City-Pairs vs. Airport-Pairs: A Market-Definition Methodology for the Airline Industry

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Abstract

This paper provides a methodology for deciding which airports warrant grouping in multi-airport metropolitan areas. The methodology is based on the comparability of incremental competition effects from nearby airports on average fares at a metropolitan area's primary airport. Results from a quarterly panel data set for the period 2003-2009 provide strong evidence that city-pairs, rather than airport-pairs, are the appropriate market definition for analyses of passenger air transportation involving many (but not all) large metropolitan areas. Based on the proposed method, we offer a recommended list of airports that should be grouped when creating city-pairs for the analysis of competition in the U.S. domestic airline industry.

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1. Introduction

In the vast empirical economics literature on the airline industry, researchers typically study the impact of the characteristics of an airline market on market outcomes. A common outcome variable is the level of airfares, and the fare impact of market competition (a key characteristics variable) is the focus of many studies. Other outcome variables of interest include fare dispersion, delays, flight frequency, etc., with researchers linking such variables to a variety of market characteristics.

In carrying out such studies, researchers must first make a crucial choice: how to define the relevant market? While the answer seems obvious on one level (i.e., a market involves travel between two cities), the market-definition question is less straightforward when it is recognized that the largest "cities" are vast metropolitan areas often containing several commercial airports that "compete" for passengers. Then, the issue is whether these multiple airports should be grouped and viewed as a single destination for passengers, or whether each of the multiple airports should be treated as a separate destination. When the first approach is followed, "city-pairs" constitute airline markets, while under the second approach, markets are taken to be "airport-pairs."

The choice between these approaches matters in answering the kinds of questions posed

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by researchers, and likewise for public policy decisions. For example, the measured level of competition will tend to be higher when markets are viewed as city-pairs rather than airport-pairs, given that flights to multiple airports are all counted. With higher measured competition, regression estimates of the fare impact from adding an extra competitor to a market may be affected, as will fare impacts based on other competition measures such as the Herfindahl index, which can be affected by market definition.

Market definition is also a crucial factor guiding government regulatory decisions regarding the airline industry.[1] For example, in evaluating proposed airline mergers, the post-merger level of competition in airline markets is a key concern. A merger that would reduce competition (or eliminate it entirely) in a given airport-pair market may look more benign under the city-pair approach, given that service to other airports in the metro area is also counted in deriving market competition.[2] Another example of a policy decision heavily influenced by an assessment of the relevant geographic market was the recent decision by the U.S. Department of Transportation ("DOT") to condition a proposed exchange of airport slots at Washington National ("DCA") and New York LaGuardia ("LGA") airports between US Airways and Delta on the divestiture of a portion of the slots the parties had agreed to exchange.[3] In its decision,

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[1] The focus of this paper is on defining the markets for the carriage by air of passengers. We do not here attempt to define the market for airport services.

[2] As noted by one former Deputy Assistant Attorney General of the Antitrust Division of the U.S. Department of Justice: "The so-called "relevant market" in which we evaluate whether a particular merger will lessen competition is not the whole industry. Rather, we have to look at the markets in which passengers buy air travel. These markets are the particular origin and destination city pairs (and occasionally airport pairs) on which passengers fly. It is competition in particular city pair markets that is relevant to competition for passengers." See, *Antitrust for Airlines, Remarks by J. Bruce McDonald,* Deputy Assistant Attorney General, Antitrust Division, U.S. Department of Justice, Presented to the Regional Airline Association President's Council Meeting, November 3, 2005.

[3] See *Notice of a Petition for Waiver and Solicitation of Comment on Grant of Petition with Conditions*, Department of Transportation, Federal Aviation Administration, Docket No. FAA-2010-0109, Petition for Waiver and Other Relief, July 21, 2011. US Airways had agreed to trade 132 of its LGA slots pairs for 42 of Delta's slot pairs at DCA in addition to a transfer of one of Delta's route authorities to São Paulo, Brazil and $65 million. DOT has conditioned the transaction on the divestiture of 8 slot pairs at DCA and 16 slot pairs at LGA to "new entrant and limited incumbent carriers."

DOT wrote as follows:

> We also recognized that there does exist a low level of competition among the Washington and New York City area airports, but at an insufficiently low level such that one airport can exert enough competitive influence on the fares at another airport to substantially reduce yield disparities among the airports and constitute a true substitute for it.[4]

DOT's market definition analysis consisted primarily of a simple comparison of average prices per mile (i.e., "yields") across airports. This analysis found that prices at DCA and LGA were higher than those at other Washington (i.e., IAD and BWI) and New York City (i.e., JFK and EWR) area airports, which in turn led DOT to conclude that LGA and DCA are separate "markets."

Many empirical papers in the literature use the airport-pair approach to market definition. These studies include several early studies exploring the effect of market structure and competition on airfares following deregulation, (for example, Borenstein (1989, 1991), Brueckner, Dyer and Spiller (1992) or Brueckner and Spiller (1994)) and numerous studies of the competitive effects of international alliances and antitrust immunity (e.g., Brueckner and Whalen (2000), Brueckner (2003), and Whalen (2007)). The city-pair approach is followed by an alternative set of papers, including studies of competition and airfares by Berry (1990), Evans and Kessides (1993, 1994), and Berry, Spiller and Carnall (2006), studies of the impact of airline mergers (e.g., Werden, Joskow and Johnson (1991), Peters (2006)), studies of low cost carrier (LCC) entry (e.g., Bogulaski, Ito and Lee (2004)), as well as numerous studies of domestic codesharing (e.g., Bamberger, Carlton and Neumann (2004), Ito and Lee (2007) and Gayle (2008)).[5] Finally, another set of studies that examine the effect of LCC presence on market fares

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[4] *Ibid*, footnote 36.

[5] Other papers studying the effects of domestic codesharing using airport pairs include those by Armantier and Richard (2008, 2006).

(e.g., Morrison (2001), Goolsbee and Syverson (2008), Brueckner, Lee and Singer (2010)) use airport-pairs as the unit of observation, but allow for the impact of competition at the city-pair level by explicitly modeling competitive effects from adjacent airports within a metro area.[6] In choosing between the two approaches, the authors of these studies apparently took several factors into account, including their innate view of the "right" level of market definition, the purpose of the study, and the convenience of the two approaches from a data-manipulation perspective. However, the literature offers no systematic, formal method for choosing between the two approaches to market definition. The purpose of the present paper is to propose such a method.

The method asks whether the airports in a multiple-airport metro area can be grouped into a single destination. The answer to this question may be "yes" for some metro areas, and "no" for others. As a result, the method does not produce a uniform endorsement of the city-pair or airport-pair approach across all metro areas. Instead, it produces a mixture of the two approaches, depending on the grouping outcomes in different metro areas. Consider, for example, the case of travel between city 1, which contains airports *A* and *B*, and city 2, which contains airports *C* and *D*. Suppose the methodology indicates that airports *C* and *D* should be grouped and that airports *A* and *B* should be treated as distinct destinations. The result is then identification of two distinct travel markets involving city 1 and city 2: the market for travel between airport *A* in city 1 and either of city 2's airports, and the market between airport *B* in city 1 and either of city 2's airports.

[6] In addition to the published literature, several U.S. DOT studies (e.g., 1996, 2002) of the impact of LCC service on domestic airline competition also assume city-pairs. Likewise, recent studies of the impact of mergers conducted by the U.S. Government Accountability Office (GAO) also rely on city-pairs. See *Potential Mergers and Acquisitions Driven by Financial and Competitive Pressures*, United States Government Accountability Office, Report to the Subcommittee on Aviation Operations, Safety, and Security, Committee on Commerce, Science, and Transportation, U.S. Senate, July 2008.

Grouping of a metro area's airports is appropriate when they are perceived as close substitutes in the eyes of passengers. One means of judging substitutability is via an airport-choice study using passenger or household-level data, which would include driving time to the different airports, average fare levels, flight frequencies and other information. For a recent representative study of this type, see Ishii, Jun and Van Dender (2009); earlier papers include several studies by Pels, Nijkamp and Rietveld (2003, 2001, 2000) and Harvey (1986, 1986).

Our paper presents a grouping method that measures substitutability in a different manner, focusing on the spillover effect of competition across airports. To understand the method, consider travel from either of city 1's two airports, *A* and *B*, to airport *X* in a different city. While the levels of competition on the individual *A*-*X* and *B*-*X* routes will affect the respective fares on those routes, spillover effects arise *when the level of competition on the B-X route affects fares on the A-X route*, and vice versa. The existence of such spillovers indicates that airports *A* and *B* are substitutes, with passengers willing to switch between them as conditions change. In other words, when the number of airlines serving route *B*-*X* rises, airlines on the *A*-*X* route react to the threat of passenger loss to the now-more-competitive (and presumably cheaper) *B*-*X* route by cutting their fares, a spillover effect that would be absent if passengers did not perceive airports *A* and *B* as substitutes.

Our method prescribes the grouping of airports *A* and *B* when these spillovers are sufficiently strong, indicating that the airports are highly substitutable in the eyes of consumers. When the spillovers are weak, the method indicates that airports *A* and *B* should be treated as separate destinations.[7] The details of the method are explained in section 2 of the paper, and

[7]This notion of spillovers resulting from passenger switching to other nearby airports is closely related to the concept of market definition outlined by the US Department of Justice and Federal Trade Commission in their August 2010 *Horizontal Merger Guidelines*, which state "In considering likely reactions of customers to price increases for the relevant product(s) imposed in a candidate geographic market, the Agencies consider any

section 3 then applies the method to the largest multiple-airport metro areas in the U.S., leading to grouping recommendations for each area.

The paper is closely related to our previous study, Brueckner, Lee and Singer (2010), which carries out a comprehensive analysis of the impact of competition on domestic airfares. However, that paper makes no attempt to group airports in multiple-airport metro areas, instead viewing airline markets as airport-pairs. But, following the lead of several papers on the competitive impact of low-cost carriers (e.g., Goolsbee and Syverson 2008, Morrison 2001, Dresner, Lin and Windle 1996), the study measures the impact of "adjacent competition" (at different metro-area airports) along with the effect of "in-market" competition, thus explicitly taking account of competitive spillovers. The present paper, which studies a more limited set of markets, takes the additional step of using the spillover estimates to group airports. Given this difference, a natural question arises. If spillover estimates are available, why is it necessary to group airports? Why throw away the separate estimated impacts of in-market and adjacent competition, which are lost when a metro area's airports are grouped into a single destination?

The answer is that grouping may be useful in making public policy decisions, which often rely on a broad view that abstracts from the kinds nuances captured in our previous paper. For example, as mentioned above, government regulators are often interested in understanding the extent to which potential airline mergers or other asset transactions may reduce competition. If grouping of airports in at least some multiple-airport metro areas is justified on substitutability grounds, yielding more-inclusive market definitions, then mergers or asset transactions are much

reasonably available and reliable evidence, including: how customers have shifted purchases in the past between different geographic locations in response to relative changes in price or other terms and conditions…" and "… evidence on whether sellers base business decisions on the prospect of customers switching between geographic locations in response to relative changes in price or other competitive variables…".

less likely to reduce competition to critical levels than if grouping is not indicated.[8] Therefore, a grouping methodology like the one developed in this paper can be useful to policy makers in formulating a broad view of merger/asset-transaction impacts. Policy decisions can also be guided on a more detailed level, however, by the kinds of estimates contained in our other study.

Finally, we emphasize that, while the proposed methodology can serve as a useful guide to airport grouping for both researchers and policy makers analyzing competitive issues in U.S. airline industry, it should not be the *only* information taken into consideration. For example, direct survey information from passengers in particular metropolitan areas (as in Ishii, Jun and Van Dender (2009) or Pels, Nijkamp and Rietveld (2003)) may indicate that two airports are more closely linked than our methodology would suggest.[9] In this sense, the methodology (and the resulting airport groupings) proposed in this paper provide sufficient—but not necessary—conditions for grouping airports. This issue is discussed at greater length in Section 4.

2. The Method

2.1. Metro areas studied

This section describes the methodology for airport grouping. The method is applied

[8] The question of airport-pairs versus city-pairs was also recently played out in a private litigation matter seeking an injunction to stop the United-Continental merger. Plaintiffs in this lawsuit argued that airport-pairs were the relevant market: "More important than the split of authority over airport pairs, however, is the rationale that makes using airport pairs appropriate in particular cases, including this one. The argument for using city pairs instead of airport pairs is that neighboring airports in the same metropolitan area discipline prices at the city's principal airport or hub. If this in fact occurs, then one would expect to see price uniformity at the hub, occupied by the network carrier, and the surrounding satellite airports, from which LCCs fly. If there is not price convergence or uniformity, then one can conclude that the hub and its airport pairs are separate markets, at least for a significant segment of customers, who are subject to the price disparity" See Plaintiffs' Post-Hearing Memorandum, Case3:10-CV-02858-RS, September 13, 2010, page 33. The judge in this matter ruled, however, that "…although defendants need not establish what they believe to be the relevant market on plaintiffs' motion for a preliminary injunction, given the substantial evidence suggesting city-pairs, plaintiffs' effort to establish anything else never leaves the gate" See Order Denying Motion For Preliminary Injunction, in *Michael C. Malaney, et al., Plaintiffs, vs. UAL Corporation, United Air Lines, Inc., And Continental Airlines, Inc*., United States District Court, Northern District of California, Case No. 3:10-CV-02858-RS.

[9] For example, while our methodology suggests virtually no link between Los Angeles International Airport and Burbank Airport, studies by these authors based on survey data suggest that these airports may be substitutes.

separately to the major multiple-airport metro areas, with the exception of several areas where small airport sizes present an obstacle.[10] The first step is identification of the metro area's "primary" airport, a choice that is usually obvious based on traffic levels but is sometimes less straightforward. The second step is categorization of the metro area's other airports into "core" and "fringe" categories, based on distance to the primary airport (the primary airport is part of the core category). For example, in the case of the Los Angeles metro area, the primary airport is LAX (Los Angeles International), the other core airports are Burbank (BUR) and Long Beach (LGB), and the fringe airports are Orange County (SNA) and Ontario (ONT). The methodology asks whether other airports in the core group, as well as possibly fringe airports, can be grouped with the metro area's primary airport based on competition spillovers. See Table 1 for a list of metro areas, their primary airports and other core airports, and their fringe airports. Table 1 corresponds closely with the list of "composite cities" used by the U.S. DOT in their 2002 study of LCC competition, which was "based on composite cities to account for inter-airport competitive dynamics in metropolitan areas with multiple airports."[11]

[10] For example, Phoenix's Sky Harbor (PHX) and Mesa (AZA) airports are within relatively close proximity to one another (i.e., 33 driving miles) but there is insufficient service at AZA to perform our econometric analysis. A similar lack of data prohibits application of our method to other multiple-airport metropolitan areas such as Orlando (MCO, SFB) and Fort Myers (PGD, RSW).

[11] See *The Low-Fare Evolution, Part II –Third Quarter 2002*, U.S. Department of Transportation, Office of Aviation and International Affairs, Aviation Analysis Domestic Aviation Competition Issue Brief Number 19. The primary differences between our metro area grouping *candidates* and the groupings *assumed* by DOT are that we allow for the potential grouping of CVG and DAY and also test for two fringe airports in the New York City area (HPN and ISP), which were not included in DOT's Appendix A. DOT also included two airports that, for the period of our analysis, had limited or no commercial service (EFD in the Houston metropolitan area and DET in the Detroit metropolitan area).

Table 1: Primary, Core and Fringe Airports By Metropolitan Area

	Primary Airport	Other Core Airports	Fringe Airports
Boston	BOS	MHT, PVD	
Chicago	ORD	MDW	
Cincinnati	CVG	DAY	
Cleveland	CLE	CAK	
Dallas	DFW	DAL	
Detroit	DTW	FNT	
Houston	IAH	HOU	
Los Angeles	LAX	BUR, LGB	SNA, ONT
Miami	MIA	FLL	PBI
New York	LGA	EWR, JFK	HNP, ISP
San Francisco	SFO	OAK, SJC	
Tampa	TPA	PIE	SRQ
Washington, DC	DCA	IAD, BWI	

Table 2: Primary Airport's Share of Metropolitan Area Domestic O&D Passengers, 1980-2009

	Primary Airport	Other Core Airports	1980	1985	1990	1995	2000	2005	2009
Boston	BOS	MHT, PVD	92%	93%	84%	86%	70%	67%	73%
Chicago	ORD	MDW	99%	85%	80%	73%	68%	69%	68%
Cincinnati	CVG	DAY	61%	66%	66%	68%	69%	70%	62%
Cleveland	CLE	CAK	95%	94%	90%	96%	91%	84%	80%
Dallas	DFW	DAL	69%	71%	75%	74%	77%	82%	78%
Detroit	DTW	FNT	99%	98%	97%	98%	96%	93%	93%
Houston	IAH	HOU	63%	57%	50%	57%	62%	68%	64%
Los Angeles	LAX	BUR, LGB	90%	86%	83%	85%	85%	78%	80%
Miami	MIA	FLL	61%	62%	59%	56%	39%	33%	33%
New York	LGA	EWR, JFK	46%	33%	47%	40%	43%	39%	36%
San Francisco	SFO	OAK, SJC	73%	66%	62%	51%	51%	40%	56%
Tampa	TPA	PIE	100%	93%	100%	95%	97%	98%	95%
Washington, DC	DCA	IAD, BWI	69%	64%	55%	45%	33%	33%	34%

Source: US DOT O&D Survey.

As noted by the numerous academic studies (e.g., Morrison 2001, Dresner, Lin and Windle 1996) as well as several U.S. DOT (1996, 2002) studies, competition from "adjacent" airports—in particular from LCCs at these airports—has resulted in a significant amount of traffic diversion from primary airports. Table 2 illustrates this phenomenon by summarizing the share of each primary airport's domestic O&D passengers within its respective metropolitan area at five year intervals between 1980 and 2009. In considering Table 2, it is important to note that between 1971 and 1979, Southwest Airlines operated solely as an intrastate Texas carrier.[12]

2.1. Measuring competition

To measure competition spillovers, the analysis focuses on nonstop routes from the primary airport to airports in other metro areas, subject to two restrictions.[13] Extremely short routes (i.e., less than 200 miles) are excluded, as are routes with fewer than 10 passengers per day each way (PPDEW) across all the airlines serving the route.[14] Using the U.S. DOT's Passenger Origin-Destination Survey, the passenger-weighted average fare is then computed for each route (again across all airlines), over a seven year quarterly sample running from 2003-Q1 to 2009-Q4.[15]

Competition on each nonstop route is measured by counting the number of legacy airlines serving the route as well as the number of LCCs on the route.[16] To be counted, a carrier must offer an average of at least one weekday roundtrip over the given quarter. Since competitive effects tend to be much larger for LCCs than for legacy carriers (as shown in Brueckner, Lee and Singer (2010) and other previous work), this separate enumeration is necessary. The resulting

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[12] See http://www.southwest.com/about_swa/airborne.html.

[13] Although connecting services represent another form of competition having the potential to discipline nonstop prices, we elected not to control for such competition because of potential endogeneity concerns. However, including the percentage of passengers on the route using connecting service does not materially change any of our primary results.

[14] All of the grouping recommendations contained in Section 4 are robust to the inclusion of routes less than 200 miles.

[15] We exclude from our sample the following types of itineraries: non-revenue itineraries, itineraries with directional fares including taxes and fees of less than $25 or that were coded in the DOT Survey data as "bulk" fares, and interline itineraries (i.e., those with more than one marketing carrier).

[16] For the purposes of our study, we define the legacy carriers to be American, United, Delta, Northwest, US Airways, America West, Alaska, Continental and Midwest. The LCCs are defined as Southwest, AirTran, jetBlue, Frontier, Spirit, Sun Country Independence Air, Virgin America, ATA, SkyBus, Midway, National, and Allegiant. Although Midwest and Frontier were purchased by Republic Holdings in 2009 and will begin operating as a single (low cost) carrier starting in 2010, during the period of our analysis, the two carriers operated as separate carriers.

count variables are denoted **leg_comps_in** and **lcc_comps_in**, and the quarter-to-quarter variation in these competition variables reflects entry or exit by carriers across time on the airport pair of interest.

To capture competition spillovers, we then count the number of legacy (alternatively, LCC) carriers serving the route endpoint nonstop from a core airport *different from* the metro area's primary airport. To be counted, carriers must be distinct, not also providing service between the primary airport and the route endpoint.[17] The resulting variable for legacy airlines is denoted **leg_comps_out**, and the analogous LCC competition variable is denoted **lcc_comps_out**. Like the "**in**" variables, the "**out**" variables are also measured each quarter and thus capture the impact of changes in the level of adjacent competition on fares in the primary airport pair route. Note that the "**in**" suffix denotes the primary airport and airports possibly grouped with it, while "**out**" denotes airports not grouped with the primary airport. The methodology initially assumes that the **in** category consists of the primary airport alone, with the **out** category consisting of the other core airports. The question is whether this categorization is appropriate or whether additional airports should be grouped with the primary airport.

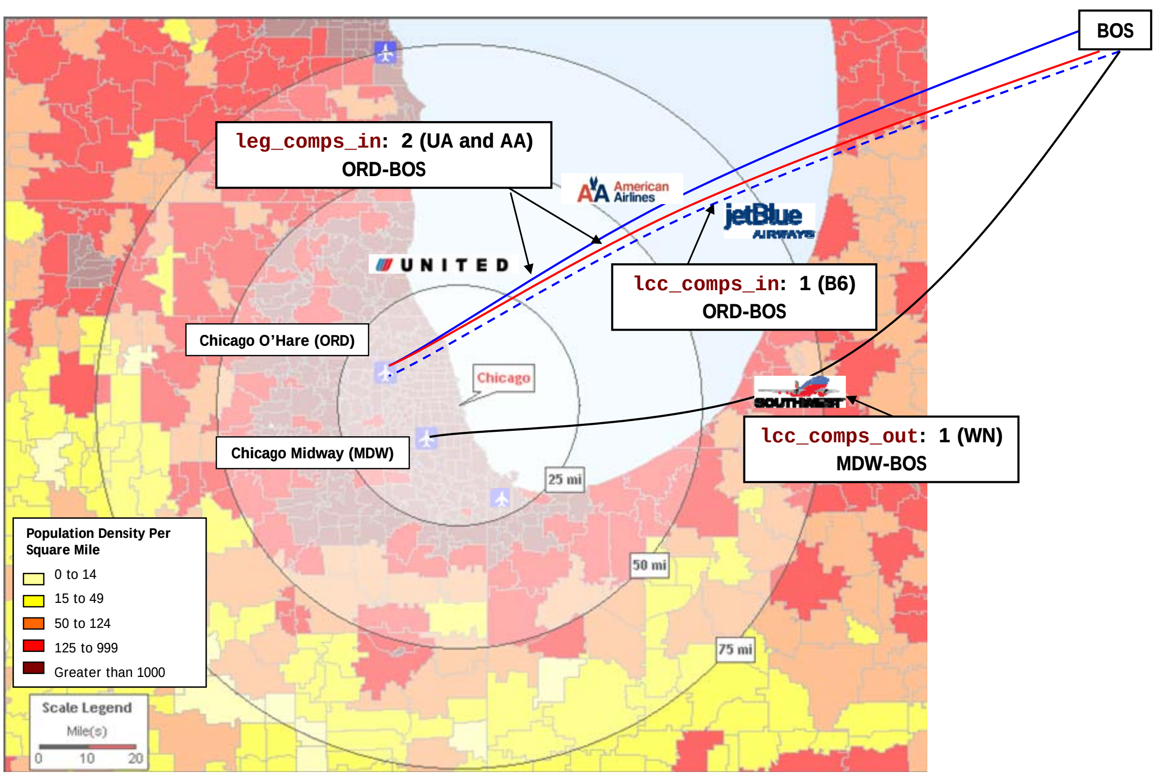
Figure 1 illustrates how these variables are defined for the Chicago O'Hare (ORD) to Boston (BOS) route. During the fourth quarter of 2009, ORD-BOS was served by two non-stop legacy competitors, United and American, so that **leg_comps_in** equals 2. jetBlue also serves ORD-BOS, and thus **lcc_comps_in** equals 1. Finally, Southwest serves BOS, but instead of using the primary airport ORD, it provides service from Midway (MDW). Thus, **lcc_comps_out** equals 1.

While this procedure is straightforward when the metro area at the other endpoint (call it

[17] For example, since Delta already serves Atlanta from New York's LaGuardia airport, when counting the number of legacy carriers serving Atlanta from core airport JFK, Delta is *not* counted.

M) contains a single airport, further considerations arise when *M* also contains multiple airports, which may be grouped. Note first that the previous description of how **in** and **out** competition is measured must be amended when the metro area *M* at the other endpoint contains grouped airports. Now, all airports within the group at *M* are considered to be the same destination, so that the number of **in** competitors of a given type (legacy or LCC) equals the number of distinct carriers providing service between metro area *N*'s primary airport and *any of the grouped airports* at *M*. Likewise, the measurement of **out** competition is also based on the grouping at *M*, with the number of **out** competitors equaling the number of distinct carriers providing service between any of *N*'s **out** airports and any of the airports in *M*'s group.

Figure 1: Example of "In" and "Out" Variable Definitions



From this discussion, it should be clear that the grouping decision for any given metro area may depend on whether airports in other metro areas are grouped. Our goal is thus to find a set of *mutually consistent* airport groupings across metro areas, as discussed more fully in subsection 2.5 below.

2.3. The grouping decision

The airport grouping decision is based on regression results, with a separate regression run for each metro area. As the preceding discussion makes clear, the data are available at the route-quarter-year level, so that a metro area whose primary airport has service to 50 endpoints will have a sample consisting of 50 (route) × 28 (quarters) = 1,400 observations. The dependent variable for the regression is the natural log of the average nonstop fare between the primary airport and a given endpoint, while the independent variables are the **in** and **out** competition variables, year and quarter effects, and route and carrier fixed effects. Connecting service plays no role in the empirical model (connecting fares, for example, are not considered).

The regression is run with passenger weighting, so that primary-airport routes with larger passenger volumes are weighted more heavily. In this and the subsequent discussion, a "route" should be viewed as ending at either a single airport or at an airport group within a multiple-airport metro area, as appropriate.

Spillover effects exist when fares on a route respond to both the **in** *and* **out** competition measures. In other words, while the presence of an additional **in** competitor is expected to reduce fares on the route, a spillover exists when an additional **out** competitor does so as well, indicating that competition *at other airports* reduces the fare for travel between the primary airport and the route endpoint.

Under our method, the airport grouping decision depends on the size of these spillovers. If the fare impact of **out** competition is "similar" in magnitude to the impact of **in** competition, then the implication is substantial substitutability between the **in** and **out** airports. That is, if the fare reduction on the primary-airport route from an additional **out** competitor (who serves the endpoint from a different airport) is approximately equal in size to the reduction from an additional **in** competitor (who serves the route itself), then the **in** airlines must view the **out** carriers as direct competitors for route traffic, indicating that the **in** and **out** airports are perceived as close substitutes by passengers.

The criterion for "similarity" in competitive effects is operationalized as follows. The regression estimates yield two sets of **in** and **out** competition coefficients, one for legacy carriers and one for LCCs. Within each set, the null hypothesis of equal coefficients is tested. In other words, the test for equality of the **leg_comps_in** and **leg_comps_out** coefficients is carried out, as is the test for equality of the **lcc_comps_in** and **lcc_comps_out** coefficients. If coefficient equality cannot be rejected for the legacy coefficients, then the **in** and **out** competitive effects for legacy carriers satisfy the similarity criterion. Similarly, failure to reject coefficient equality for LCCs means that **in** and **out** competitive effects for LCCs satisfy the similarity criterion. Note that, since competitive effects differ between legacies and LCCs, a comparison of **in** and **out** coefficients *across* carrier types would generally be inappropriate.

The last step is to translate these tests results into an airport grouping decision. The rule we apply is simple: grouping is not warranted if the similarity criterion on competitive effects is *not met for both legacy carriers and LCCs*. In other words, grouping does not occur if the hypothesis of equal coefficients is rejected for **leg_comps_in** and **leg_comps_out** and also rejected for **lcc_comps_in** and **lcc_comps_out**. In this case, competitive spillovers are not strong enough (**in** and **out** effects are not sufficiently similar), implying that the primary airport should not be grouped with any of the other airports in the core category, being instead viewed as a separate destination.

Conversely, the grouping of the airports is warranted if the similarity criterion on competitive effects is met *for either* LCCs or legacy carriers. Thus, if the equality-of-coefficients fails to reject equality for either type of carrier (or for both types simultaneously), then competitive effects are deemed to be sufficiently similar to warrant grouping.

Viewing this procedure as a test for grouping vs. non-grouping (rather than in terms of the individual coefficient tests), the implicit null hypothesis is that grouping is warranted.[18] Our approach is to reject this null hypothesis only when equality of competitive effects can be rejected for *both* legacies and LCCs, failing to reject grouping when equality is not rejected *for at least one* carrier type.

An alternate approach less likely to produce grouping would be to reject the grouping hypothesis when equality of competitive effects is rejected for at least one carrier type (rather

[18] This null hypothesis (assuming that airports in the same metro area should be grouped) is consistent with virtually all studies in the literature that examine airport substitution in multi-airport metropolitan areas (e.g., Ishii, Jun and Van Dender (2009) or Pels, Nijkamp and Rietveld (2003)), studies of the impact of airline mergers by current or former U.S. DOJ economists (e.g., Werden, Joskow and Johnson (1991), Peters (2006)), other recent studies providing a measure of airport spillover effects (e.g., Forbes (2008)) as well as the literature studying the impact of LCC competition on the domestic airline industry (e.g., Morrison (2001), Goolsbee and Syverson (2008)). Moreover, the assumption is also consistent with numerous U.S. DOT (e.g., 1996, 2002) and GAO (2008) studies that *assume* city-pairs when studying domestic airline competition and the approach used by the U.S. DOJ to analyze airline mergers: "United and US Airways also compete for the $1 billion the U.S. government spends on air travel, and were the only two, or two of only three bidders, on many *city pairs.* (emphasis added). See *Department Of Justice And Several States Will Sue To Stop United Airlines From Acquiring US Airways*, July 27. 2001. See also, *Antitrust for Airlines, Remarks by J. Bruce McDonald*, Deputy Assistant Attorney General, Antitrust Division, U.S. Department of Justice, Presented to the Regional Airline Association President's Council Meeting, November 3, 2005, noting that "Reviewing any particular merger, we first identify the city pairs in which the merging carriers both provide service." See also *Airline Mergers: Issued Raised by the Proposed Merger of United and Continental Airlines*, Testimony before the Committee on Commerce, Science and Transportation, U.S. Senate, U.S. GAO, May 27, 2010, noting (at footnote 22) that "It is generally preferable, time permitting, to assess city-pair, rather than airport-pair, changes in competition. Some larger U.S. cities (New York, Chicago, Los Angeles, Washington D.C.) have more than one commercial airport that can compete for passenger traffic." Finally, the assumption is consistent with the stylized facts (such as those presented in Table 2 above) that demonstrate that in many large metropolitan areas, there have been sizable shifts passengers across airports within a metropolitan area over the past three decades.

than for both types), with grouping requiring failure to reject for both types.[19] As a practical matter, however, because legacy and LCC service in multiple-airport metropolitan areas is frequently bifurcated (with legacy carriers providing most or all of their service from one airport and LCCs providing most or all of their service from the other), the "both" test can only be applied to a handful of metropolitan areas (Washington, New York City, San Francisco and Miami/Ft. Lauderdale), making it impractical as a general decision criterion.

When a metro area does not have enough legacy service from non-primary airports to allow estimation of the **leg_comps_out** coefficient, the grouping procedure focuses solely on the LCC competition coefficients.[20] The airports are grouped if the hypothesis of equal **lcc_comps_in** and **lcc_comps_out** coefficients cannot be rejected.

Also, in a handful of metropolitan areas with bifurcated service across airports (i.e., LCC service focused at the "out" airport and legacy carrier service focused at the primary airport), the pattern of coefficients suggests strong competition spillovers, but strict application of our test would reject grouping. In these cases, the **lcc_comps_out** effect *is actually stronger* than the **lcc_comps_in** effect, and the difference is sufficiently large to lead to rejection of the null hypothesis of coefficient equality.[21] In such cases, we follow common sense and group the airports.

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[19] A variant of this approach would be to use the compound null hypothesis that the **in** and **out** coefficients are equal for legacies *and* for LCCs, in which case grouping would be rejected on the basis of a single test rather than two separate equality tests.

[20] For example, the Dallas/Fort-Worth metropolitan area, there are two large airports (DFW and DAL), but the only two routes with legacy carrier service from DAL (DAL-IAH and DAL-MEM) are also served by the same carriers from DFW. Therefore there are no additional legacy carriers providing service from DAL, and **leg_comps_out** is equal to zero for all routes. In order to perform the legacy (or LCC) test, we require there to be at least 5 routes with legacy (LCC) **in** service and 5 routes with non-overlapping legacy (LCC) **out** service, over the course of the sample period.

[21] In Houston, legacy and LCC service is almost entirely bifurcated between the two main airports (Houston Intercontinental and Houston Hobby), with the result that neither the LCC nor the legacy test can be performed. In this case, we base our grouping decision on the magnitude of the **lcc_comps_out** coefficient, as seen below.

2.4. The power of the test as an issue

As the preceding discussion makes clear, the "affirmative" outcome under our method (airport grouping) occurs when we *fail to reject* the null hypothesis of grouping. The danger in any statistical procedure where key conclusions rely on failure to reject the null hypothesis is that test's power may be low. That is, while standard statistical tests are constructed to limit the probability of rejecting a null hypothesis when it is true, the probability of failing to reject the hypothesis when it is false (i.e., the power of the test) is not constrained and has the potential to be low. Given the nature of the grouping question, this limitation of our method is unavoidable. The same limitation appears in other studies where an affirmative conclusion comes from failure to reject a null hypothesis.

2.5. Second-stage tests

If a metro area has just one other airport aside from the primary airport (for example, Cleveland vs. Canton-Akron), then no further questions arise after the grouping test is carried out. However, when several additional airports are present, the grouping test may raise further questions. Suppose, for example, that the metro area has two additional core airports along with the primary airport, and suppose that the application of the above procedure indicates grouping, suggesting that the primary airport and the two other core airports should be viewed as a single destination. A natural question is then whether *only one* of the other core airports, rather than both, should be grouped with the primary airport, with the third airport treated as a separate destination.

This "subgrouping" issue can be addressed by extending the initial method, via additional second-stage grouping tests. Letting the primary airport be denoted *P* and the other core airports be denoted *A* and *B*, these tests are conducted pairwise between airports. In the first test, airport

A is viewed as a single **out** airport and *P* as the **in** airport. The grouping test is then carried out in the manner described above. In the second test, airport *B* is viewed as the single **out** airport and *P* again as the **in** airport, and the procedure is repeated. If both tests support pairwise grouping (with *A* and *P* grouped in a pairwise comparison, and *B* and *P* also grouped), then the initial indication that all three airports should be grouped is reinforced. Alternatively, the tests could give different answers, with the second-stage tests suggesting that only two of the airports should be grouped. In this case, "outside" information (i.e., factors not including in the formal test) can be considered before reaching a final grouping decision.[22]

Likewise, suppose that a metro area has more than one non-primary core airport, and that the first-stage tests *do not* support grouping of these airports with the primary airport. In this case, it still may be appropriate to group the primary airport with *one* of the other core airports but not the entire set, and second-stage tests can guide this decision. The tests are carried out as described above, with separate pairwise comparisons made between the primary airport and each of the other core airports. These tests may indicate that the primary airport is appropriately grouped with one but not all of the other core airports.

The remaining question concerns the handling of fringe airports. These airports are sufficiently remote from the primary airport to be excluded from the initial grouping tests, but this exclusion is tested more formally. If the first- and second-stage tests described above indicate grouping of all the core airports, then they are treated collectively as **in** airports, with competition and fares measured for the group, while the fringe airports are treated as **out** airports. The grouping test is then carried out for these categories, and if the results do not support grouping, then no additions to the initial core group are necessary. Otherwise the fringe

[22] Another possibility is that the second-stage tests reject any grouping, in which case the first- and second-stage tests give conflicting results, making the overall outcome inconclusive.

airports can be added to produce a larger group.[23] By contrast, if the initial tests do not support any grouping of the core airports, then grouping of the more-remote fringe airports need not even be considered.

2.6. Mutually consistent groupings

With the grouping methodology explained, it is useful to revisit the question of mutually consistent airport groupings. The key observation is that, under our methodology, the grouping pattern in *other metro areas* (*M*) may affect the grouping decision for airports in *a given metro area* (*N*). The reason is that, when airports in a metro area *M* are grouped, the number of routes from metro area *N* to *M* decreases relative to the ungrouped case, with **in** and **out** competition counts likely to be higher on the consolidated route than on the individual routes. As result, the **in** and **out** competition coefficients are likely to be affected, and the results of the equality tests may change. Therefore, the grouping patterns in other multiple-airport metro areas may affect the grouping decision in a given metro area.

For a set of airport groupings across metro areas to be mutually consistent, the groupings must validate one another. In other words, the grouping pattern chosen for metro area *N* based on the groupings for other metro areas *M* must elicit these same groupings when the *M*-area groupings are themselves chosen (taking groupings in *N* and other metro areas as given). Formally, let F_i denote the collection of airports in metro-area i, let G_i denote a partition of these airports into groups, let $G = \{G_1,\dots G_k\}$ denote the set of groupings for all k metro areas, and let G_{-i} denote the set of groupings for metro areas other than i. Then, a prescribed set of airport groupings G^* is *mutually consistent* when the recommended grouping for metro area i, conditional on the groupings G_{-i}^* in other metro areas, is G_i^*, with this statement holding for i =

[23] When there is more than one fringe airport, the second-stage test described above can also be performed.

1,2,…,*k*. The airport groupings derived in the next section meet this criterion for mutual consistency, a point that will be reiterated in section 4.

2.7. Competitive Effects Estimates

Finally, as described above, the **leg_comps_in** and **leg_comps_out** coefficients provide estimated effects of additional legacy **in** and **out** competitors on fares, and similarly for the corresponding coefficients on the **lcc** variables. It is natural to ask whether these coefficients give the best possible estimates of competitive effects, or whether they should be viewed differently. On the one hand, the current model is parsimonious, being designed to tackle the airport groupings issue, which means that it may give a less accurate picture of competitive effects than a more richly specified model like that of Brueckner, Lee and Singer (2010).[24] Moreover, our approach treats the competition variables as exogenous, which could lead to simultaneity bias in their estimated coefficients. While Gayle and Wu (2011), relying on a sophisticated entry model, find that such bias is negligible, this concern is further reduced by our use of route fixed effects to capture unmeasured, time-invariant route characteristics. Such characteristics may be correlated with the competition measures while also affecting fares (thus creating bias), but controlling for them via fixed effects eliminates the problem. More generally, since our empirical goal is to make a comparison of **in** and **out** competitive effects to judge the *relative* strength of spillovers and thus decide on airport groupings, we are less concerned with the actual *magnitudes* of the **in** and **out** coefficients than if our goal were to measure the sizes of competitive effects as accurately as possible. Therefore, our approach is defensible.

[24] For example, in the current model, we are unable to separate the competitive effect of Southwest from other LCCs, since this would require that Southwest serve at least five destinations from both the primary and other core airports, which it does not in many metropolitan areas of interest, such as Houston, Dallas, Chicago and Washington. Likewise, the current model does not separately control for factors such as potential competition or the number of LCC or legacy connect competitors, both of which are controlled for in Brueckner, Lee and Singer (2010).

3. Airport Groupings for U.S. Metro Areas

This section of the paper presents airport groupings for U.S. metro areas, using the methodology described in section 2. Each subsection covers a particular metro area.

3.1. Washington, D.C. metro area.

Table 3 shows the case of Washington, D.C. The primary airport for this metro area is assumed to be Washington Reagan National (DCA), which is closest to the city's center and thus preferred by many travelers. The remaining core airports are Washington-Dulles (IAD) and Baltimore-Washington (BWI), which are located 29 and 36 miles, respectively, from DCA.[25] The metro area has no fringe airports.

As seen in Table 3, legacy and LCC carriers have served 67 nonstop routes from DCA over the sample period, with 66 of these routes served by legacies and 10 served by LCCs. Among these 67 DCA routes, non-overlapping legacy service (i.e., by legacy carriers other than those serving the route from DCA) was provided to 51 of the route endpoints from the **out** airports, IAD and BWI, while non-overlapping LCC service was offered to 52 of the DCA route endpoints from the **out** airports.

As can be seen from the DCA vs. IAD+BWI column of Table 3, all the competition coefficients are significant. An additional LCC **in** competitor reduces the fare by 8.8 percent, while an additional **out** competitor leads to a 3.4 percent fare reduction. The legacy **in** effect is 3.8 percent, but the **out** coefficient is larger, at 9.2 percent. While the test rejects equality of the legacy **in** and **out** coefficients (the *p*-value is 2.9 percent), coefficient equality cannot be rejected for LCCs, where the *p*-value is 22.6 percent. The outcome of the LCC test thus implies grouping of the three airports.

[25] The distances between airports are driving distances from Google Maps.

Table 3: Washington, DC

	Distance from (miles) City Center	Primary Airport
DCA (Primary Airport)	4.4	--
IAD (Core Airport)	27	29.1
BWI (Core Airport)	31.8	35.7

Number of Markets With:†	DCA vs. IAD+BWI	DCA vs. IAD	DCA vs. BWI
Service from primary airport	67	67	67
LCC "in"	10	10	10
LCC "out"	52	39	43
Legacy "in"	66	66	66
Legacy "out"	51	51	4

Regression Results

	DCA vs. IAD+BWI	DCA vs. IAD	DCA vs. BWI
lcc_comps_in	-0.0885*	-0.0882	-0.113*
lcc_comps_out	-0.0345*	-0.0258*	-0.0485*
leg_comps_in	-0.0377*	-0.0458*	-0.0418*
leg_comps_out	-0.0920**	-0.0960**	0.00677
Constant	5.279**	5.297**	5.260**
Observations	1551	1551	1551
R-squared	0.811	0.810	0.807

Null Hypothesis	p-value	p-value	p-value
lcc_comps_in = lcc_comps_out	0.226	0.177	0.131
leg_comps_in = leg_comps_out	0.029	0.047	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Table 3 also shows the results of the second-stage grouping tests. The DCA vs. IAD column, which applies when IAD is the single out airport, shows estimated coefficients similar to those in the first regression. As a result, the tests again show that the hypothesis of equal **in** and **out** coefficients cannot be rejected at the 5 percent level for LCCs (the *p*-value is 17.7 percent), although equality can be rejected for legacies. The implication is then that DCA and IAD should be grouped.

The results when BWI is the single **out** airport and DCA the **in** airport are shown in the DCA vs. BWI column. In carrying out the grouping test for this case, an obstacle is the small number of DCA routes (equal to 4) for which non-overlapping legacy **out** service exists. When this type of count falls below 5 routes, we do not carry out the equality test, even though an estimated **leg_comps_out** coefficient can be estimated (hence the N/A in place of the *p*-value). However, the test of equality for the LCC **in** and **out** coefficients fails to reject the null hypothesis, with a *p*-value of 13.1 percent. Under our procedures, this single test result supports grouping of DCA and BWI. Therefore, both second-stage tests reinforce the conclusions from the first-stage test, namely, that DCA, IAD and BWI should be grouped.[26]

3.2. New York metro area

LaGuardia Airport (LGA) is designated as the primary airport for the New York metro area, with John F. Kennedy (JFK) and Newark (EWR) being the other core airports. The fringe airports for the metro area are Islip (ISP) and White Plains (HPN). JFK and EWR are respectively 12 and 23 miles distant from LGA, while fringe airports are 30 and 47 miles distant, respectively.

As seen in Table 4, nonstop service from LGA has been provided on 63 routes over the course of the sample period, with legacies serving 62 of these routes and LCCs serving 16. As in the case of DCA, substantial **out** service is provided on the LGA routes by both types of carriers, a testimony to the large sizes of the **out** airports.[27]

The LGA vs. JFK+EWR column of Table 4 shows the regression coefficients for the **in** and **out** competition variables, with the year, quarter, carrier and route coefficients suppressed for purposes of presentation. The table shows large, statistically significant LCC competition coefficients, with **in** and **out** effects of 17.8 and 21.8 percent respectively. Not surprisingly, the test for equality of these coefficients fails to reject the null hypothesis, with a *p*-value of 32

[26] Although the U.S. DOT has recently argued in the proposed US Airways-Delta slot swap that DCA represents a separate market, an earlier DOT study (2002) assumed DCA, IAD and BWI were in the same market. Likewise, a 2005 U.S. DOT study also noted that "We typically define Washington city-pair markets as including only Washington Dulles (IAD) and Reagan National (DCA) airports. This definition excludes Baltimore/Washington Airport (BWI). In certain cases, we have observed that competition at BWI, located approximately thirty miles from downtown Washington, can influence traffic and fares at Washington Dulles and/or Reagan National airports, particularly in cases where a low-fare carrier begins offering service from BWI." See *Independence Brings More Low-Fare Competition to the East Coast – First Quarter 2005*, U.S. Department of Transportation, Office of Aviation and International Affairs, Aviation Analysis Domestic Aviation Competition Issue Brief Number 27.

[27] Recall that the endpoint of a route may be a group of airports in a multiple-airport metro area. Therefore, the number of individual airports served will generally exceed this route count. Additionally, although 63 routes have been served from LGA over the sample period, the number of routes served in any particular quarter can vary.

percent. With the **leg_comps_in** coefficient showing a significant 6.9 percent fare decline from an extra legacy competitor and the **out** coefficient insignificant, the equality test rejects the null hypothesis at below the 5 percent level. However, since the LCC test shows the required similarity of **in** and **out** competitive effects, grouping is favored by at least one of the equality tests, and thus we conclude that LGA, JFK and EWR should be grouped.

Table 4: New York, NY

	Distance from (miles)						
	City Center	Primary Airport	Number of Markets With:†	LGA vs. EWR+JFK	LGA vs. EWR	LGA vs. JFK	LGA+JFK+EWR vs. HPN+ISP
LGA (Primary Airport)	9.4	--	**Service from primary airport**	63	63	63	93
EWR (Core Airport)	16.6	23	**LCC "in"**	16	16	16	46
JFK (Core Airport)	17.1	12	**LCC "out"**	23	5	23	9
HPN (Fringe Airport)	33.4	30.3	**Legacy "in"**	62	62	62	91
ISP (Fringe Airport)	51.3	46.7	**Legacy "out"**	52	50	24	0

Regression Results

	LGA vs. EWR+JFK	LGA vs. EWR	LGA vs. JFK	LGA+JFK+EWR vs. HPN+ISP
lcc_comps_in	-0.178**	-0.0891**	-0.173**	-0.173**
lcc_comps_out	-0.218**	0.0270	-0.218**	-0.0273
leg_comps_in	-0.0690**	-0.0885**	-0.0757**	-0.0418**
leg_comps_out	-0.00146	0.0162	-0.00777	N/A
Constant	5.248**	5.278**	5.279**	5.322**
Observations	1351	1351	1351	2079
R-squared	0.845	0.813	0.844	0.913
Null Hypothesis	**p-value**	**p-value**	**p-value**	**p-value**
lcc_comps_in = lcc_comps_out	0.315	0.003	0.271	0.0000
leg_comps_in = leg_comps_out	0.000	0.001	0.001	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Turning to the second-stage grouping tests, the LGA vs. JFK column of Table 4 shows the results when JFK is the single **out** airport. The estimates are similar to those from first-stage, with large LCC **in** and **out** coefficients, and a smaller **in** effect for legacies but an insignificant **out** effect. Coefficient equality is rejected for legacies, but not for LCCs (the *p*-value is 27 percent), reinforcing the grouping of LGA and JFK from the first-stage test. The LGA vs. EWR column shows a significant LCC **in** effect but an insignificant **out** effect, a pattern that also holds for the legacy coefficients. As a result, the equality tests lead to rejection of coefficient equality at below the 5 percent level for both legacies and LCCs, suggesting that EWR and LGA should not be grouped. Given this result, which contrasts with the grouping of EWR with LGA and JFK under the first-stage test, outside information can be considered to reach a final grouping. Discussion of these outside considerations for the New York City case is deferred to section 4.1 below.

If LGA, JFK and EWR were grouped, then a further second-stage test verifies that the fringe airports (HPN and ISP) should not be added to this group. Fares and **in** competition are now computed treating LGA+JFK+EWR as a group, with ISP and HPN being the **out** airports. The results, shown in the LGA+JFK+EWR vs. ISP+HPN column, yield a strong rejection of **in** and **out** coefficient equality for LCCs. However, since no legacy **out** competition exists from these new **out** airports, the **leg_comps_out** coefficient cannot be estimated. But given that the single LCC coefficient test indicates no grouping, adding HPN and ISP to a LGA+JFK+EWR group is not warranted.

3.3. Boston metro area

The primary airport for the Boston metro area is Logan International (BOS). The other core airports are Manchester, New Hampshire (MHT) and Providence, Rhode Island (PVD), which are often viewed as alternatives to BOS.[28] These airports are somewhat distant from BOS, at 55 and 62 miles, respectively, and they could alternately be considered as fringe airports, leaving BOS as the only core airport. However, our procedures would be unaffected by whether these airports are categorized as core or fringe (a first-stage grouping test would not exist in the latter case, with the fringe grouping test doing all the work).

[28] For example, despite the fact that Southwest Airlines recently began to serve BOS, it continues to promote both PVD and MHT as "Boston Area" airports. See http://www.southwest.com/travel_center/routemap_dyn.html and http://www.southwest.com/flight/?int=GSUBNAV-AIR-BOOK&forceNewSession=yes. Likewise, in 2006, Manchester Airport officially changed its name to *Manchester-Boston Regional Airport.* See: http://www.flymanchester.com/about/history.php.

Table 5: Boston, MA

	Distance from (miles) City Center	Primary Airport
BOS (Primary Airport)	3.7	--
MHT (Core Airport)	52.6	55.2
PVD (Core Airport)	59.8	61.9

Number of Markets With:†	BOS vs. MHT+PVD	BOS vs. MHT	BOS vs. PVD
Service from primary airport	55	55	55
LCC "in"	35	35	35
LCC "out"	12	9	12
Legacy "in"	52	52	52
Legacy "out"	0	0	0

Regression Results

	BOS vs. MHT+PVD	BOS vs. MHT	BOS vs. PVD
lcc_comps_in	-0.134**	-0.133**	-0.135**
lcc_comps_out	0.0219	0.0322	0.0110
leg_comps_in	-0.0776**	-0.0754**	-0.0777**
leg_comps_out	N/A	N/A	N/A
Constant	5.299**	5.289**	5.298**
Observations	1224	1224	1224
R-squared	0.832	0.832	0.832

Null Hypothesis	p-value	p-value	p-value
lcc_comps_in = lcc_comps_out	0.000	0.005	0.001
leg_comps_in = leg_comps_out	N/A	N/A	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

As seen in Table 5, nonstop service from BOS has been provided on 55 routes over the sample period, with legacies serving 52 of these routes and LCCs serving 35. While 12 of the BOS route endpoints have had additional LCC service from the **out** airports, none of the endpoints have had non-overlapping legacy **out** service. As a result, the coefficient for **leg_comps_out** cannot be estimated, so that the grouping test relies only on the LCC coefficients. As seen in the BOS vs. MHT+PVD column of the table, the equality test for these coefficients strongly rejects the null hypothesis (with a *p*-value of less than 1 percent). This outcome is understandable given that the **lcc_comps_out** coefficient is positive and insignificant while the **lcc_comps_in** coefficient is significant and fairly large in magnitude, indicating that an additional LCC **in** competitor reduces BOS fares by 13.4 percent. Therefore, the tests reject grouping of the **out** airports with BOS, implying that they should be treated as separate destinations.

Second-stage tests can be carried out to look for confirmation of this negative conclusion. The BOS vs. PVD and BOS vs. MHT columns show that equality of LCC coefficients is rejected in each case, showing that these pairwise groupings are not warranted (legacy tests cannot be carried out). Therefore, the negative conclusion of the first-stage test is affirmed.

3.4. Chicago metro area

The primary airport for the Chicago metro area is O'Hare International (ORD), with Midway (MDW), which is 26 miles distant (but closer to city center than ORD), being the other core airport. As seen in Table 6, service was provided on 115 routes from ORD over the sample period, with legacy carriers (mainly United and American, for whom ORD is a hub) serving 115 of these routes and LCCs serving 10.

Since there is non-overlapping legacy **out** service from MDW for only 2 ORD routes, the equality of coefficients test for legacies is not carried out even though the **legacy_comps_out** coefficient can be estimated.[29] But, with LCC **out** service provided to 54 ORD endpoints, the LCC test can be carried out, using the estimated **in** and **out** effects of 10.7 and 8.3 percent, both of which are significant. Given the similarity of these coefficients, the equality test unsurprisingly fails to reject the null hypothesis, with a *p*-value of 40.4 percent. The legacy test is unavailable, but the results of the LCC test indicate grouping of ORD and MDW.

[29] Although the **leg_comps_out** coefficient can be estimated, it should not be viewed as meaningful, given the small sample size for legacy **out** competition.

Table 6: Chicago, IL

	Distance from (miles) City Center	Primary Airport	Number of Markets With:†	ORD vs. MDW
ORD (Primary Airport)	18.2	--	Service from primary airport	115
MDW (Core Airport)	11.2	26.1	LCC "in"	10
			LCC "out"	54
			Legacy "in"	115
			Legacy "out"	2

Regression Results

	ORD vs. MDW
lcc_comps_in	-0.107**
lcc_comps_out	-0.0826**
leg_comps_in	0.0402*
leg_comps_out	-0.0517*
Constant	5.122**
Observations	2683
R-squared	0.815

Null Hypothesis	p-value
lcc_comps_in = lcc_comps_out	0.404
leg_comps_in = leg_comps_out	N/A

** $p<0.01$, * $p<0.05$
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

3.5. Los Angeles metro area

The primary airport for the Los Angeles metro area is Los Angeles International (LAX), and the other core airports are the Burbank-Glendale-Pasadena Airport (BUR) and Long Beach (LGB), which are, respectively, 32 and 22 miles distant from LAX. The fringe airports are John Wayne-Orange County (SNA) and Ontario (ONT), which are 41 and 57 miles from LAX, respectively. As seen in Table 7, service has been provided on 75 routes from LAX over the sample period, with legacies having served 74 of these routes and LCCs having served 34.

Since there has been non-overlapping legacy **out** service from BUR or LGB for only 4 LAX routes, the equality test for legacies is not carried out even though the **legacy_comps_out** coefficient can be estimated. But, with additional LCC **out** service provided to 15 LAX endpoints over the sample period, the LCC test can be run. As seen in the LAX vs. BUR+LGB column of the table, the LCC **in** and **out** coefficients are both significant and quite different, with the **in** effect equal to 14.0 percent and the **out** effect equal to 3.4 percent. Given the disparity between the coefficients, it is not surprising that the equality test rejects the null hypothesis, with a *p*-value well below 1 percent. Relying on this test in the absence of the legacy test, the conclusion is that LAX and the other core airports should not be grouped.

Table 7: LA Basin, CA

	Distance from (miles)						
	City Center	Primary Airport	Number of Markets With:†	LAX vs. LGB+BUR	LAX vs. 4 Others	LAX vs. LGB	LAX vs. BUR
LAX (Primary Airport)	18.8	--	Service from primary airport	75	75	75	75
BUR (Core Airport)	17.7	32.2	LCC "in"	34	34	34	34
LGB (Core Airport)	23.1	22.6	LCC "out"	15	15	14	5
SNA (Fringe Airport)	38.8	41.2	Legacy "in"	74	74	74	74
ONT (Fringe Airport)	39.7	56.6	Legacy "out"	4	8	0	4

Regression Results

	LAX vs. LGB+BUR	LAX vs. 4 Others	LAX vs. LGB	LAX vs. BUR
lcc_comps_in	-0.140**	-0.138**	-0.140**	-0.134**
lcc_comps_out	-0.0336*	-0.0242	-0.0338*	0.00291
leg_comps_in	-0.0651**	-0.0650**	-0.0641**	-0.0676**
leg_comps_out	-0.0145	-0.00898	N/A	-0.0116
Constant	5.306**	5.302**	5.300**	5.297**
Observations	1574	1574	1574	1574
R-squared	0.966	0.966	0.966	0.966
Null Hypothesis	**p-value**	**p-value**	**p-value**	**p-value**
lcc_comps_in = lcc_comps_out	0.000	0.000	0.000	0.0000
leg_comps_in = leg_comps_out	N/A	0.002	N/A	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Second-stage tests can be carried out to look for confirmation of this negative conclusion. The LAX vs. LGB and LAX vs. BUR columns show that equality of LCC coefficients is rejected in each case, showing that these pairwise groupings are not warranted (legacy tests cannot be carried out). Therefore, the negative conclusion of the first-stage test is affirmed.

In the Los Angeles area, an alternate categorization of airports might be defensible, with all the area airports aside from LAX viewed as core airports. In other words, SNA and ONT would become core airports, with the fringe category empty. The LAX vs. 4 others column of Table 7 shows the results of reapplying our methodology under this different categorization.

Now, enough **out** service is available to run both the legacy and LCC tests. But equality of coefficients is rejected for both legacies and LCCs, showing that this alternate airport categorization fails to overturn the previous conclusion against airport grouping in Los Angeles.

In section 4.2 below, we discuss why the grouping methodology may not provide sufficient evidence against grouping of LAX with other airports in the Los Angeles area in light of findings based on direct surveys of passengers (e.g., Ishii, Jun and Van Dender (2009)), which suggest that LAX could be grouped with the other core airports.

3.6. San Francisco metro area

The primary airport for the San Francisco metro area is San Francisco International (SFO), and the other core airports are Oakland (OAK) and San Jose (SJC), which are, respectively, 32 and 34 miles distant from SFO. Table 8 shows that during the sample period, service has been provided on 55 routes from SFO, with legacies having served 54 of these routes and LCCs having served 22.

Given ample **in** and **out** service from both types of carriers, both equality tests can be carried out. As seen in the SFO vs. OAK+SJC column of the table, the LCC **in** and **out** effects are fairly large at 14.8 and 12.4 percent, respectively, and both are significant. Since the coefficients are close in magnitude, the null hypothesis of equality cannot be rejected, with a *p*-value of 18.7 percent. The legacy **in** effect is 12.0 percent and statistically significant, and since the **out** effect is significantly positive, it comes as no surprise that equality is rejected, with a *p*-value well below 1 percent. However, given the LCC results, the grouping test suggests that SFO should be grouped with OAK and SJC.

The remaining columns of Table 8 indicate whether the second-stage tests affirm this conclusion. The SFO vs. OAK column shows coefficient estimates very similar to those in the first column, and the equality tests yield the same conclusions: rejection of coefficient equality for legacies and failure to reject for LCCs. These conclusions imply grouping of SFO and OAK. However, in the SFO vs. SJC column, both **out** coefficients become insignificant, while the **in** coefficients retain significance. The result is a rejection of coefficient equality for both legacies and LCCs, implying that SFO and SJC should not be grouped.

Table 8: San Francisco, CA

	Distance from (miles): City Center	Distance from (miles): Primary Airport	Number of Markets With:†	SFO vs. OAK+SJC	SFO vs. OAK	SFO vs. SJC
SFO (Primary Airport)	12.8	--	Service from primary airport	55	55	55
OAK (Core Airport)	21	31.8	LCC "in"	22	22	22
SJC (Core Airport)	45.9	34.4	LCC "out"	27	27	14
			Legacy "in"	54	54	54
			Legacy "out"	9	6	5

Regression Results

	SFO vs. OAK+SJC	SFO vs. OAK	SFO vs. SJC
lcc_comps_in	-0.148**	-0.168**	-0.0886**
lcc_comps_out	-0.124**	-0.147**	-0.0220
leg_comps_in	-0.119**	-0.117**	-0.131**
leg_comps_out	0.0441*	0.0647*	0.0308
Constant	5.683**	5.661**	5.680**
Observations	1158	1158	1158
R-squared	0.954	0.956	0.950
Null Hypothesis	**p-value**	**p-value**	**p-value**
lcc_comps_in = lcc_comps_out	0.187	0.256	0.006
leg_comps_in = leg_comps_out	0.000	0.000	0.000

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Therefore, the second-stage tests call for modification of the first-stage conclusion that all three airports should be grouped. Instead, only SFO and OAK should be grouped, a conclusion that makes sense in light of survey evidence in numerous studies suggesting strong substitutability between SFO and OAK (e.g., Ishii, Jun and Van Dender (2009) and Pels, Nijkamp and Rietveld (2001, 2003)).[30]

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[30] Ishii, Jun and Van Dender (2000) found, for example, that "[b]usiness travelers find OAK and SJC to be similar substitutes to SFO, but leisure travelers find OAK to be a much better substitute, controlling for included airport characteristics" (p. 221). Moreover, Pels, Nijkamp and Rietveld (2003) found that "it appears that SFO is a substitute for both OAK and SJC, while OAK and SJC are less a substitute" (p. 76). Furthermore, a 2002 survey

3.7. Miami metro area

The core airport for the Miami metro area is Miami International (MIA). Fort Lauderdale (FLL), 27 miles distant, is the other core airport, while West Palm Beach (PBI), 72 miles distant, is a fringe airport.

As seen in Table 9, nonstop domestic service has been provided on 37 routes from MIA over the sample period, with legacies having served 37 of these routes and LCCs having served 6. As in the cases of DCA and LGA, substantial additional legacy and LCC **out** service is provided to the endpoints of the MIA routes.

The MIA vs. FLL column of the table shows insignificant LCC competition impacts, but a significant legacy **in** effect is combined with an insignificant **out** effect. While coefficient equality is rejected for LCCs, equality is not rejected for legacies (the p-value is 14.7 percent). Thus, on the basis of the legacy test, MIA and FLL should be grouped.

The second-stage test asks whether the fringe airport PBI should be added to the MIA-FLL group. In the MIA + FLL vs. PBI column of Table 9, the LCC **in** coefficient (based on treating MIA and FLL as a single destination) is significantly negative. Since the **out** coefficient is insignificant, the equality test unsurprisingly rejects equality. Since there is non-overlapping

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conducted by Charles River Associates/Polaris Research found that almost one third (31%) of Bay Area OAK passengers originated their trip from counties closer to SFO than OAK (or those equidistant from the airports), indicating a high degree of substitutability between the two airports. See *Air Passengers From the Bay Area's Airports, 2001 and 2002, Volume 1: Overview and Methods*. Charles River Associates and Polaris Research and Development. CRA no. D03144-00, showing that 16% of OAK passengers were from San Francisco county, 7% from Sonoma county, 4% from Marin county and 3% from San Mateo county. Finally, a 1996 U.S. DOT study likewise found significant "halo effects" from Southwest's presence at OAK on prices at SFO: "Obvious examples of this [effect] involve Oakland and San Francisco, where Southwest serves some cities from one of these airports but not the other, yet Southwest's presence at either clearly affects price and traffic at both. Salt Lake City is a good example of this. Southwest serves Salt Lake City - Oakland and not Salt Lake City - San Francisco, yet between the third quarters of 1992 and 1995 Southwest's presence in the former market caused average prices to drop 43 percent and traffic to more than double in the latter market. Numerous such examples of the "halo" effect exist all across the country." *The Low Cost Airline Service Revolution,* U.S. Department of Transportation, (1996), page 11.

legacy **out** service for only two MIA + FLL routes, the legacy test is not carried out. But relying solely on the LCC equality test, the conclusion is that the three airports should not be grouped, leaving MIA and FLL as the Miami grouping.

Table 9: Miami, FL

	Distance from (miles)				
	City Center	Primary Airport	Number of Markets With:†	MIA vs. FLL	MIA+FLL vs. PBI
MIA (Primary Airport)	8.7	--	Service from primary airport	37	57
FLL (Core Airport)	25	27.5	LCC "in"	6	44
PBI (Fringe Airport)	69.2	71.6	LCC "out"	25	5
			Legacy "in"	37	42
			Legacy "out"	17	2

Regression Results

	MIA vs. FLL	MIA+FLL vs. PBI
lcc_comps_in	0.0479	-0.0731**
lcc_comps_out	-0.0225	-0.0129
leg_comps_in	-0.0445*	-0.0360*
leg_comps_out	-0.0210	0.0629
Constant	5.341**	5.341**
Observations	899	1152
R-squared	0.863	0.861
Null Hypothesis	**p-value**	**p-value**
lcc_comps_in = lcc_comps_out	0.007	0.000
leg_comps_in = leg_comps_out	0.147	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

3.8. Dallas metro area

The primary airport for the Dallas metro area is Dallas-Ft. Worth International (DFW), and Love Field (DAL), which is 19 miles distant (but much closer to the city center), is the other core airport. From Table 10, service has been provided on 121 routes from DFW over the sample period, with legacies (mainly American, for whom DFW is its largest hub) having served 121 of these routes and LCCs having served 10.

Since there is no non-overlapping legacy **out** service from DAL, the coefficient equality test for legacies cannot be carried out. But since additional LCC **out** service has been provided from Love Field to 13 DFW endpoints, the LCC test can be run. The LCC **in** and **out** effects are large at 18.0 and 43.5 percent, respectively, and both are significant. Given the large size of the **out** effect, coefficient equality can be rejected at well below the 1 percent level. While this outcome would ordinarily reject grouping, the coefficient sizes suggest the opposite conclusion. In particular, the fact that the **out** effect is more than three times as large as the **in** effect, with both coefficients significant, points to the existence of substantial competitive spillovers from DAL to DFW. Under these circumstances, grouping of the airports is warranted.

Table 10: Dallas, TX

	Distance from (miles)			
	City Center	Primary Airport	Number of Markets With:†	DFW vs. DAL
DFW (Primary Airport)	20.5	--	**Service from primary airport**	121
DAL (Core Airport)	7.5	19.4	**LCC "in"**	10
			LCC "out"	13
			Legacy "in"	121
			Legacy "out"	0

Regression Results

	DFW vs. DAL
lcc_comps_in	-0.180**
lcc_comps_out	-0.435**
leg_comps_in	0.00190
leg_comps_out	N/A
Constant	5.350**
Observations	2660
R-squared	0.864

Null Hypothesis	**p-value**
lcc_comps_in = lcc_comps_out	0.000
leg_comps_in = leg_comps_out	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

3.9 Tampa metro area

The primary airport for the Tampa metro area is Tampa International (TPA), with St. Petersburg-Clearwater (PIE), which is 18 miles distant, being the other core airport. As seen in Table 11, service has been provided on 58 routes from TPA, with legacies having served 40 of these routes and LCCs having offered service on 49.

Table 11: Tampa, FL

	Distance from (miles) City Center	Primary Airport
TPA (Primary Airport)	8.9	--
PIE (Core Airport)	18.4	17.7
SRQ (Fringe Airport)	60.8	52.4

Number of Markets With:†	TPA vs. PIE	TPA+PIE vs. SRQ
Service from primary airport	58	59
LCC "in"	49	51
LCC "out"	6	1
Legacy "in"	40	40
Legacy "out"	0	0

Regression Results

	TPA vs. PIE	TPA+PIE vs. SRQ
lcc_comps_in	-0.0659**	-0.0769**
lcc_comps_out	-0.0835**	-0.0588
leg_comps_in	0.0278	0.0199
leg_comps_out	N/A	N/A
Constant	5.040**	5.050**
Observations	1237	1238
R-squared	0.785	0.791

Null Hypothesis	p-value	p-value
lcc_comps_in = lcc_comps_out	0.569	N/A
leg_comps_in = leg_comps_out	N/A	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Since there is no non-overlapping legacy **out** service for TPA routes, the **leg_comps_out** coefficient cannot be estimated. As seen in the TPA vs. PIE column of the table, the LCC **in** and **out** coefficients are both significantly negative at 6.6 and 8.4 percent, respectively, and equality of these coefficients cannot be rejected (the *p*-value equals 56.9 percent). Given that the **legacy** test is unavailable, the LCC test alone determines our decision, and it indicates grouping of TPA and PIE.[31]

3.10 Cleveland metro area

The primary airport for the Cleveland metro area is Cleveland International (CLE), with Canton-Akron (CAK), which is 51 miles distant, being the other core airport.[32] As seen in Table 12, service has been provided on 56 routes from CLE, with legacies (mainly Continental, for

[31] Although Sarasota/Bradenton (SRQ) is a fringe airport, as seen in Table 11, there is not enough non-overlapping SRQ service to carry out second-stage tests.

[32] There is no fringe airport. As in the case of Boston, CAK could be treated as fringe, with CLE being the single core airport, with no effect on our procedures.

whom CLE is a hub) having served 56 of these routes and LCCs having served 7.

Table 12: Cleveland, OH

	Distance from (miles)		Number of Markets With:†	CLE vs. CAK
	City Center	Primary Airport		
CLE (Primary Airport)	11.9	--	Service from primary airport	56
CAK (Core Airport)	49.5	51.2	LCC "in"	7
			LCC "out"	9
			Legacy "in"	56
			Legacy "out"	1

Regression Results

	CLE vs. CAK
lcc_comps_in	-0.0617*
lcc_comps_out	-0.174**
leg_comps_in	0.0113
leg_comps_out	0.0264
Constant	4.666**
Observations	1041
R-squared	0.922

Null Hypothesis	p-value
lcc_comps_in = lcc_comps_out	0.022
leg_comps_in = leg_comps_out	N/A

** $p<0.01$, * $p<0.05$
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Since there is non-overlapping legacy **out** service on only one CLE route, the legacy test cannot be performed, although the **leg_comps_out** coefficient can be estimated. The LCC coefficients are both significant, but the **in** effect (at 6.2 percent) is smaller than the **out** effect, which equals 17.4 percent. Given the disparity between the coefficients, the equality test unsurprisingly rejects the null hypothesis. But, as in the case of Dallas, rejecting grouping on the basis of the test would be inappropriate given the evidence of substantial competitive spillovers from CAK to CLE, which are larger than the **in** effect.[33] Therefore, grouping of CLE and CAK is warranted.

3.11. Cincinnati metro area

The primary airport for the Cincinnati metro area is Cincinnati/Northern Kentucky

[33] Interestingly, the only significant competition effect at CLE is from LCC competition at CAK.

International (CVG), with Dayton (DAY), which is 79 miles distant, being the other core airport.[34] As seen in Table 13, service has been provided on 92 routes from CVG, with legacies (mainly Delta, for whom CVG is a hub) having served all of these routes and none served by LCCs.

Table 13: Cincinnati, OH

	Distance from (miles)			
	City Center	Primary Airport	Number of Markets With:†	CVG vs. DAY
CVG (Primary Airport)	13.3	--	Service from primary airport	92
DAY (Core Airport)	66.3	79.1	LCC "in"	0
			LCC "out"	6
			Legacy "in"	92
			Legacy "out"	8

Regression Results	CVG vs. DAY
lcc_comps_in	N/A
lcc_comps_out	-0.0584*
leg_comps_in	-0.0582**
leg_comps_out	-0.0353
Constant	5.866**
Observations	1669
R-squared	0.787

Null Hypothesis	p-value
lcc_comps_in = lcc_comps_out	N/A
leg_comps_in = leg_comps_out	0.509

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Since there is no LCC **in** service from CVG, the **lcc_comps_in** coefficient cannot be estimated. But, with additional legacy **out** service having been provided to 8 CVG endpoints, both legacy coefficients can be estimated, and the results show an **in** effect of 5.8 percent and an insignificant **out** effect. Despite the difference between the coefficients, the equality test cannot reject the null hypothesis (the *p*-value is 50.9 percent). Therefore the test implies that CVG and

[34] Again, there is no fringe airport, but DAY could be treated as fringe rather than core with no effect on our procedures.

DAY should be grouped.[35]

3.12. Detroit metro area

The primary airport for the Detroit metro area is Detroit Metropolitan (DTW), while Flint (FNT), which is 75 miles distant, is the other core airport.[36] As shown in Table 14, service has been provided on 90 routes from DTW, with legacies (mainly Northwest, for whom DTW is a hub) having served 89 of these routes and LCCs having offered service on 21.

Table 14: Detroit, MI

	Distance from (miles) City Center	Distance from (miles) Primary Airport	Number of Markets With:†	DTW vs. FNT
DTW (Primary Airport)	22.2	--	Service from primary airport	90
FNT (Core Airport)	67.8	74.9	LCC "in"	21
			LCC "out"	7
			Legacy "in"	89
			Legacy "out"	1

Regression Results

	DTW vs. FNT
lcc_comps_in	-0.148**
lcc_comps_out	-0.0438*
leg_comps_in	-0.115**
leg_comps_out	-0.163**
Constant	5.525**
Observations	1766
R-squared	0.883

Null Hypothesis	p-value
lcc_comps_in = lcc_comps_out	0.000
leg_comps_in = leg_comps_out	N/A

** p<0.01, * p<0.05
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

Since there has been non-overlapping legacy **out** service from FNT for only 1 DTW

[35] Although the grouping of two airports that are nearly 80 miles apart may seem counterintuitive, several surveys of Cincinnati area passengers confirm this finding. For example, one recent survey of 17,000 passengers at CVG airport found that only 23% of passengers used CVG for "all or most" of their personal or leisure trips. Likewise, 82% of business passenger responded that their firms encouraged them to use surrounding airports because of price. See http://www.cvgsurvey.com/. Likewise, our findings are also consistent with one U.S. DOT study found that "Cincinnati's high fares have motivated certain travelers to seek out lower fares at other airports in the region. One of the purposes of Delta's rollout of Simplifares in Cincinnati was to stem the diversion of revenue and traffic to other cities, such as Louisville and Dayton, where fares were generally lower than those available from Cincinnati." See *Fare Restructuring in Cincinnati – Second Quarter 2005*, Domestic Aviation Competition Issue Brief Number 28, U.S. Department of Transportation, Office of Aviation and International Affairs, Aviation Analysis.

[36] FNT could be treated as a fringe airport with no effect on the conclusions.

route, the equality of coefficients test for legacies is not carried out.[37] But, with additional LCC **out** service having been provided to 7 DTW endpoints, the LCC test can be run. The LCC **in** and **out** effects are, respectively, 14.8 and 4.4 percent (both are significant), and this disparity allows the equality test to reject the null hypothesis, with a *p*-value well below 1 percent. Although the legacy test is unavailable, the results of the LCC test by itself indicate that DTW and FNT should not be grouped.

3.13. Houston metro area

The primary airport for the Houston metro area is Houston Intercontinental (IAH), with Houston Hobby (HOU), which is closer than IAH to the city center, being the other core airport. As seen in Table 15, service has been provided on 100 routes from IAH, with legacies (mainly Continental, for whom IAH is its primary hub) having served all of these routes over the course of the sample period, while LCCs served only 2 of the routes. Instead of serving Houston through IAH, LCCs serve the metro area through HOU, with non-overlapping LCC service provided to 29 of the IAH endpoints. Only 4 of the IAH routes have had non-overlapping legacy service from HOU.

Given the bifurcation of legacy and LCC service at the two airports, neither the legacy test nor the LCC test is performed. But the **lcc_comps_out** coefficient is significant and large at 15.5 percent, suggesting strong competitive spillovers at IAH from HOU. Thus, even though the equality tests cannot be performed, the size of this LCC **out** effect justifies grouping of HOU and IAH.[38]

[37] In this case, the **leg_comps_out** coefficient cannot be estimated, given that the variable is perfectly collinear with the route fixed effects (a consequence of no inter-temporal variation).

[38] Note that even though the **lcc_comps_in** coefficient is significantly larger than the **lcc_comps_out** coefficient, it is based only two routes, and therefore should not be viewed as meaningful.

Table 15: Houston, TX

	Distance from (miles)			
	City Center	Primary Airport	Number of Markets With:†	IAH vs. HOU
IAH (Primary Airport)	21.7	--	Service from primary airport	100
HOU (Core Airport)	14.6	32.3	LCC "in"	2
			LCC "out"	29
			Legacy "in"	100
			Legacy "out"	4

Regression Results

	IAH vs. HOU
lcc_comps_in	-0.345*
lcc_comps_out	-0.155**
leg_comps_in	-0.0326
leg_comps_out	0.0172
Constant	5.585**
Observations	2026
R-squared	0.910

Null Hypothesis	p-value
lcc_comps_in = lcc_comps_out	N/A
leg_comps_in = leg_comps_out	N/A

** $p<0.01$, * $p<0.05$
† Number of markets where at some point during the sample period there was service
Carrier and route fixed effects and yearly and quarterly dummies suppressed
Robust Standard Errors
Dependent variable: ln(fare)
Data is quarterly from 2003 Q1-2009 Q4
Regressions are at the airport pair quarter level and are weighted by passengers

4. Additional Considerations

4.1. Additional considerations for New York

One measure of an economic decision rule's reliability—especially in instances where the rule's recommendations may be used to influence policy decisions—should be its ability to generate recommendations that conform to a "common sense" understanding of how markets work. The recommended groupings in Section 3 conform closely to such a "common sense" view for most of the largest multiple-airport metropolitan areas. One important metropolitan area where the formal test mechanism does not provide a clear grouping recommendation is New York, where the first-stage tests suggest grouping of LGA, EWR and JFK, but where the second stage test suggests that EWR should *not* be grouped with LGA and JFK. As discussed in Section 3 above, when the first-stage and second-stage tests are not self-reinforcing, outside information needs to be taken into consideration.

Continental's Newark hub is currently the largest "hub" airport in the New York City area[39] and its growing economic importance to the region has been documented in several studies.[40] Likewise, the U.S. DOJ chose to group the three large New York City area airports when assessing the competitive impact of granting Continental antitrust immunity as a member of the Star Alliance, even on short-haul, business oriented routes (presumably where airport choice matters the most). In particular, in its analysis of potential competitive issues in U.S.-Canada markets, DOJ "agree[d] with the [DOT] Order that the competitive structure of transborder routes is very similar to U.S. domestic routes" (page 27) but in assessing competition in the New York-Montreal and New York-Toronto markets (where Continental and immunized Star member Air Canada overlapped from Newark), DOJ noted that "The New York-Montreal/Toronto markets are currently served by four carriers on a non-stop basis – American [from LGA and JFK], Delta [from JFK] and the two Applicants [from EWR]."[41] These findings are also consistent with a recent study by Forbes (2008) studying competitive spillovers in the New York City area.[42]

Thus, in light of the EWR's hub status, recent findings from the academic literature, the DOT and DOJ findings discussed above and the findings from our first-stage tests, we believe a grouping of all three core New York City may be warranted.

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[39] For example, in June 2010, Continental offered 400 daily flights to 143 destinations from EWR versus 154 daily flights to 29 destinations by US Airways from LGA, 169 daily flights to 95 destinations from JFK by Delta and 150 daily flights to 53 destinations from JFK by jetBlue.

[40] See, for example, *Impacts of Continental Airlines Operations on the New York-New Jersey Regional Economy*, NERA Economic Consulting, November 2009.

[41] See footnote 71 of *Public Comments of the Department of Justice on the Show Cause Order*, Joint Application of Air Canada, The Austrian Group, British Midland Airways Ltd, Continental Airlines, Inc., Deutsche Lufthansa Ag, Polskie Linie Lotniecze Lot S.A., Scandinavian Airlines System, Swiss International Air Lines Ltd., Tap Air Portugal, United Air Lines, Inc. to Amend Order 2007-2-16 under 49 U.S.C. §§ 41308 and 41309 so as to Approve and Confer Antitrust Immunity, Docket OST-2008-0234, (June 26, 2009).

[42] Forbes (2008) found that each minute of delay at LGA lowered fares on a route from LGA by approximately $1.42, but that the price reduction increased to $2.44 per minute on routes the author defined as "competitive" including service from both JFK and EWR.

4.2. Additional considerations for Los Angeles

Although the coefficient equality tests alone do not imply any grouping of Los Angeles area airports, the tests can be supplemented by the results of other empirical studies that have relied on survey data of passengers. For example, based on the results of their study of travel between the San Francisco and Los Angeles metro areas, Ishii, Jun and Van Dender (2009) state that "both business and leisure travelers find BUR to be a better substitute for LAX than ONT or SNA. This likely reflects the relative proximity of BUR to Los Angeles proper, compared to ONT or SNA" (p. 222).[43] Although LGB was not covered by the study, a similar conclusion may apply to this airport. Given these observations, LAX, BUR and LGB could also reasonably be grouped.[44]

4.2. Summary of groupings

Table 16 shows the airport groupings implied by our methodology as well as modified groupings that draw on additional information. Whether the pure method-based groupings or the modified groupings are preferable is a matter of judgment, which can be left to the reader.

It should be noted that mutual consistency of the groupings is established based on the modified approach. In other words, the regressions for each metro area *outside* of Los Angeles assume that the LAX grouping is LAX + BUR + LGB.[45] Mutual consistency of the pure method-based groupings is also satisfied, although the regression estimates for metro areas other

[43] Recall from Table 7 that LAX is 19 miles from the city center, and that BUR and LGB are 18 and 23 miles, respectively from the city center.

[44] Moreover, as noted earlier, several US DOT studies (2002, 2003) group LAX with both our other core (BUR, LGB) *and* fringe airports (SNA, ONT).

[45] Although the second-stage tests for New York City conflict with the first-stage test by suggesting that EWR should not be grouped with LGA, consideration of other relevant factors lead us to follow the first-stage test. Thus both the method-based groupings and modified groupings treat LGA+JFK+EWR as a group. However, if we were to follow the second-stage tests, so that only LGA and JFK are grouped, then the groupings listed in Table 16 are not mutually consistent. In this case, the SFO+OAK grouping disappears for San Francisco-area airports, so that SFO is not grouped with other airports.

than Los Angeles would be slightly different from the ones reported in the preceding tables, due to the different groupings for this metro area

Table 16: Airport Groupings

City	P-Values for Equality Tests: Legacy	LCC	Primary Test Results	Groupings Implied	Additional Information	Conclusion
Boston *Primary: BOS* *Other Core: MHT, PVD*	N/A	0.000	Legacy N/A LCC effects unequal	**ungrouped**		**ungrouped**
Chicago *Primary: ORD* *Other Core: MDW*	N/A	0.404	Legacy N/A LCC effects equal	**ORD+MDW**		**ORD+MDW**
Cincinnati *Primary: CVG* *Other Core: DAY*	0.509	N/A	Legacy effects equal LCC N/A	**CVG+DAY**	Survey of CVG passengers www.cvgsurvey.com	**CVG+DAY**
Cleveland *Primary: CLE* *Other Core: CAK*	N/A	0.022	Grouping supported by size of LCC_out effect	**CLE+CAK**		**CLE+CAK**
Dallas *Primary: DFW* *Other Core: DAL*	N/A	0.000	Grouping supported by size of LCC_out effect	**DFW+DAL**		**DFW+DAL**
Detroit *Primary: DTW* *Other Core: FNT*	N/A	0.000	Legacy N/A LCC effects unequal	**ungrouped**		**ungrouped**
Houston *Primary: IAH* *Other Core: HOU*	N/A	N/A	Grouping supported by size of LCC_out effect	**IAH+HOU**		**IAH+HOU**
Los Angeles *Primary: LAX* *Other Core: BUR, LGB* *Fringe: SNA, ONT*	N/A	0.000	Legacy N/A LCC effects unequal	**ungrouped**	Ishii, Jun and Van Dender (2009)	**LAX+LGB+BUR**
Miami *Primary: MIA* *Other Core: FLL* *Fringe: PBI*	0.147	0.007	Legacy effects equal LCC effects unequal	**MIA+FLL**		**MIA+FLL**
New York *Primary: LGA* *Other Core: EWR, JFK* *Fringe: HPN, ISP*	0.000	0.315	Legacy effects unequal LCC effects equal	**LGA+EWR+JFK**		**LGA+EWR+JFK**
San Francisco *Primary: SFO* *Other Core: OAK, SJC*	0.000	0.187	Legacy effect unequal LCC effects equal	**SFO+OAK**	Ishii, Jun and Van Dender (2009), Pels, Nijkamp and Rietveld (2003), U.S. DOT (1996)	**SFO+OAK**
Tampa *Primary: TPA* *Other Core: PIE* *Fringe: SRQ*	N/A	0.569	Legacy N/A LCC effects equal	**TPA+PIE**		**TPA+PIE**
Washington, DC *Primary: DCA* *Other Core: IAD, BWI*	0.029	0.226	Legacy effect unequal LCC effects equal	**DCA+IAD+BWI**		**DCA+IAD+BWI**

Notes: Test results are for the potential grouping of primary airports with other core airports.

5. Conclusion

A critical first step in virtually all empirical research on the airline industry is a decision regarding the appropriate "markets" to study, a step that usually involves the choice between airport-pairs and city-pairs. Even though we adopted the airport-pair approach in Brueckner, Lee and Singer (2010), that paper demonstrated that failing to take account of competition (particularly by LCCs) from adjacent airports is likely to result in an incomplete picture of the competitive landscape. But while providing a strong endorsement for a broader (i.e., city-pair) approach, Brueckner, Lee and Singer (2010) did not provide researchers and policy makers who wish to use city-pairs as their unit of observation with a clear prescription for how to construct these city-pairs (that is, which airports to group as a single destination in large metropolitan areas).

The current paper provides a straightforward method for generating these groupings based on the magnitude of competitive spillovers across airports within a metropolitan area. In addition to providing further evidence that airport groupings are needed for appropriate market definitions when studying the link between competition and airfares, our analysis also provides a set of recommended groupings that are mutually consistent and conform to a common sense view of how airline markets should be delineated in the largest U.S. metropolitan areas.

Although we believe that our method provides a sound approach, we emphasize that it yields sufficient, but not necessary, conditions for constructing airport groupings. Thus, while competitive spillovers are clearly a key criterion for market definition, other available information should also be considered, including passenger surveys and airport proximity. Nor should our recommended list of airport groupings be considered as static, since, as carriers expand their services and add new routes, a reapplication of our methodology could alter the airport groupings summarized in Table 16.[46]

[46] As discussed earlier, there is currently not enough **in** and **out** service to perform our tests in large, multiple-airport metropolitan areas such as Phoenix and Orlando, a deficiency that new service could remedy.

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