we use the following strategy. We compute the marginal costs for aeronautical (c_o^a) and non-aeronautical (c_o^c) activities of each airport under different pricing schemes using our parameter estimates.[12] Then, we check if the relevant constraints in the different programs of the airport (in particular, nonnegative profits for airports under profit-maximizing and Ramsey pricing schemes) are satisfied with these estimated marginal costs. After controlling for these non-negative profit constraints, we run an adequacy test using bootstrap methods. More broadly, we perform 1,000 bootstrap replications of our original dataset to obtain the standard errors of marginal costs and the critical values for the t-test. The null hypothesis is that marginal costs associated with a particular pricing scheme are positive and significant.

12 We obtain a proxy for the aeronautical fee, p_o^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_o^c.

Three main remarks can be made on these simulations. First, none of the pricing schemes under a two-sided market structure fit our model, i.e., the implied marginal costs are not both positive; see Table A3 in the Appendix. We can conclude that the airports in our dataset 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 when the airports consider the markets one-sided, i.e., they choose the prices separately for each side, thus neglecting their interdependency. Third, airports are using different pricing schemes for passengers and airlines. The results are presented in Table 4 and Table 5, under profit maximization and Ramsey pricing, respectively.

Table 4 shows the estimated marginal costs for both aeronautical and non-aeronautical sides, their standard deviations, t-statistics and the 5% critical values under one-sided profit-maximizing prices. As the table shows, we find that the marginal cost of commercial services obtained under profit maximization are statistically significantly greater than zero; hence, we can conclude that the prices for commercial services correspond to profit-maximizing prices. The latter provide positive marginal costs, which vary widely from $28 for Atlanta Airport to $1,312 for JFK.

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 (19). Table 5 shows the implied marginal costs for the aeronautical side under Ramsey pricing scheme with different weights (λ) as well as their standard deviations, t-statistics and 5% critical values. There are a few points worth noting. First, marginal costs are statistically significantly greater than zero for a weight $\lambda = 0.5$ for 7 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 $\lambda = 0.6$. Finally, Atlanta International Airport (ATL) is known to be one of the most efficient airports, i.e., with the lowest cost. (See ATRS, 2012.) We find that it puts the highest weight, $0.7 \leq \lambda \leq 0.8$, on the profit-maximizing price. As Atlanta airport has lower marginal costs, it has a higher ability to put more weight on profit-maximizing prices.[13] On the commercial side, none of the airports in our sample satisfies Ramsey prices. The implied marginal costs are either negative or positive but do not satisfy the nonnegative profit constraint.

[Insert TABLE 4]

Finally, as mentioned earlier, Pigouvian prices are equivalent to Ramsey prices where the weight λ is set to zero. We find positive marginal costs on both sides under this scheme; however, the values are too large so that they lead to huge losses on both sides. Hence, we rule out Pigouvian prices on both sides. Given these results, we can conclude that airports are using profit-maximizing prices on the non-aeronautical side because we obtain positive marginal costs with nonnegative profits only under this scheme. On the other side of the market, we have two main findings: First, the results are not consistent with Pigouvian prices because the implied marginal costs under this scheme lead to huge losses. Second, we obtain positive marginal costs with nonnegative profits under both profit-maximizing and Ramsey pricing schemes. However, marginal costs implied by profit maximization lead to zero profits, while implied profits by Ramsey pricing are strictly positive. Although we cannot reject profit maximization on the aeronautical side statistically, the fact that the airports in our sample are publicly owned points toward Ramsey prices on the aeronautical side. Figures from financial statements of airports such as JFK and SFO support this conclusion.[14,15]

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[13] For the sake of exposition, we only present test results where the implied marginal costs satisfy relevant constraints of different pricing schemes. All other results are available upon request.

[14] According to the 2011 financial statement of JFK published by the Port Authority of New York and New Jersey, total operating expenses of JFK airport were $2,564,969, which leads to an operating cost of $79.55 per flight given the figures in our data, and this number is much closer to the marginal cost obtained under the Ramsey pricing scheme.

[Insert TABLE 5]

In the U.S., because most airports are publicly owned, they have no incentive to set unfair prices. Although the Federal Aviation Administration is allowed to regulate the airports, no regulation has been effectively implemented. (See Gillen, 2011.) The airports' business models as implied by our empirical model are in line with what the entire airport industry seems to do in the real world: Airports are maximizing profits on commercial services and are maximizing welfare on aeronautical services. Thus, our tools can be used to evaluate the situation in other countries. In the regulation of private airports, the choice between single till and dual till price-cap regulation is a largely debated issue. Although there are some theoretical and empirical articles 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 articles may not hold any longer. We believe that the methodology and findings we present here will shed light on the pricing and regulation of airports.

That the publicly owned or regulated airports are applying profit-maximizing prices for non-aeronautical services and Ramsey pricing for aeronautical services is in line with the views of other experts. (See Gillen, 2011.) It explains why airports' owners are advocating for dual till regulation under which prices of non-aeronautical services are not regulated, while airlines are calling for a single till regulation, which claims that both services, aeronautical and non-aeronautical, must be considered together in the determination of price caps.[16] (See IATA, 2007.) Table A2 in the Appendix shows that on the one side, the ticket price elasticity is high so

[15] The financial statement supplied for the San Francisco airport reports operating costs of $494,940 for 2011, which leads to an operating cost of $14.10 per flight. This value is again much closer to what we obtain as the marginal cost under the Ramsey pricing scheme.

[16] Note that the International Air Transport Association supports the single till regulation for airports. (See IATA, 2007).

that the demand for air transport is highly elastic, indicating that competition among airlines for attracting passengers is fierce; on the other side, it shows that the aeronautical price elasticity is very low for some airports such as JFK, Chicago and San Francisco so that the demand for frequencies is inelastic, which explains that airports can exploit their monopoly position to raise the price of aeronautical services. These results are not counterintuitive and are certainly in line with what the industry does in the real world. Clearly, we owe these results to the two-sided market approach we have adopted. As Zhang and Zhang (2010), Czerny (2006) and Bilotkach *et al.* (2012) did not consider the two-sided structure of the market when discussing the economic issues of single and dual regulation, their predictions and conclusions may not hold any longer.

C. Airport Privatization

In the previous section, we have concluded that the airports in our dataset are pricing passengers and airlines under a separated platform setting and that 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 given by Equations (5), (8), (17) and (18) for the optimal ticket prices for each airline on each route, p_{odj}, the implied passenger demand, q_{odj} and the optimal airport prices, p_o^a and p_o^c under the assumption that the monopolist airport is maximizing its profits under a two-sided market structure. Moreover, the marginal cost per passenger of airlines, c_{odj}^q, in Equation (8) is replaced by Equation (10). Remember that Equations (5) and (8) are passenger demand and airline pricing equations that were derived in *Sections 3.1* and *3.2*. Equations (17) and (18) give the first order conditions of profit maximization problem of a monopoly airport under a two-sided market setting. As already mentioned, these conditions are different than the usual Lerner index because the airport is internalizing two-sided network effects.[17] A priori, one would expect that the pricing of a private firm that internalizes these effects would be welfare enhancing. However, our simulations show that this may not be true for some airports in our dataset.

After obtaining these optimal values, we can compute the consumer surplus, profits of the airlines and the airports and the social welfare. Table 6 displays these values under the current pricing regime, while the results of the simulation are presented in Table 7. Our results show that the welfare effect of privatization of the airports is different for each airport. For example, for Chicago airport, a private profit-maximizing airport would lead to a social welfare increase of more than 100%, while for Minneapolis-St. Paul airport, this would result in a social welfare decrease of more than 2%. The effect of privatization on the number of total passengers using air transport is also airport dependent. The number of passengers originating from Chicago, JFK and San Francisco would increase, while for all other airports, this number would decrease. This is mostly due to the decrease in mean ticket price that the airlines charge from Chicago, JFK and San Francisco airports. Moreover, the decrease in ticket prices might be attributable to the decrease in aeronautical charges; however, the aeronautical fee decreases at all airports except Atlanta and Salt Lake City. Finally, our last result is on the optimal price for commercial activities, p_o^c. Under the scenario of private profit-maximizing airport, this price would increase by a minimum of 0.3% (Salt Lake City) and maximum of 19% (George Bush), making it more expensive for passengers to travel. Given that the airports in our model are monopolists and that 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.

[17] Note that compared to the usual first order equations in a model of differentiated products under Bertrand competition, the marginal costs of each side of the market are "corrected" for the effect of the externality raised by the other side. Indeed, the margin of each side is impacted by their marginal effect on the margin of the other side of the platform. For instance, if the passengers are exerting positive network effects on airlines, the margin on the passenger side will be adjusted downward.

Our simulation results have important implications for policy analysis. First, as seen from Table 7, the effect of privatization on social welfare would be airport (origin) specific; for most airports, it would be social welfare enhancing, while for Minneapolis-St. Paul airport, it would not. Second, such a case would lead the airports to charge passengers higher prices, which may necessitate regulation if these price increases are too high. Third, under the current situation of the industry, with a one-sided Ramsey pricing scheme, some airports, such as JFK or San Francisco, set the aeronautical fee too high, most probably as a result of not accounting for the two-sided network effects.

[Insert TABLE 6]

Finally, it should be noted that we could not incorporate the fleet structure of airlines into our model. Hence, in the simulations, we assume that the capacities of aircraft landing in the different airports are constant. One could imagine that the change in landing fees due to a change in the regulation could lead airlines to change their fleet structure. If an airline is able to adopt its fleet structure according to passenger demand, it can decrease its cost and thus increase its profit. In such a case, the loss in social welfare stemming from the loss in consumer surplus may be offset or decreased by the gains in airlines' profits.

[Insert TABLE 7]

VI. Conclusion

This article 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 dataset from the U.S., 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 social welfare.

We obtain four main results. First, 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. Other than for Minneapolis-St. Paul airport, the two-sided pricing scheme would increase social welfare.

The main contribution of the article 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 article is the first one to consider the business model of airports under two-sided market structures. Combining these two facts, the article as a whole contributes to the literature on the regulation of airports because 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 the competition analysis of airports. Our results show that airports practice two separate pricing rules meaning they are indeed pricing under dual till. Although the private airport has an incentive to consider two-sidedness a priori, our simulation results show that it may not be welfare enhancing. In such a case, it would be better to regulate the airport, i.e., we need to find a way to force the airport to increase welfare, and it will only be possible by considering both services, namely aeronautical and non-aeronautical. Thus, we will need single till regulation. It is similar to a *global price cap* under which one regulates the access to and the usage of the network, where the access is determined by the landing fees and the usage is driven in particular to parking fees in the case of airports. (See Laffont and Tirole, 2000, for a definition of global price cap).

The topic is very fruitful for future work. Our model can 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. In addition to all these, the debate of single till versus dual till can be revisited under the structure provided here.

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TABLES

TABLE 1 - REVENUE DECOMPOSITION OF AIRPORTS

Airport	**Aeronautical Revenue (million dollars)**	**Share**	**Non-aeronautical Revenue (million dollars)**	**Share**
Hartsfield-Jackson Atlanta International	53.17	0.25	158.02	0.75
Chicago O'Hare International	340.26	0.69	155.23	0.31
George Bush Intercontinental	230.73	0.74	81.74	0.26
Minneapolis-St.Paul International	87.42	0.58	62.08	0.42
John F.Kennedy International	553.78	0.78	155.79	0.22
San Francisco International	259.01	0.65	141.18	0.35
Salt Lake City International	41.70	0.51	39.80	0.49
Baltimore/Washington International	69.66	0.58	50.77	0.42
Dulles International	137.45	0.70	56.86	0.30
Average Airport	197.02	0.60	100.16	0.40

TABLE 2 - VARIABLE SUMMARY STATISTICS

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Ticket Fare, (in dollars), p_{odj}	65.73	44.82	3.73	258.74
Number of Passenger, q_{odj}	2209.87	1835.76	1.00	12105.00
Number of Passenger on O-D, q_{od}	5356.91	3643.66	18.00	19714.00
Flight Frequency, f_{odj}	401.81	273.88	9.00	1554.00
Flight Frequency at Origin, f_o	71123.12	35183.83	30819.00	113417.00
Daily Parking Fee (in dollars)	21.05	6.58	12.00	31.00
Landing Fee (in dollars)	310.85	322.69	28.87	1312.19
Average Shopping Area (in acres)	48.46	34.70	20.44	139.79
Number of Destinations	19.72	16.44	1.00	43.00
Distance (in miles)	1135.02	691.71	215.00	4243.00
Income in Origin (in thousand dollars)	44.16	6.59	36.21	59.44
Distance to Business District (in miles)	10.09	4.52	3.00	20.00

TABLE 3 PARAMETER ESTIMATES OF THE TWO-EQUATION SYSTEM

Demand Variables	**Parameter**	**Estimate**	**Std. Error**
Price	α_0	0.03^{***}	0.01
Price*Income	α_1	-0.0002^{*}	0.0001
ln $s_{j\|od}$	σ	0.47^{**}	0.23
Flight Accesibility	β^j	-25.14^{***}	4.53
Total Flight Frequency at Origin	β^o	$-8x10^{-6^{***}}$	$3x10^{-6}$
Daily Parking Fee	β^c	$\_10^{-5^{***}}$	$5x10^{-6}$
Constant	β_0	-1.54^{*}	0.81
Average Shopping Area	β_1	0.02^{***}	0.002
Number of Destinations	β_2	0.29^{***}	0.09
Population at Destination	β_3	$4.7x10^{-5^{***}}$	$9x10^{-6}$
Distance	β_4	0.0005^{***}	$1.6x10^{-4}$
Distance Squared	β_5	10^{-7}	$5x10^{-8}$
Distance to Business District	β_6	-0.05^{***}	0.01
$\ln(Total\ Distance\ Flown)$	β_7	-0.25^{***}	0.10
$\ln(Total\ Distance\ Flown)$	β_8	-0.03^{***}	0.01
JetBlue Airways	β_9	-1.52^{***}	0.37
Continental Airlines	β_{10}	-0.35	0.3
Delta Airlines	β_{11}	-0.29^{*}	0.15
Northwest Airlines	β_{12}	-0.10	0.15
United Airlines	β_{13}	0.16	0.14
US Airways	β_{14}	0.21	0.38
Southwest Airlines	β_{15}	-0.92^{***}	0.25
Other airlines	β_{16}	-0.57^{***}	0.16
Cost Variables	**Parameter**	**Estimate**	**Std. Error**
Constant	λ_0	8.70	36.01
Distance	λ_1	0.03^{*}	0.02
Origin Destination Hub	λ_2	30.61^{**}	13.45
Distance Squared	λ_3	10^{-6}	$4x10^{-6}$
Number of Passengers	λ_q	-0.05^{***}	0.02
Flight Frequency	λ_f	0.15	0.10
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	0.0224
Test	DF	Statistics	P-value
Hansen J (Over-identification)	7	8.45	0.29

Notes: The individual coefficient is statistically significant at the ***1%, **5% or *10% significance level.

TABLE 4 ADEQUACY TEST OF PROFIT MAXIMIZATION PRICING UNDER A ONE-SIDED SETTING

Airports	c_o^a	Std. Dev.	$t^*_{0.05}$	t	c_o^c	Std. Dev.	$t^*_{0.05}$	T
ATL	28.87**	0.00082	0.61	35209.34	15.98**	0.00132	1.48	12067.30
BWI	264.11**	0.00040	0.75	668467.06	12.00**	0.00006	1.53	206247.96
IAD	272.20**	0.00124	0.75	218770.90	17.00**	0.00003	1.69	494965.79
IAH	292.26**	0.00014	0.70	2037293.92	17.00**	0.00001	1.67	1458592.88
JFK	1312.19**	0.00232	0.96	565343.51	18.00**	0.00001	1.61	3516292.24
MSP	186.91**	0.00060	0.68	310210.68	18.00**	0.00007	1.61	256177.06
ORD	352.87**	0.00114	0.67	308415.86	31.00**	0.00003	1.48	1096360.74
SFO	483.99**	0.00083	0.91	584836.24	20.00**	0.00002	1.62	819357.61
SLC	74.45**	0.00237	0.70	31390.79	28.00**	0.00027	1.55	104811.41

Notes: c_o^a is the aeronautical and c_o^c is the non-aeronautical marginal cost of origin airport. Profit constraint in profit maximizing pricing is satisfied in grey highlighted lines. The individual coefficient is statistically significant at the ***1%, **5% or *10% significance level.

TABLE 5 ADEQUACY TEST OF RAMSEY PRICING FOR AERONAUTICAL SERVICES UNDER ONE-SIDED SETTING

$\lambda = 0.5$					$\lambda = 0.6$				
Airports	c_o^a	Std. Dev.	$t^*_{0.05}$	t	Airports	c_o^a	Std. Dev.	$t^*_{0.05}$	t
ATL	61.26	6.47	1.81	9.46	ATL	44.38	5.87	1.71	7.57
BWI	126.13**	13.02	1.72	9.69	BWI	-117.16	33.16	1.64	-3.53
IAD	171.01**	17.38	1.76	9.84	IAD	-283.5	54.93	1.49	-5.16
IAH	72.65**	7.61	1.87	9.55	IAH	-1353.58	145.81	1.44	-9.28
JFK	183.22**	18.17	1.77	10.08	JFK	-2616.47	279.62	1.51	-9.36
MSP	145.44**	14.28	1.80	10.19	MSP	-54.36	26.99	1.58	-2.01
ORD	85.76**	8.92	1.90	9.83	ORD	-342.53	44.38	1.68	-7.72
SFO	155.16**	15.56	1.74	9.97	SFO	-436.95	69.51	1.54	-6.29
SLC	112.75	12.51	1.88	9.01	SLC	44.25**	14.71	1.68	3.01
$\lambda = 0.7$					$\lambda = 0.75$				
Airports	c_o^a	Std. Dev.	$t^*_{0.05}$	t	Airports	c_o^a	Std. Dev.	$t^*_{0.05}$	t
ATL	27.5**	5.32	1.87	5.17	ATL	19.06**	22.49	0.36	0.85
BWI	-360.46	51.66	1.63	-6.98	BWI	-482.10	146.56	0.71	-3.29
IAD	-738.02	98.37	1.46	-7.50	IAD	-965.27	121.83	1.46	-7.92
IAH	-2779.82	296.53	1.35	-9.37	IAH	-3492.94	416.68	1.31	-8.38
JFK	-5416.16	552.47	1.47	-9.80	JFK	-6816.00	1224.54	0.91	-5.57
MSP	-254.15	40.64	1.68	-6.25	MSP	-354.05	169.07	0.44	-2.09
ORD	-772.72	79.07	1.66	-9.77	ORD	-987.81	134.70	1.26	-7.33
SFO	-1029.05	131.50	1.38	-7.83	SFO	-1325.10	162.16	1.42	-8.17
SLC	-24.26	17.47	1.66	-1.39	SLC	-58.52	42.65	0.73	-1.37
$\lambda = 0.8$									
Airports	c_o^a	Std. Dev.	$t^*_{0.05}$	t					
ATL	10.62**	4.79	1.71	2.22					
BWI	-603.75	77.98	1.54	-7.74					
IAD	-1192.53	141.63	1.41	-8.42					
IAH	-4206.06	442.12	1.38	-9.51					
JFK	-8215.84	838.08	1.37	-9.80					
MSP	-453.94	54.60	1.43	-8.32					
ORD	-1202.9	117.26	1.39	-10.26					
SFO	-1621.15	191.51	1.28	-8.47					

Notes: Profit constraint in Ramsey pricing is satisfied in grey highlighted lines. The estimated value is statistically significant at the ***1%, **5% or *10% significance level.

TABLE 6 STATE OF THE INDUSTRY UNDER THE CURRENT PRICES

	Passengers		Airlines		Airport		
Airports	q_o	**CS**	p_{odj}	**Profits**	p_o^a	p_o^c	**Profits**
ATL	0.1812	0.0113	57.15	6.3653	28.87	16	1.1126
ORD	0.2250	0.0173	69.47	8.3726	352.86	31	28.0044
IAH	0.0262	0.0005	85.27	1.0149	292.26	17	13.6806
MSP	0.0750	0.0014	55.80	2.8167	186.91	18	2.1456
JFK	0.1013	0.0006	72.63	4.1109	1312	18	36.4014
SFO	0.0801	0.0006	98.90	0.3820	483.99	20	1.1545
SLC	0.0421	0.0188	60.35	1.5086	74.45	28	1.2166
BWI	0.0653	0.0124	41.91	2.6130	264.00	12	4.2523
IAD	0.0371	0.0028	68.93	1.6426	272.20	17	3.4171

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

TABLE 7 VALUES UNDER A PRIVATE PROFIT MAXIMIZING AIRPORT'S PRICES

	Passengers		Airlines		Airport			SW
Airports	q_o	**CS**	p_{odj}	**Profits**	p_o^a	p_o^c	**Profits**	**Change**
ATL	0.1794	0.1431	59.34	6.8100	361.34	16.29	38.8209	10.63%
ORD	0.2387	0.0210	62.58	9.2461	221.64	31.20	14.1468	100.67%
IAH	0.0231	0.0005	95.08	1.0692	113.09	20.21	2.5189	1.55%
MSP	0.0672	0.0016	61.80	2.7049	145.44	18.40	0.0005	-2.37%
JFK	0.1049	0.0008	67.31	4.4381	207.39	18.10	0.7796	18.21%
SFO	0.0823	0.0059	96.96	4.2178	278.40	20.63	4.3269	26.58%
SLC	0.0370	0.0167	69.22	1.5198	107.42	28.09	2.5446	3.61%
BWI	0.0641	0.1685	45.14	2.8009	220.05	12.53	2.9561	15.24%
IAD	0.0360	0.0036	72.89	1.8447	229.09	17.19	1.9611	4.91%

Notes: i) Total number of passengers (q_o), total consumer surplus (CS) and total airline and airport profits are in millions. ii) Social Welfare (SW) is in percentage change.

APPENDIX

TABLE A1 - AIRPORTS

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 A2 - TICKET PRICE ELASTICITY AND AIRPORT PRICE ELASTICITY

Airport	Ticket price elasticity	Airport price elasticity	Aeronautical price elasticity
ATL	1.73	0.0008	1.69
BWI	1.16	0.0003	0.9
IAD	1.70	0.065	1.68
IAH	2.45	0.0039	0.51
JFK	2	0.4367	0.38
MSP	1.55	0.052	1.43
ORD	1.99	0.024	0.56
SFO	2.3	0.0138	0.65
SCL	1.83	0.0002	1.90

TABLE A3 - PRICING UNDER A TWO-SIDED SETTING

	Pigouvian		**Profit Maximization**		$\boldsymbol{\lambda = 0.1}$		$\boldsymbol{\lambda = 0.2}$	
Airports	c_o^a	c_o^c	c_o^a	c_o^c	c_o^a	c_o^c	c_o^a	c_o^c
ATL	-996.34	997238.77	352127.58	-112294.75	-241.83	47873.35	-235.90	41197.14
BWI	5601.36	-895105.99	-2301872.68	200922.78	5865.36	-1684380.69	4935.22	-1468046.23
IAD	12295.76	-162468.03	-767918.52	69329.77	15223.89	-147645.09	12076.12	-122794.96
IAH	12183.63	-199237.64	-1994621.32	201172.21	10256.19	-159559.98	7766.70	-120080.85
JFK	18774.74	-56838.16	-2234894.04	56283.73	15486.35	-10365.06	11670.80	-7724.80
MSP	212091.21	-4112839.22	-19034054.44	2210817.47	-8435.00	89120.49	-6819.51	70414.44
ORD	4293.55	-9552198.71	-34868778.56	2309312.11	3063.95	-149782.70	2370.63	-114075.64
SFO	8122.45	-796205.42	-5247171.41	381735.86	6457.60	-203087.89	5117.20	-158747.94
SLC	-15825.76	18717912.94	1938012.73	-399104.12	-28502.01	84659377.96	-25275.76	75198045.87

	$\boldsymbol{\lambda = 0.3}$		$\boldsymbol{\lambda = 0.4}$		$\boldsymbol{\lambda = 0.5}$		$\boldsymbol{\lambda = 0.6}$	
Airports	c_o^a	c_o^c	c_o^a	c_o^c	c_o^a	c_o^c	c_o^a	c_o^c
ATL	-229.97	34520.93	27844.72	12292126.41	-218.12	21168.50	-212.20	14492.29
BWI	4005.07	-1251711.77	-1035377.31	-70456350.10	2144.79	-819042.85	1214.65	-602708.39
IAD	8928.35	-97944.84	-73094.72	-164668061.59	2632.81	-48244.59	-514.96	-23394.47
IAH	5277.22	-80601.72	-41122.59	-148417056.03	298.25	-1643.46	-2191.23	37835.67
JFK	7855.24	-5084.54	-2444.28	-77434084.71	224.12	195.98	-3591.43	2836.24
MSP	-5204.02	51708.40	33002.35	159370368.64	-1973.04	14296.31	-357.55	-4409.73
ORD	1677.32	-78368.57	-42661.50	-52330605.06	290.68	-6954.44	-402.63	28752.63
SFO	3776.80	-114407.99	-70068.04	-54609671.04	1096.01	-25728.09	-244.39	18611.86
SLC	-22049.51	65736713.79	56275381.70	591880136.13	-15597.01	46814049.62	-12370.76	37352717.54

	$\boldsymbol{\lambda = 0.7}$		$\boldsymbol{\lambda = 0.8}$		$\boldsymbol{\lambda = 0.9}$	
Airports	c_o^a	c_o^c	c_o^a	c_o^c	c_o^a	c_o^c
ATL	-206.27	7816.08	-200.34	1139.86	-194.42	-5536.35
BWI	284.51	-386373.93	-645.63	-170039.48	-1575.78	46294.98
IAD	-3662.73	1455.66	-6810.50	26305.78	-9958.27	51155.91
IAH	-4680.71	77314.80	-7170.19	116793.93	-9659.68	156273.06
JFK	-7406.99	5476.50	-11222.55	8116.76	-15038.11	10757.02
MSP	1257.94	-23115.78	2873.43	-41821.82	4488.93	-60527.87
ORD	-1095.95	64459.69	-1789.27	100166.76	-2482.58	135873.83
SFO	-1584.79	62951.81	-2925.18	107291.76	-4265.58	151631.71
SLC	-9144.51	27891385.45	-5918.26	18430053.37	-2692.01	8968721.28

TABLE A4 - MARGINAL COST AND MARGIN OF AIRLINES (BY AIRPORT)

Airport	Code	Ticket Fare (dollars)	Marginal Cost (dollars)	Margin (%)
Hartsfield-Jackson Atlanta International	ATL	57.46	33.15	49.01
Chicago O'Hare International	ORD	71.93	46.69	43.98
George Bush Intercontinental	IAH	85.26	58.99	39.55
Minneapolis-St.Paul International	MSP	58.43	33.02	54.22
John F.Kennedy International	JFK	98.53	73.34	36.23
San Francisco International	SFO	106.81	75.54	35.63
Salt Lake City International	SLC	81.59	58.25	37.01
Baltimore/Washington International	BWI	60.22	34.52	50.11
Dulles International	IAD	83.18	54.36	49.52
Average		78.16	51.99	43.91

TABLE A5 - MARGINAL COST AND MARGIN OF AIRLINES (BY AIRLINE)

Airline	**Code**	**Ticket Fare (dollars)**	**Marginal Cost (dollars)**	**Margin (%)**
American Airlines	AA	79.39	53.76	39.56
Alaska Airlines	AS	83.97	62.13	26.01
JetBlue Airways	B6	36.89	11.21	70.88
Continental Airlines	CO	83.63	54.11	47.39
Delta Airlines	DL	77.62	52.14	40.12
Frontier Airlines	F9	50.01	27.48	47.81
AirTran Airways	FL	42.70	19.08	59.14
America West Airlines	HP	77.47	54.11	38.33
Spirit Airlines	NK	47.22	23.91	53.42
Northwest Airlines	NW	68.85	40.12	48.31
Sky West Airlines	SY	32.41	8.77	75.12
United Airlines	UA	94.59	68.41	36.95
US Airways	US	71.06	44.65	41.91
Southwest Airline	WN	50.77	23.03	62.35
Midwest Airlines	YX	46.98	22.94	52.44