Determinants of Fares and Operating Revenues at U.S. Airports

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Abstract

Using data for 49 large U.S. airports from 1998 through 2002, we estimate how average fares, aeronautical revenues per passenger or per flight, and concession revenues per passenger, depend on factors relating to the demand for air transportation, to delays at the airport, and to the market environment in which the airports operate. We find that fares tend to be higher when competition between airlines at the airport is weaker, but find no effect of the presence of substitute airports on average fares. Aeronautical revenues per unit of output are lower, however, when substitute airports are available. Longer delays lead to lower aeronautical revenues when there are substitute airports, but when there is no substitute airport, longer delays are associated with higher aeronautical revenues.

Keywords: airports, airport revenues, airlines, air transportation, market structure, delays

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1. Introduction

This paper empirically investigates the dependence of average fares for flights out of U.S. airports, of airports' average aeronautical revenues per passenger or per flight, and of concession revenues per passenger, on the airports' market environment and on service quality. Service quality is measured by delays, which are partly the result of congestion. One question of interest is whether service quality is reflected in prices and whether this relation is affected by the degree of competition, as is suggested by theoretical work on competition between congestible facilities (cf. section two). More in general, we investigate the dependence of fares and charges on market characteristics at the airport level. This approach contrasts with much of the literature on the airline industry, which focuses on airlines rather than airports, and on fares but not airport charges.

The empirical work is guided by a view of the airline industry as one where airlines and airports provide complementary services that jointly produce transport between cities or regions. Airlines compete in an oligopoly, and airports are the single or one of several providers of egress from, and access to, a city or region. In a number of cases airlines and airports effectively are vertically integrated, and this may affect the level and structure of airport revenues as well as airports' decisions. Such constraints on airports' independence, and the fact that it is not clear whether airport behavior is well described by assuming profit maximization, may lead to a weaker impact of market structure on airport prices than on airline fares. One of the goals of the analysis is to find out whether airport charges nevertheless respond to market conditions in ways similar to fares. In doing so, we distinguish between aeronautical revenues and concession revenues.

The econometric approach is to estimate a system of equations in which the average fare for departing from an airport, the aeronautical charge per passenger or per flight, the concession revenue per passenger, the number of departing flights, delays, and passenger demand are the endogenous variables. Indicators of market demand, of market structure, and of capacity are treated as exogenous, and we take into account that in hub airports passenger volume is only partially related to demand for travel to or from the region in which the airport is located. The system is estimated on annual data for 49 large U.S. airports from 1998 through 2002.

We find that average fares at an airport are not lower in the presence of a nearby airport that provides service to a similar set of destinations, but aeronautical revenues per unit of output are. Longer average delays at an airport do not lead to lower fares at that airport, but aeronautical charges are higher, unless there are substitutes for the airport (in which case the elasticity of aeronautical revenues with respect to delays is approximately -0.7). There also is evidence that delays are longer at airports for which there are substitute airports. Other results are largely in line with expectations. With respect to fares, we find that increased airline concentration at an airport leads to higher fares, except when Southwest Airlines is the largest carrier at that airport. Hub fares are lower than non-hub fares, and fares at slot-constrained airports are higher. Aeronautical charges per passenger are found to decline with the number of departures and the number of destinations offered, and they are higher if the airport is located in a high-income area. Being a slot-constrained airport and having a large share of international passengers increases average charges. Increased airline concentration, however, reduces charges, maybe because dominating airlines capture part of the airport surplus. The effect is weaker when Southwest Airlines is the largest carrier at the airport. Concession revenues per passenger are higher at airports not dominated by Southwest Airlines, where there is airport competition, and where there are a lot of international passengers. Airline concentration affects concession revenues negatively. Hubs make less concession revenue per passenger, because fewer passengers require rental car and parking services.

The rest of the paper is structured as follows. Section two discusses the role of airports in U.S. air transportation, and connects our research to various strands of literature. Section three discusses data and summary statistics, and section four provides detail on the estimation. Concluding comments are in section five.

2. Context and literature

Large U.S. airports are publicly owned,[1] and provide services for commercial aviation (large carriers, air taxis and commuters) and for general and military aviation. This paper focuses only on commercial aviation, which generates most revenues and represents the majority of output at large airports (U.S. DOT 2003b). Airports make revenues from aeronautical services but also, and to a large and increasing extent, from concessionary services like retail shops, parking and rental car services.

The overall airport revenue structure is as follows. Concession revenue represents slightly more than half of total airport revenue on average, but its share dropped with the slump in travel in 2001 and especially 2002. Aeronautical revenue consists mainly of landing fees and terminal rents (84% combined). Rental fees are likely to be the subject of contracts between carriers and airports, so the response to market shocks may be slow and possibly also limited. Concession revenue consists for nearly 25% of revenues from terminal businesses, and 20% comes from rental car activities; the single largest source of concession revenue is parking (39.1%). Variations across airports in the revenue structure are large. This may be related to business strategies, to local conditions, or to accounting practices, neither of which are captured in the explanatory data. For this reason, and because accounting conventions for some subcategories changed between 1998 and 2002, the econometric analysis will refer to the aggregate revenue sources, aeronautical and concession revenue, where idiosyncratic variation hopefully is less of a problem.

While airlines have been in a nearly constant state of turmoil since deregulation in 1978, airports' financial performance has been more stable. This is partly explained by the fact that the demand for airport services is less volatile than that for air transportation, because there are fewer substitutes for airports. Another explanation may be that long run contracts between airlines and airports have partly shielded airports from revenue risk related to fluctuating demand. It has indeed been the business model of many large airports to rely on revenue generated by one or a few large carriers, and to let airlines assume financial risk. The cost of this type of vertical integration for the airport is that it

[1] 63.9% of commercial service airports are owned by a local government, the rest by a single purpose authority (FAA/OST, 1999).

gives up some control, with some cases where an airline effectively controls the airport (possibly including decisions on capacity expansion, through "majority in interest clauses" as well as access to current capacity). There are indications that the control of airports by airlines is becoming smaller: the share of exclusive use gates at large airports is declining (FAA/OST, 1999), and "hub premia" are declining (Borenstein, 2005). One reason may be that airport authorities have begun to seek more independence, through the adoption of more flexible agreements between carriers and airports.[2] Other reasons are the rising market share of low cost carriers, because of which legacy carriers' hub airports face more uncertainty, and the increased use of regional jets (with 50 to 70 seats) instead of mainline jets (with more than 110 seats), which leads to more aircraft operations for the same amount of passengers.[3] These changes have been underway since the 1990s, but were intensified by the demand shock in 2001. The frequent bankruptcies of large carriers render reliance on a small number of large carriers especially risky. The most extreme example is the announcement of U.S. Airways after its emergence from bankruptcy that it would renege on its contracts with Pittsburgh airport, unless substantial charge reductions were allowed.

Against this background, it is relevant to analyze current relations between market characteristics, service quality, fares and revenues at the level of an airport. While the focus on airports is unusual, our work is closely related to part of the literature on airline competition. One strand of the literature (e.g. Borenstein, 1989, Berry, 1990, Morrison and Winston, 1989, and Berry, Carnall and Spiller, 1997) studies of the effect of airport dominance on fares. A general finding is that a larger airport presence increases the value of an airline at an airport, and this leads to higher fares. Recent work suggests that the effects of airport dominance are different when substitute airports exist. Borenstein (2005) provides evidence that the presence of a nearby substitute airport may reduce the impact of airport dominance on airfare. Morrison (2001) shows that the presence of, in particular, Southwest at a nearby airport reduces fares. The connection between market

[2] Passenger Facility Charges, introduced in 1990, were designed to provide airports with a source funds for infrastructure expansion that is not airline specific. Hartmann (2002) finds that increased flexibility in the arrangements between airports and airlines positively affects airlines' probability of offering a non-stop airport connection, keeping service characteristics (including prices) exogenous.

[3] There were 9 regional jets in 1993, and 976 in 2002. The increase in per passenger airport costs associated with the increased use of regional jets may be particularly large when regional jet operations are concentrated in peak hours (as is the case according to U.S. DOT 2003b), so exacerbating congestion.

concentration and quality of service (delays) has been investigated as well. Mazzeo (2003) finds that on-time performance is worse on concentrated routes. Januszewski (2003) finds that longer delays lead to lower prices, but more so when substitute flights at the same or a nearby airport are available. Theoretical work on competition between congestible facilities, like airports, suggests that oligopolies may provide less quality (e.g. in the form of longer delays), at lower prices, than a monopoly (Van Dender, 2005; De Borger and Van Dender, 2005).

3. Data and summary statistics

In constructing the dataset, we assume that most trips are round trips, and focus on an airport's role as a trip origin.[4] The airports' market environment is described by variables that affect passenger demand for departures from the airport and by variables capturing the market structure, for example airline concentration at the airport and the presence of substitute airports. We also take account of arrival and departure delays, as indicators of congestion, or more generally of the quality of service provided by the airport.

Table 1 provides variable labels and a brief description of the variables used in the empirical analysis. The variables are defined at the level of an airport for all years from 1998 through 2002. Prices are in constant dollars of 2000, and italics indicate that logarithms are used in the estimation. Detailed on data sources is in Appendix 1. Table 2 shows descriptive statistics, using natural units instead of logs.

It should be noted that explanatory variables are defined in different dimensions. Socio-demographic variables are defined for the geographical location of the airport, neglecting the characteristics of destinations that are reached from that airport. Fares are defined on the level of a flight from a passenger's origin to her destination; given the hub-spoke structure of many airlines' networks, such flights often consist of more than one segment. In contrast, variables relating to air traffic are from the T-100 data bank, which implies that they are defined at the level of a flight segment

[4] The assumption implies symmetry between origin- and destination-based analyses. Comparisons of origin- and destination-based regressions with earlier models suggest that the assumption is reasonable. Note that we focus on the number of departing passengers as a measure of output, not flights or seats.

Table 1 Variables with brief explanation

1. %dom_pass:	the share of passengers departing for a domestic airport
2. aero_rev:	aeronautical revenue per passenger
3. airportfare:	average fare for flights departing from the airport
4. airtime:	average segment time out of the airport
5. all_del:	average total delay at the airport
6. arr_del:	average arrival delay at the airport
7. capacity:	passenger capacity, approximated by highest passenger volume
8. cluster:	airport is close to, and assumed to be a substitute for, one or more other airports
9. competition:	index of destination overlap if cluster=1, otherwise 0
10. conc_rev:	concession revenue per passenger
11. departures:	flight segments departing from the airport
12. dep_del:	average departure delay at the airport
13. destinations:	number of segment destinations served from the airport
14. distance:	average distance for segments departing from the airport
15. freight:	volume of air cargo out of the airport
16. freight_hub:	airport is a cargo hub for an airline (1) or not (0)
17. hhi:	Herfindahl concentration index for airlines serving the airport
18. hub:	airport is a passenger hub for an airline (1) or not (0)
19. income_cap:	income per capita in the metropolitan area where the airport is located
20. overlap:	degree to which airlines serve the same destinations from the airport
21. passengers:	number of passengers departing on segments from the airport
22. population:	population size in the metropolitan area where the airport is located
23. slot_constr:	airport is slot constrained (1) or not (0)
24. WN or not:	legacy carrier (AA, CO, DL, NW, UA, US) (1), Southwest (0)

Table 2 shows that the average airport in the sample has 9.4 million passengers that use it as an origin (if all trips are symmetrical roundtrips, there will be 18.8 million passengers per year); airports like Baltimore-Washington Intl, Pittsburgh Intl and Salt Lake City Intl. are of this average size. The smallest airport is Tucson Intl airport in Arizona, with 1.5 million departing passengers. The largest one is William B. Hartsfield airport in Atlanta, where 40 million passengers depart per year. The mean fare in the dataset is $161; mean fares for departing from an airport range from $83 to $243. Aeronautical revenue and concession revenue per departing passenger both are around $7.7. Of all airports in the dataset, 42% are in a cluster (i.e. a substitute airport is assumed to exist), and 41% function as network hubs (cf. Appendix 1 for lists of airports in clusters and hub airports). The concentration index is 30% on average, but ranges from 8% to 96%. Most airport serve mainly domestic travelers. Only JFK has more international travelers than domestic travelers; at MIA the distribution is 50/50. The average flight distance out of an airport is 759 miles. Standard deviations for some key variables are large, indicating considerable heterogeneity between airports and across time.

Table 2 Descriptive statistics – variables in natural units, 245 obs.[5]

		Mean	Std. Dev.	Min	Max
%dom_pass	%	0.929	0.115	0.432	1.000
aero_rev	millions $	7.658	4.917	1.542	32.906
airportfare	$	160.956	35.392	82.558	242.810
airtime	hours	2.370	0.753	1.002	4.471
all_del	minutes	14.774	6.001	1.212	37.615
arr_del	minutes	6.516	3.366	-0.565	19.032
capacity	passengers	10,100,000	8,747,591	1,791,002	39,800,000
cluster	dummy	0.422	0.495	0.000	1.000
competition	truncated	0.275	0.328	0.000	0.890
conc_rev	millions $	7.788	3.325	3.121	24.502
departures	#	45,977	47,961	3,502	232,117
dep_del	minutes	8.258	2.744	1.778	18.583
destinations	#	69.426	47.590	10.000	195.000
distance	miles	759.346	299.274	277.167	2,043.197
freight	million tons	205	378	2	1,730
freight_hub	dummy	0.040	0.197	0.000	1.000
hhi	index	0.296	0.190	0.078	0.961
hub	dummy	0.406	0.492	0.000	1.000
income_cap	$	32,562	5,004	23,382	47,139
overlap	index	0.297	0.184	0.074	0.970
passengers	#	9,424,663	8,289,715	1,558,340	39,800,000
population	#	5,336,389	5,814,527	336,225	21,700,000
slot_constr	dummy	0.080	0.272	0.000	1.000
WN or not	dummy	0.618	0.487	0.000	1.000

The following time patterns are noteworthy. Average passenger numbers increase from 1998 to 2000, and drop by more than 600,000, or nearly 7%, in 2001 and 2002, because of the business cycle and because of 9/11. The number of departures and average delays follow the demand pattern, although there seems to be a lag in the response (departures only drop strongly in 2002). Average fares are around $166 in 1998-2000, and fall to ca. $150 afterwards. However, total aeronautical and passenger-based revenue are of the same order of magnitude on average, so that airport revenues per

[5] For the variables calculated from T-100 data, the statistics shown are based on all flights included in the raw data. The estimation results shown later are based on these variables. One concern is that these data imply high occupancy levels (205 passengers on average) and high destination counts. More realistic occupancy levels and destination counts are obtained when low frequency flights are excluded from T-100. For example, when only flights are included that depart at least 20 times per month, the average occupancy rate is 87, and the average number of destinations is 16. The models have been estimated with these data as well, and the results are virtually identical.

passenger show an increase after the demand shock.[6] In the econometric model, we have experimented with separate estimations for 1998-2000 and 2001-2002. Results which are of central interest here are not affected. In the results presented here, the time dimension is handled by the inclusion of year dummies.

A distinction can be made between airports on the basis of the type of airline that has the largest market share for departing passengers at that airport: Southwest, and legacy carriers. The classification is useful, as there are some notable differences between the groups.[7] As expected, fares are lower at Southwest airports than at other ones. On average, aeronautical revenue per passenger is a bit larger in legacy airports than in Southwest airports, but concession revenue is the same. Southwest uses smaller airports with fewer destinations and shorter average segment distances, and the airports serve nearly exclusively domestic passengers; these characteristics suggest that the airports have lower costs, but it could also be the case that Southwest requires fewer services or negotiates lower prices. Only 10% of Southwest airports are hubs, against 60% for legacy airports. Southwest airports and legacy airports are similar in terms of service quality (delays) and in the degree of concentration. In the econometric model, all airports are pooled, but some explanatory variables are interacted with a dummy variable indicating the type of airport, or airline fixed effects are included.

3. Specification and estimation results

The economic model contains six endogenous variables, all expressed in logarithms: (1) the average fare for a flight departing from an airport in a given year (*airportfare*), (2) aeronautical revenue per passenger (*aero_rev*), (3) concession revenue per passenger (*conc_rev*), (4) the number of passengers using an airport as a flight

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[6] Closer inspection confirms that airport revenues do not follow the pattern of demand over time: aeronautical revenue keeps increasing, and passenger spending at the airport only falls slightly in 2002. Airport revenue seems less sensitive than fares to fluctuations in demand for air transportation. A potential explanation is that contracts between airlines and airports fulfill their purported role of reducing risks for airport (in exchange for reduced airport control by the airport management, as well as potentially anti-competitive effects in allocating airport access.)

[7] Alternative airport classifications are possible: hub versus non-hub airports, and medium size versus large airports. Network hub status is indicated by a dummy variable that equals one for airports that are generally thought to be some carrier's hub. Large and small airports are distinguished on the basis of the administrative distinction between large and small hubs. By and large, these groupings are similar to the one discussed in the text, in the sense that many airports dominated by legacy carriers are hub airports and many hub airports are large airports. By contrast, Southwest focuses on smaller non-hub airports.

segment origin per year (*passengers*), (5) the number of flight segments departing from an airport per year (*departures*), (6) average delay of flight segments at the airport per year (*all_del, arr_del or dep_del*). Endogeneity is accounted for through the use of a 2SLS estimator, where the instruments are given by the reduced form of the structural model defined below.[8]

The first three equations intend to capture the effect of market characteristics on the average prices that passengers and airlines pay for using an airport. First, the average fare depends on demand, which is endogenous, and on the degree of competition between airlines at the airport as well as between airports, and on average delays. The indicators of competition are airline concentration at the airport, and the overlap between destinations offered by different airlines. Dummy variables allow for differences between hub and non-hub airports, between airports that are slot-constrained and those that are not, and between small and large airports. Year and airline fixed effects are included as well.

Second, aeronautical revenues per passenger, or per departing flight, are regressed on a set of variables representing the volume of services provided (departures instead of passengers, and freight), and on similar indicators of the degree of competition at the airport and between airports. The share of domestic passengers is included as well, as earlier research has shown that costs and revenues are higher for international passengers (Oum and Yu, 2004).

Third, concession revenues are explained by similar variables, where passenger volumes are used instead of the number of departures, as spending in concessions is driven by the number of passengers rather than the number of flights.

The fourth equation estimates market demand for passenger departures from an airport, as a function of local income and population. Hub status is included because hub airports serve passengers for whom the airport is not the travel origin or destination. The cluster dummy is included to check if passenger demand at an airport is negatively affected by the presence of one or more substitute airports. The number of *flight* departures, an explanatory variable in the aeronautical revenue equation, is itself

[8] We prefer 2SLS over 3SLS because the non-price equations are intended as controls rather than well-specified equations. However, the 2SLS and 3SLS results are nearly identical, and they differ somewhat from OLS results.

explained by passenger loads, distance and network hub status. Finally, delays are endogenous. The explanatory variables are passenger volumes, capacities (as approximated by the maximum passenger volume for the airport between 1998 and 2002), and a dummy variable indicating whether there are substitutes for the airport or not. The model can be estimated to obtain similar results using either arrival delays, departure delays, or the sum of these two ("all delays"), but not with arrival and departure delays separately. The full structural form of the model is as follows, where italics indicate logarithms and endogenous variables appearing on the right-hand side are underlined:

(1) *airportfare* = *airportfare* (*passengers*, hhi, hhi*(WN or not), overlap, hub, competition, *all_del**competition, *all_del*, *distance*, slot_constr, hubsize, year dummies, airline dummies, constant)

(2) *aero_rev* = *aero_rev* (*departures*, *freight*, destinations, hhi, hhi*(WN or not), hub, competition, *all_del**competition, *all_del*, *income_cap*, *income_cap**(WN or not), freight_hub, %dom_pass, *distance*, slot_constr, before and after 2000, airline dummies, constant)

(3) *conc_rev* = *conc_rev* (WN or not, cluster, *passengers*, hub, hhi, hhi*(WN or not), *income_cap**(WN or not), *income_cap*, *all_del*, *airtime*, %dom_pass, year dummies, constant)

(4) *passengers* = *passengers* (*airportfare*, *income_cap*, *population*, *distance*, hub, *destinations*, cluster, year dummies, constant)

(5) *departures* = *departures* (*passengers*, *distance*, hhi, hub, *destinations*, constant)

(6) *all_del* = *all_del* (*passengers*, *capacity*, competition, hhi, hub, slot_constr, constant) – alternatively, *arr_del* and *dep_del* can be used

The specification neglects a range of possible endogeneities. For example, airport capacities and airline concentration are treated as exogenous variables, and the delay equations approximate a technical relationship, but abstract from service quality as decision variables except through the inclusion of the cluster dummy variable. Also, many variables are crudely measured (e.g. hub status, dominance of an airport by a carrier), and all of them are aggregated to the airport – year level. Lastly, potentially important explanatory variables, like vertical relations between airlines and airports, are not directly measured but hopefully are captured in fixed effects instead. Nevertheless, a number of effects are plausible and precisely estimated, and they are not heavily dependent on the precise specification. We discuss those results next.

Table 3 **Estimation results, 2SLS, by airport type: airportfare equation, concession revenue equation, and aeronautical revenue equation**

Table 3a **Airport fare equation**

airportfare; R-sq. = 0.788	Coef.	Std. Err.	t
passengers	0.006	0.021	0.300
hhi	-0.756	0.124	-6.100
hhi*(WN or not)	1.222	0.121	10.140
overlap	0.044	0.098	0.450
hub	-0.101	0.037	-2.730
competition	-0.406	0.448	-0.910
all_del *competition	0.165	0.175	0.940
all_del	0.032	0.107	0.300
distance	0.175	0.037	4.680
slot_constr	0.134	0.033	4.060
hubsize	-0.033	0.031	-1.040
D1999	0.015	0.022	0.680
D2000	0.054	0.034	1.590
D2001	0.030	0.029	1.050
D2002	0.045	0.059	0.760
WNdum	0.052	0.044	1.180
UAdum	0.028	0.033	0.850
COdum	0.093	0.043	2.180
NWdum	0.033	0.050	0.660
DLdum	-0.142	0.036	-3.950
USdum	0.079	0.048	1.670
constant	3.700	0.377	9.810

Table 3b.1 **Aeronautical revenue per passenger**

aero_rev ; R-sq. = 0.483	Coef.	Std. Err.	t
departures	-0.262	0.112	-2.330
freight	0.131	0.060	2.200
destinations	-0.005	0.002	-3.180
hhi	0.040	0.477	0.080
hhi*(WN or not)	0.707	0.461	1.540
hub	0.132	0.134	0.990
competition	5.065	2.521	2.010
all_del *competition	-1.999	0.973	-2.050
all_del	0.609	0.339	1.800
income_cap	-0.265	0.295	-0.900
income_cap *(WN or not)	1.320	0.388	3.410
freight_hub	0.578	0.198	2.920
%dom_pass	-1.015	0.638	-1.590
distance	0.154	0.190	0.810
slot_constr	0.803	0.130	6.180
before and after 2000	0.126	0.099	1.270
WNdum	13.465	3.977	3.390
UAdum	-0.190	0.140	-1.350
COdum	0.400	0.159	2.510
NWdum	-0.417	0.216	-1.940
DLdum	-0.374	0.155	-2.410
USdum	-0.361	0.227	-1.590
constant	-10.017	3.563	-2.810

Table 3b.2 **Aeronautical revenue per departing flight**

aero_rev ; R-sq. = 0.791			
departures	-0.380	0.111	-3.410
freight	0.101	0.059	1.710
destinations	-0.004	0.002	-2.180
hhi	-1.743	0.473	-3.680
hhi*(WN or not)	0.439	0.456	0.960
hub	0.074	0.132	0.560
competition	5.263	2.498	2.110
*all_del*competition*	-2.059	0.964	-2.130
all_del	0.708	0.336	2.110
income_cap	-0.340	0.293	-1.160
income_cap(WN or not)*	0.570	0.384	1.480
freight_hub	0.441	0.196	2.250
%dom_pass	-1.799	0.632	-2.850
distance	0.222	0.188	1.180
slot_constr	0.832	0.129	6.460
before and after 2000	0.081	0.098	0.820
WNdum	5.541	3.942	1.410
UAdum	-0.018	0.139	-0.130
COdum	0.281	0.158	1.780
NWdum	-0.427	0.214	-2.000
DLdum	-0.119	0.154	-0.780
USdum	-0.270	0.225	-1.200
constant	6.302	3.531	1.780

Table 3c **Concession revenue per passenger**

conc_rev ; R-sq. = 0.611	Coef.	Std. Err.	t
WN or not	7.046	2.454	2.870
cluster	0.202	0.054	3.750
passengers	-0.146	0.048	-3.030
hub	-0.235	0.070	-3.340
hhi	-0.982	0.180	-5.450
hhi*(WN or not)	0.058	0.273	0.210
income_cap *(WN or not)	-0.682	0.237	-2.870
income_cap	0.442	0.188	2.350
all_del	0.232	0.131	1.770
airtime	-0.230	0.094	-2.460
%dom_pass	-1.405	0.227	-6.180
D1999	-0.018	0.052	-0.340
D2000	-0.071	0.068	-1.050
D2001	0.133	0.060	2.220
D2002	0.178	0.106	1.680
constant	2.725	1.953	1.390

Table 3a shows that the average fare increases with the degree of airline concentration, when the largest carrier at an airport is a legacy carrier (elasticity estimate of -0.756 + 1.222 = 0.466). But when Southwest Airlines is the biggest airline at the airport, more concentration leads to lower fares (elasticity of -0.756). Fares increase with distance (because of costs), and are higher at slot-constrained airports. All else equal, departing from a hub airport is cheaper than from a non-hub airport, maybe because hub economies are translated in lower fares. Delays and airport competition are included as explanatory variables, once as such and once in their interacted form. We find no effect, however, of any of these variables on the average fare charged at an airport. The absence of airport competition effects may mean that airports are weaker substitutes than is assumed here (despite evidence to the contrary in Ishii et al., 2005), or that airline competition in itself keeps fares low and there is no extra effect of nearby airports. A further possibility is that airlines use the different airports to differentiate products, and no negative price effect exists on the level of the airport cluster. With respect to the effect of delays, we note that earlier work, on a more disaggregate level, has established that delays affect fares and that the effect is different depending on the degree of competition at and between airports (Januszewski, 2003; Mazzeo, 2003). We hypothesize that such effects are too small to be visible in our aggregated fare variable.

Next, consider the equation explaining aeronautical revenue per departing passenger (Table 3b.1) and per departing flight (Table 3b.2). The overall explanatory power is weaker than for the fare equation when the dependent variable is aeronautical revenue per passenger, but the equation performs better when aeronautical revenue per departure is used instead, and both equations indicate similar effects. We highlight some results. First, revenues per flight and per passenger decline with volume. Second, freight hubs (of which there are two: Louisville and Memphis) have relatively high aeronautical revenue per passenger, and to a lesser extent also per flight. This reflects that the freight share of total traffic is high at these airports. Third, high incomes lead to higher aeronautical revenue per passenger for airports where a legacy carrier dominates (maybe because of higher input prices, hence higher costs), but the effect is weaker at Southwest-dominated airports. Fourth, a high share of international passengers and slot constraints lead to high aeronautical revenues.

We find that aeronautical revenues, measured per passenger or per flight, are lower in the presence of airport competition (for per passenger revenues, the estimated elasticity is 5.065-1.999*2.69 = -0.31; for per flight revenues, it is 5.263-2.059*2.69 = -0.28). The effect of delays is negative as well in the presence of airport competition, with point estimates of elasticities of 0.609-1.999*0.67 = -0.73 for revenues per passenger, and 0.708-2.059*0.67 = -0.67 for revenues per departing flight (where the latter is more precisely estimated). Note, however, that when there is no airport competition, delays lead to higher aeronautical revenues per flight (elasticity of 0.7). Since delays are higher when there is a nearby substitute airport (see below), one possible interpretation is that competition leads to lower quality at lower prices (an effect also described in theoretical work on the subject).

With respect to concession revenue per passenger, we find that it is much a higher at airports dominated by a legacy carrier. It also is higher in clustered airports (possibly an income effect not captured by the local income variable), and it declines with the volume of passenger passing through the airport. Note that income itself leads to higher concession revenues when Southwest is the largest carrier, but to lower incomes when legacy airlines dominate. One interpretation is that legacy carriers choose to concentrate their (hub) operations where incomes are relatively low. Southwest dominated airports are likely to be in high income areas, as Southwest mainly seeks to be present in dense (high income) markets.

Hub airports make less concession revenue per passenger, which is at least partially explained by the fact that connecting passengers do not require parking and rental car services, which are the major sources of concession revenue. Higher airline concentration at an airport leads to lower concession revenues, which may indicate that airlines capture part of the airport surplus when they dominate the airport. A high share of international travelers increases per passenger concession revenue. International passengers tend to arrive at the airport longer before departure than domestic passengers, and may fill the additional waiting time by increased spending.

Lastly, concession revenue per passenger is lower as passenger volumes rise. The reason may be that the larger airports have a larger share of regular travelers, who need to spend less on concession services or are better informed about more attractive off-airport services, or the large number of passengers may reflect hub functions that are imperfectly captured in the hub dummy..

Table 4 **Estimation results, 2SLS, by airport type: passenger volume equation, departures equation and delay equations**

Table 4a **Passenger volume equation**

passengers ; R-sq. = 0.835	Coef.	Std. Err.	t
airportfare	-0.788	0.167	-4.720
income_cap	0.556	0.194	2.870
population	0.152	0.038	4.040
distance	0.457	0.085	5.370
hub	0.199	0.073	2.740
destinations	0.013	0.001	15.750
cluster	-0.225	0.084	-2.690
D1999	0.007	0.068	0.100
D2000	0.005	0.069	0.080
D2001	-0.153	0.069	-2.200
D2002	-0.324	0.071	-4.560
constant	7.871	1.974	3.990

Table 4b **Number of departures**

departures *;* R-sq. = 0.939	Coef.	Std. Err.	t
passengers	1.009	0.045	22.190
distance	-0.230	0.077	-3.000
hhi	2.199	0.123	17.840
hub	0.148	0.062	2.380
destinations	0.000	0.001	-0.480
constant	-4.810	0.695	-6.920

Table 4c **Average total delays**

all_del ; R-sq. = 0.056	Coef.	Std. Err.	t
passengers	4.682	0.601	7.790
capacity	-4.530	0.600	-7.550
competition	0.170	0.098	1.730
hhi	0.152	0.174	0.870
hub	-0.003	0.097	-0.030
slot_constr	-0.198	0.119	-1.650
constant	0.461	0.902	0.510

We now briefly discuss the equations explaining quantity demanded, the number of departures, and the sum of arrival and departure delays at each airport. According to the demand equation, the elasticity of demand for flight *segments* with respect to flight *fares* is -0.8.[9] The equation also indicates that airports in more populated areas and with higher incomes[10] transport more passengers, as do hub airports and airports serving many destinations. Note that the cluster dummy, indicating the presence of substitute airports, has a clear negative effect on passenger volumes.[11]

The departures equation finds that more passengers lead to proportionally more departures. Airport concentration also leads to more departing flight segments, as does hub status. Interestingly, when departures are measured only for segments that are served relatively frequently (at least twenty departures per month), the coefficient on the passengers variable falls to 0.85, suggesting that in denser markets the relation between passenger volume and flight departures is less than proportional (but leads to higher occupancy rates instead).

The delay equation suggests that volume-capacity ratios positively affect arrival and departure delays (this is the case for arrival delays, departure delays, and all delays). The airport competition variable is insignificant, but replacing it with the cluster dummy variable leads to a significantly positive estimate on that variable (elasticity of 0.12 with t-statistic of 1.98). This suggests that delays are longer at airports for which substitutes exist. One interpretation is that in multiple airport areas, the ratio of traffic volumes to capacity is higher than elsewhere because of high demand. Another interpretation is that the presence of competition tends to negatively affect service quality (but also leads to lower prices, at least for airlines).

[9] Estimating the model separately for airport types shows that for Southwest dominated airports, the elasticity is very high and significant (around -1.2), while for legacy carrier dominated airports, it is indistinguishable from zero.

[10] Estimating the same equation separately for hubs and non-hubs clarifies that demand increases with income and with distance at non-hubs, but not a hub airports.

[11] Here too, we find that airport competition affects demand at non-hubs, but not at hubs (as is found in the estimates for those groups).

5. Summary and conclusion

The results of the econometric analysis are largely in line with expectations. The qualitative effects of variables describing market structure and market demand affect fares and airport revenues per passenger are conform to theory, and the size of the effects is reasonably and precisely estimated for a number of them. Noteworthy results are that the effect airline concentration on airport fares is positive, except when most passengers flying out of the airport with Southwest airlines. When an airport is close to another airport, aeronautical revenues (but not fares) are likely to be lower. Delays are associated with higher aeronautical revenues at airports outside clusters, but the effect is negative when substitute airports are available. There also is evidence that delays are longer when substitute airports are available. Concession revenues per passenger are clearly lower at hub airports, however, because connecting passengers do not use rental car and parking services.

There are obvious shortcomings to the analysis. A clearer and more precise picture of the determinants of U.S. airport operating revenues requires at least two improvements. First, the flight and passenger services that the airports provide could be disaggregated. In this paper, all services are defined at the airport, but segment services can also be defined in terms of airport pairs per airline, and average fares can be disaggregated to destinations. This disaggregated approach approximates travel markets more closely, and is therefore likely to yield more precise and additional insights. Second, better indicators of the vertical relations between airports and airlines could be constructed. The current analysis assumes that those vertical relations tend to differ between Southwest airports and legacy airports. While this distinction turns out to be useful, more precise indicators (of, for example, gate assignment practices) are likely to be more informative.

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Appendix 1 Data sources

The data cover 60 medium and large hub airports in the U.S. from 1998 to 2002. It is obtained by merging aggregated versions of the following basic sources:

- Form 127 of airports' financial reports ('CATS reports'), downloadable from http://cats.crownci.com/reports/Reports.cfm?insideApp=Yes, for years 1996 to 2004. The reports summarize the revenues, expenditures, proceeds, investment expenditures, and debt payments of more than 400 US airports. Revenues are described in most detail, including distinctions between subcategories of aeronautical operating revenue, non-aeronautical operating revenue, and non-operating revenue. The data are in the form of yearly aggregates.
- The T-100 segment data, which supply information on domestic and international flight segments by U.S. and foreign air carriers, by air carrier, by origin and destination airports, and by service class, for enplaned passengers, freight, and mail. These data are at: http://www.transtats.bts.gov/Tables.asp?DB_ID=110&DB_Name=Air%20Carrier%20Statistics%20%28Form%2041%20Traffic%29&DB_Short_Name=Air%20Carriers.
- The airline on-time data, containing per-flight delay indicators. These data contain a smaller number of airports than the other datasets, being roughly limited to the medium and large hubs. They are at http://www.transtats.bts.gov/Tables.asp?DB_ID=120&DB_Name=Airline%20On-Time%20Performance%20Data&DB_Short_Name=On-Time.
- Airfare data from the airport competition plans (http://ostpxweb.dot.gov/aviation/index.html), which contain (among others) average fares per carrier per airport, for years 1998-2002. These data are derived from the DOT's origin and destination survey.

Variables describing characteristics of the metropolitan area in which an airport is located were obtained from http://www.bea.gov/bea/regional/data.htm. For these variables, 2004 data are extrapolated using 1996-2003 data.

- Dollar values were converted to 2000 prices using the CPI for urbanized areas.

I combine these basic sources as follows. First, only large and medium hub airports within the 50 states plus the District of Columbia are retained. This means that at most 73 airports can be observed for 9 years, i.e. there are 657 potential observations.

The Form 127 data are merged with the T-100 and the On-Time data, after aggregation of the latter two datasets by airport. As both T-100 and On-Time data are on a flight basis, the aggregation can be done by origin or by destination airport. I carried out both, but have only used the origin-based aggregation up to now (early experiments comparing origin- and destination-based aggregations showed little difference). Before the aggregation took place, a Herfindahl index describing airline concentration at the airport as well as some weighted averages were calculated on the airport level; in addition the passenger share of the largest carrier was retained for each airport. These data were merged with the fare data from the airport competition plans (leading to loss of observations for 1996, 1997, 2003 and 2004).[12] Ultimately 5 x 58 = 290 observations remain.

[12] This loss of time series variation is outweighed by the gain of having a relatively accurate measure of the fare variable. Without a good fare variable, the estimation of (in particular) the passenger volume equation is problematic. (Essential for a good fare variable on the airport level is that it reflects fare variation over carriers, since carrier presence strongly varies over airports. Short of that, it is not very different from a distance variable.)

The following table lists the airports in the dataset, and indicates their hub status and whether they are in a cluster or not. The clusters are as follows: {(SFO, SJC, OAK), (LAX, BUR, ONT, SNA), (FLL, MIA), (DFW, DAL), (IAH, HOU), (IAD, DCA, BWI), (ORD,MDW), (LGA, EWR, JFK), (BOS, MHT, PVD)}

airport	code	acluster	hub	airport	code	acluster	hub
ALBUQUERQUE INTL	ABQ	0	0	ORLANDO INTL	MCO	0	0
WILLIAM B HARTSFIELD	ATL	0	1	MEMPHIS INTL	MEM	0	1
AUSTIN-BERGSTROM INTL	AUS	0	0	MIAMI INTL	MIA	1	1
BRADLEY INTL	BDL	0	0	MINNEAPOLIS-ST PAUL INTL	MSP	0	1
NASHVILLE INTL	BNA	0	0	NEW ORLEANS INTL	MSY	0	0
GENERAL EDWARD LAWRENCE LOGAN	BOS	1	0	OAKLAND INTL	OAK	1	0
BURBANK-GLENDALE-PASADENA	BUR	1	0	EPPLEY AIRFIELD	OMA	0	0
BALTIMORE-WASHINGTON INTL	BWI	1	0	ONTARIO INTL	ONT	1	0
CLEVELAND-HOPKINS INTL	CLE	0	1	CHICAGO O'HARE INTL	ORD	1	1
CHARLOTTE/DOUGLAS INTL	CLT	0	1	PALM BEACH INTL	PBI	1	0
PORT COLUMBUS INTL	CMH	0	0	PHILADELPHIA INTL	PHL	0	1
DALLAS LOVE FIELD	DAL	1	1	PITTSBURGH INTERNATIONAL	PIT	0	1
RONALD REAGAN WASHINGTON NATIONAL	DCA	1	0	RALEIGH-DURHAM INTL	RDU	0	0
DALLAS/FORT WORTH INTL	DFW	1	1	RENO/TAHOE INTL	RNO	0	0
DETROIT METRO WAYNE	DTW	0	1	SOUTHWEST FLORIDA INTL	RSW	0	0
NEWARK INTL	EWR	1	1	SAN DIEGO INTL	SAN	0	0
FORT LAUDERDALE/ HOLLYWOOD INTL	FLL	1	0	SAN ANTONIO INTL	SAT	0	0
WASHINGTON DULLES INTERNATI	IAD	1	1	LOUISVILLE INTL	SDF	0	0
GEORGE BUSH INTERCONTINENTAL	IAH	1	1	SAN FRANCISCO INTL	SFO	1	1
INDIANAPOLIS INTL	IND	0	0	SAN JOSE INTERNATIONAL	SJC	1	0
JACKSONVILLE INTL	JAX	0	0	SALT LAKE CITY INTL	SLC	0	1
JOHN F KENNEDY INTL	JFK	1	0	SACRAMENTO METRO	SMF	0	0
MC CARRAN INTL	LAS	0	1	JOHN WAYNE AIRPORT-ORANGE C	SNA	1	0
LOS ANGELES INTL	LAX	1	1	LAMBERT-ST LOUIS INTL	STL	0	1
LAGUARDIA	LGA	1	0	TAMPA INTL	TPA	0	0
KANSAS CITY INTL	MCI	0	0	TUCSON INTL	TUS	0	0