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A long drive: Interregional airport passenger “leakage” in the U.S

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HIGHLIGHTS

- We examine the literature (academic and in practice) on U.S. airport passenger leakage.
- We focus on leakage from small and medium airports to large airports by personal vehicle.
- Key points of focus to further the research on interregional airport leakage are identified.
- Airport passenger leakage is a multimodal, inter-regional planning problem rather than solely an airport problem.
- Furthering the research depends on interregional data collection coordinated by cities, regions, and airports.

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ABSTRACT

Airport passenger leakage is the phenomenon of air travelers foregoing their local airport to access large hub airports with better flight options and airfares. Interregional passenger leakage has not received extensive attention from the research community; this review was conducted in light of changes in the U.S. aviation system over the last 15 years. We examine the U.S. airport passenger leakage literature, focusing specifically on leakage from small and medium airports to large airports by personal vehicle. We emphasize the need for on-going data collection, to support advanced methodological applications and development. This allows for empirically-based definitions of airport catchment in an interregional context, and support airport planning and marketing activities. We also observe a need for more attention to integrated multimodal, interregional planning – specifically, understanding the air and ground connectivity of the interregional transportation system, particularly in the U.S. where public transport provision is largely absent interregionally.

Contents

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1. Introduction

Airport passenger “leakage” is the phenomenon of air travelers choosing to drive relatively long distances to access larger hub airports, bypassing their local airport. Air passengers “leak” across regions to take advantage of convenient flight schedules, lower airfares, and other amenities at the larger (substitute) airport – features that can override the added cost of driving longer distances. Interregional airport passenger leakage has been documented for decades from airports in small or rural cities (Grubesic & Wei, 2012; Innes & Doucet, 1990; Kanafani & Abbas, 1987; Wittman, 2014). However, in more recent years, there is evidence that airline mergers, alliances, and decisions to cut operational costs and increase efficiency (coined “capacity discipline”) have reduced and degraded air services from small and medium-size airports. This has further resulted in these airports losing passengers to neighboring large airports (Ryerson, 2016b; Sharkey, 2015). But the subject of passengers “leaking” from a U.S. airport designated a small or medium hub (FAA, 2016) to large hub airports[1], often travelling well over 100 miles, has received less scrutiny from the research community. Despite airport competition and leakage being an issue worldwide, in this paper we focus specifically on the U.S. context in light of changes in the U.S. aviation industry.

Airport passenger leakage is a concern for airport operators, airlines, and ultimately, the traveler. Airport sponsors – typically cities or sub-state governmental authorities – have long sought to attract airlines to their airports, believing that air services stimulate regional economic development (Brueckner, 2003; Button & Taylor, 2000; Button, Doh, & Yuan, 2010; Green, 2007; Sheard, 2014). In fact, air service is viewed as so critical to a local economy that many airport sponsors throughout the world provide incentive packages funded by airport revenue to retain and build new service (Hihara, 2012; Malina, Albers, & Kroll, 2012; Ryerson, 2016a). Moreover, as passengers “leak” to an out-of-region airport, airlines will experience depressed demand at the local airport, leading to reduced flight schedules and higher fares. This vicious cycle is a detriment to passenger service, business development, and tourism at small and mid-sized cities.

This article's objectives are to: 1) identify the changing forces in both the U.S. aviation and surface transportation industries which make interregional airport passenger leakage a critical issue for researchers and decision makers, 2) review the methodological approaches that have been employed to assess leakage data, and 3) identify a research agenda to more comprehensively and rigorously understand leakage issues in the U.S. We target this review to researchers as well as industry practitioners looking to understand how airport passenger leakage has been studied in the past, in order to analyze future trends and impacts.

2. Changes in the U.S. aviation system facilitating airport passenger leakage

The first decade of the 21st century was characterized by a period of significant change in the U.S. aviation industry, resulting in growing mismatches between aviation demand and supply in proximate regions. The century began after a period of large-scale growth in flight departures (Goetz & Vowles, 2009). In contested markets airlines found that they could compete for passengers more effectively by adding targeted frequency, most notably by scheduling flights at times very close to those of their competitors (Borenstein & Netz, 1999; Hanlon, 1989; Wei & Hansen, 2005). Airlines purchased small regional jet aircraft seating 40–75 passengers to facilitate adding service frequency on key routes (GAO, 2014). However, the 2000s saw seven major U.S. airlines consolidate into three during a period of large variations in fuel price and economic recession. The newly merged airlines consolidated their networks and established fewer, more concentrated airline hubs, reducing flights on less profitable routes typically operated by small regional jets (Ryerson & Kim, 2013). Major airports situated in the largest cities (particularly in the Northeast corridor) and leisure regions such as Florida saw increases in their air service, while airports in smaller metropolitan areas (particularly the Rust Belt, Appalachia, Mississippi Valley, and parts of Idaho, Montana, and the rest of the Intermountain West) lost significant air service (Fuellhart, Ooms, Derudder, & O'Connor, 2016). In this era of “capacity discipline,” airlines are mainly flying certain (profitable) routes and charging higher airfares due to reduced competition. This has resulted in widening discrepancies in flight frequency, number of destinations served, and airfares at airports with significant service versus those without (Brueckner, Lee, & Singer, 2013; Governing: the States and Localities, 2013).

Although there are many studies on air and rail competition, there have been fewer studies on the competition between air and driving (Erhardt, Freedman, Stryker, Fujioka, & Anderson, 2007, pp. 130–138; Levinson, Gillen, & Kanafani, 1998). While there are modes other than driving available for intercity travel (such as intercity bus, or less frequently, rail), private vehicle travel has the largest market share in the U.S. for intercity travel below 600 miles (Resource Systems Group, Inc., 2015). Given that the per mile cost of driving decreases as a trip becomes longer, many travelers that choose to drive much longer distances to access an airport with better services do not fully realize and accurately account for the true costs of driving (VTPI, 2016). Moreover, air service discrepancies may simply overpower these driving costs.

3. Literature review scope

We bind the scope of this review to include studies on passenger leakage from small- and medium-size airports to large out-of-region hub airports in the U.S., with particular focus on quantitative modeling applications. The U.S. context creates a clear demarcation of scope; population densities in the U.S. tend to be lower than in Europe and Asia, resulting in a general lack of intercity public transport options to airports. We identify a specific competitive scenario for long-distance air travelers: travelers replacing a connecting flight from a (small-to medium-hub) local airport to a neighboring region's large hub airport with ground travel by private vehicle (or long-distance bus service, where available). These travelers effectively choose their point of entry into the aviation system over a geographic region that extends well beyond regional boundaries. Definition of these scenarios serves to exclude the literature on: competition and complementary of high-speed rail and air transport networks (Chester & Ryerson, 2014; Clewlow, Sussman, & Balakrishnan, 2012; Coogan, 2012; Lee & Chang, 2006); airport access mode choice (Jou, Hensher, & Hsu, 2011; Tam, Tam, & Lam, 2005); the U.S. Essential Air Service (EAS) program for rural airports (Cunningham & Eckard, 1987; Grubesic, Matisziw, & Murray, 2012); U.S.-Canada transborder leakage (Elwakil, Windle, & Dresner, 2013); and finally, the dynamics of a smaller airport's low-cost carrier service drawing passengers from a larger airport (Graham, 2013; Tierney & Kuby, 2008; Vowles, 2001).

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[1] These airports make up roughly the top 30 U.S. airports, each handling over 1% of the country's annual passenger boardings.

4. Airport catchments and passenger choice

4.1. Defining passenger market catchment areas

The definition of airport catchment and the determination of whether a passenger is leaking from one airport catchment to another are intrinsically linked. If an air passenger within one airport's catchment chooses an alternate airport in another region, this passenger is "leaking" from one airport market to another (Suzuki & Audino, 2003). However, defining an airport's catchment area is not a straightforward endeavor.

An airport market, or catchment, is generally described as the land area from which passengers are expected to use the services of that airport. This definition does not provide any information on the parameters of the catchment area itself; definitions differ widely in the literature and practice. For instance, Latvia's Riga International Airport defines its catchment as "the number of people living within an area in which people have approximately two hours of transport by bus, car or train to an airport." (Riga International Airport, 2009). Airports typically do not provide such clear definitions of their catchment areas. Researchers have employed numerous approaches that challenge the simplistic but most common method of "drawing concentric circles of travel distances around (the airport)" (Fröhlich & Niemeier, 2011). Lieshout (2012) employed a multinomial logit model using key variables known to influence airport choice (access time/cost, airfares, air travel time) to establish the catchment for Amsterdam's Schiphol Airport, while Fröhlich and Niemeier (2011) used stylized economic models of spatial competition to demonstrate overlapping airport catchment areas and therefore, the existence of competition. Suau-Sanchez, Burghouwt, and Pallares-Barbera (2014) considered catchment to be a function of population density and airport connectivity, as opposed to a simple function of distance (Fuellhart, 2007).

The defining difference between a passenger "leaking" to a different market versus choosing between airports in a multiple airport system should be the passenger's true origin within one or multiple catchment areas, respectively. Consider Fig. 1, which depicts airport catchment in a multiple airport system (MAS) – a set of significant commercial airports in a metropolitan region that may or may not be under the same ownership – versus interregional air passenger leakage (de Neufville & Odoni, 2003). Many MASs, such as those of the San Francisco Bay Area (SFBA), Washington/Baltimore, and Greater London, are heavily studied due to plentiful data availability. Data on airport and ground access choice within a MAS region is collected entirely under the jurisdiction of local government agencies such as metropolitan planning organizations (Shapiro, 1997). In interregional leakage, shown at the right in Fig. 1, air passengers considered to be within the catchment of one small or medium airport may choose to "leak" to a larger hub airport with more direct destinations, greater flight frequency, and lower airfares due to airlines' economies of density as well as more intense airline competition.

4.2. Passenger airport choice in MAS

Why air passengers choose one airport over another has been heavily explored in multi-airport regions. One of the earliest studies demonstrated, using a multimodal logit model, that ground accessibility and flight frequency were the dominant factors driving airport choice in the Washington D.C. area (Skinner, 1976). More airport choice studies in multiple airport regions emerged in the 1980s facilitated by the availability of passenger airport choice data, collected by regional transportation authorities to document airport access trips in their jurisdictions (Ashford & Bencheman, 1987; Harvey, 1987; Windle & Dresner, 1995). Researchers focused on the impacts of ground access characteristics, including distance and traffic congestion (Innes & Doucet, 1990), rail transit availability (Figueiredo Monteiro & Hansen, 1996; Hansen, 1995), and differentials in air service supply Cohas, Belobaba, and Simpson (1995). More complex model structures that could accommodate simultaneous choices combining airport, airline, and ground access mode choice followed, particularly for regions with plentiful data: SFBA (Basar & Bhat, 2004; Hess, 2004; Hess & Polak, 2006, 2010; Pels, Nijkamp, & Rietveld, 2001), London (Hess, 2005), and New York (Gupta, Vovsha, & Donnelly, 2008).

The results and findings from the above studies are varied; however, ground access time and flight frequency were commonly found to be the most significant determinants of airport choice. Some studies found that airport choice is most heavily influenced

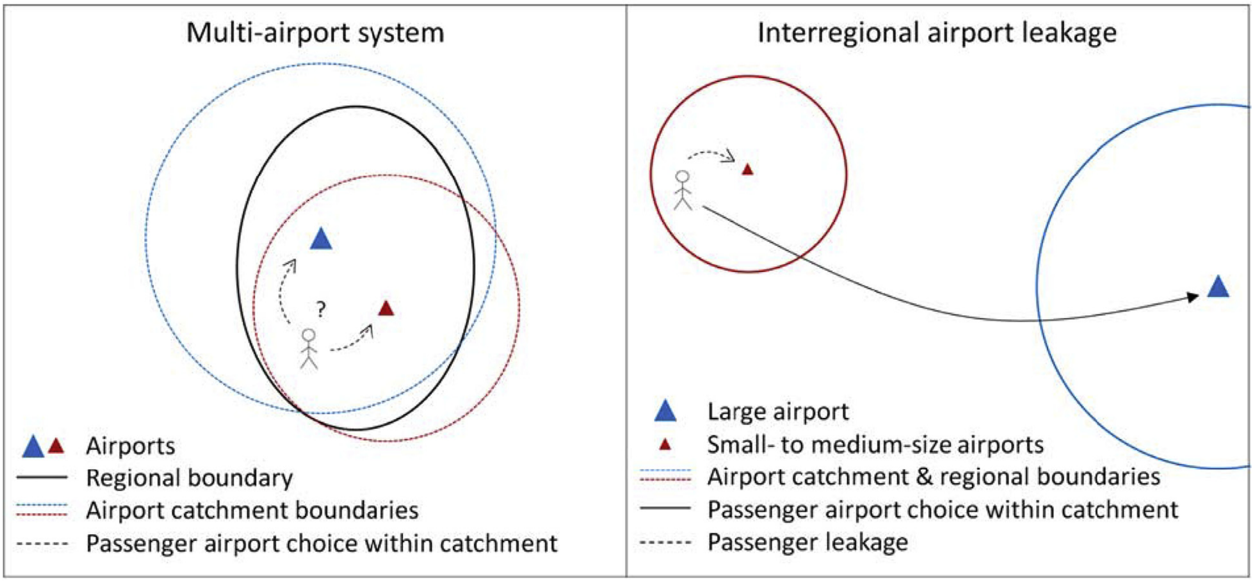

Fig. 1. The geography of airport choice in a multi-airport system (MAS) versus interregional passenger leakage.

by ground access characteristics or accessibility (Pels, Nijkamp, & Rietveld, 2003; Ishii, Jun, & Van Dender, 2009) while Harvey's study (1987) found air services characteristics to be of greatest importance. Using a survey of passengers at Hong Kong International Airport, Loo (2008) found that the most important attributes defining airport attractiveness were airfare, ground access time, flight frequencies, and number of airlines.

The vast majority of the above work on MAS airport choice considers air and ground transportation service characteristics to be exogenous to passenger demand, with two notable exceptions[2]. Hansen (1995), by estimating logit models of airport choice and employing these in a supply-and-demand equilibrium analysis, demonstrated that passenger volumes and airport services in the SFBA had a positive feedback relationship. Pels, Nijkamp, and Rietveld (2000) developed a nested logit model of passenger airport choice, and used this in a model of airport and airline competition, using the same SFBA dataset.

Based on the MAS airport choice literature, the key variables found to influence airport choice are:

Variables related to the traveler: travel group size; travel purpose (business or leisure); (ground) access travel time; airfare; availability of direct flights; flight frequency.

Variables related to the airport(s) and air service: available ground transport options and cost (personal vehicle, transit, airport shuttle, etc.); airlines serving an airport, service frequencies and aircraft types; airport amenities (parking, retail, terminal experience, etc.).

This review of airport catchment areas, and the modelling methodologies and explanatory variables used to understand MAS airport choice, provides a basic methodological background as we shift our attention to the related phenomenon of interregional airport passenger leakage.

5. Interregional airport passenger leakage

We cover the literature chronologically and in categories of academic studies and airport-driven studies, as the prevalence and types of studies performed on the subject follow historical changes in the U.S. air transportation system.

5.1. Academic studies

Studies from the 1980s and 1990s first documented the existence of airport passenger leakage, particularly at small airports located near urban regions with major hub airports (Kaemmerle, 1991; Kanafani & Abbas, 1987). Innes and Doucet (1990) evaluated residents' choices between three small airports with scheduled service in New Brunswick, Canada, using data on air service characteristics and travelers' decisions collected from travel agents in the region. Application of a multinomial logit model indicated that travelers highly preferred jet aircraft and direct travel, choosing airports farther away to obtain these services.

In the early 2000s, two studies used publicly available data to investigate airport passenger leakage. Suzuki and Audino (2003) used data from the Bureau of Transportation Statistics for 14 airport pairs throughout the U.S., where leakage was hypothesized to occur from the small/medium airport's expected catchment to a large airport up to 250 miles away. They estimated regression models demonstrating the existence of a two-way relationship between fares at the large hub airport and passenger volumes at the local airport. Fuellhart (2003) assessed passenger leakage to Baltimore-Washington International Airport (BWI) from in and around Harrisburg and Philadelphia. Although these cities are each served by their own airport, air passenger leakage was suspected to BWI from both, due to BWI's reputation for lower fares provided by low-cost carriers. The results suggested that air passengers were willing to drive an additional 70–90 miles for lower fares.

Also starting in the early 2000s were efforts to gather survey data on interregional airport choice, to support discrete choice modeling applications. A major data collection effort was undertaken for Des Moines International Airport (DSM) in Iowa (Suzuki, Crum, & Audino, 2003). DSM was very concerned about leakage of their passenger base to Kansas City International Airport, Minneapolis-St. Paul International Airport, and Omaha Eppley International Airport. The survey asked residents (via mailouts and an intercept survey at DSM) about their last trip from one of these four airports, and 317 viable responses were obtained. Multinomial logit models of airport choice indicated that travelers preferred airports with lower airfares, more non-stop services, and served by airlines with which the traveler collects frequent flyer miles. These models show that access time and flight frequency are insignificant, which is quite different from studies of MAS passenger choice. In line with previous studies, the authors found that leisure travelers were much more likely to leak than business travelers. In another study using the same dataset, Suzuki, Crum, and Audino (2004) used a discrete choice model within an endogenous airport profit maximization model. The latter model captures how a change in airfare offered by an airline at one competing airport impacts passenger volumes for other airlines and other airports. The authors showed that most airlines will experience reduced revenues when one airline reduces their airfares at the leakage airport, due to competitive responses. Another study by Suzuki (2007) modelled interregional airport and airline choice as a two-step process, challenging the assumption that people have the capacity to fully evaluate and consider all possible (out-of-region airport) options available.

A study using ticket booking data from Wyoming looked at the proportion of air passengers that substituted a connecting flight from a local airport to a hub airport, with driving directly to the hub airport (Phillips, Weatherford, Mason, & Kunce, 2005). The results of a two-stage regression indicated that leakage is positively related to the additional fare paid for a connecting flight from the local to hub airport, and that greater driving distances to the hub airport reduce leakage. Using residential zip code data collected at the Harrisburg International Airport (MDT) parking lot exit, Fuellhart (2007) assessed the spatial characteristics of MDT's passenger catchment area. A large set of observations was collected, to model the number of airport customers at a zip code using linear regression. Overall, the results show a potentially strong influence of BWI's lower airfares on leakage from MDT's core market catchment area. Zhang and Xie (2005) used logistic regression to model the probability of using a local community airport versus more distant large airports. Using data collected from an air passenger intercept survey at the Golden Triangle Regional Airport in Mississippi, the authors found that airfare, flight schedules, distance to airports, and previous experiences with the local airport are major factors impacting the choice to drive to more distant airports. Blackstone, Buck, and Hakim (2006) estimated probit models to assess the airport choices made by residents in the catchment area of Philadelphia International Airport (PHL), using phone survey data collected in 2000. The authors found that higher incomes increased the probability of having flown from Newark (EWR) or BWI, while if ground travel distance was an important consideration then the respondent was more likely to have flown from EWR, JFK, or PHL.

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[2] Models of air-HSR competition that account for supply and demand endogeneity are also found in the literature, notably (Adler, Pels, & Nash, 2010).

Concern with interregional airport passenger leakage is not confined to North America, as evidenced by a discrete choice modelling study of airport choice by passengers originating in the Campania region of southern Italy (de Luca, 2012). Although the study area is called a multi-airport region, only one of the three airports considered (Naples-Capodichino, or NAP) is located within Campania, while the two leakage airports primarily serve Rome. Stated preference data was collected via intercept surveys of Campania residents. The findings showed that the more trips an individual had made in the past, the more likely they were to travel through their closest airport (NAP). In addition, availability of a personal vehicle increased the likelihood of leaking to a Roman airport. Higher incomes also increased the likelihood of leakage to the Roman airports but only when better flight frequencies were offered. Another study looked at regional airports' loss of passengers to main airports in Norway (Lian & Rønnevik, 2011). The authors found that both fares and direct/connecting services impacted leakage levels but were not able to distinguish between the effects of these variables, as higher fares and connecting service were always prevalent at the regional airports.

A recent study focused on methods capturing the endogeneity between airfares and passenger volume shares for airport pairs with suspected leakage (Fu & Kim, 2016). The results confirmed the existence of airfare and passenger volume relationships between local and out-of-region hub airports, and that lower airfares at out-of-region airports have a greater impact on airport choices made by larger travelling groups.

5.2. Studies by airport authorities

The reality of passenger leakage, particularly as a response to “capacity discipline,” is confirmed by the actions of airport authorities to estimate and mitigate passenger leakage. There are numerous examples to be found: among them include the 19 Florida Airport Air Service Profiles (Kimley-Horn & Associates, Inc., 2012a,b), a study for Savannah/Hilton Head International Airport (Leigh Fisher, 2012), and another for Edmonton International Airport in Canada (Edmonton Airports, 1998). These reports confirm the regularity by which leakage occurs from areas served by smaller airports to those with larger airports, at distances up to 200 miles (Kimley-Horn & Associates, Inc., 2012a,b). Edmonton International Airport estimated that 750,000 Edmonton-area residents flew through Calgary International Airport annually, a hub airport 179 miles south of downtown Edmonton (Jang, 2010). Despite their ubiquity, these studies are typically limited to data descriptions; they do not include empirical modelling applications that may provide insights into the factors driving the passenger leakage – results that could inform the design of incentive programs attracting passengers back to local airports.

5.3. Synthesis of the literature

The literature suggests that leakage is a phenomenon worthy of attention from both researchers and practitioners. Overall, it has revealed that lower fares, greater flight frequency, better schedules, and direct services offered by airlines at large hub airports – in addition to passenger characteristics such as reason for travel (business or personal) and group size – are the main drivers of passenger leakage from regions served by small to medium airports. However, there remain some outstanding concerns: the range of added driving distances is large and not clearly defined (certainly there is no general consensus), and we do not thoroughly understand the drivers of out-of-region airport choice. The results available from numerous studies of MAS passenger choice do not directly address these issues, while the applied literature provides anecdotal treatments rather than statistically valid results.

The modeling techniques applied in both the numerous MAS and less-prevalent leakage studies (discrete choice models, game theoretic equilibrium models), in addition to a broader range of data visualization and network analysis models, are appropriate for continued investigation and tracking of interregional airport leakage. However, in order to do so, there are at least two key considerations to be made. Firstly, disaggregate traveler survey data (i.e., survey data collected at the individual person or household level) facilitating studies of interregional airport passenger leakage is typically not collected by government agencies. Researchers have collected this data themselves, often as part of projects funded by local airport authorities concerned about passenger loss. As a result, there have been a very limited number of these studies (Blackstone et al., 2006; Innes & Doucet, 1990; Suzuki et al., 2003; de Luca, 2012). This lack of disaggregate data has not allowed for broader application of well-accepted quantitative methodologies, which in turn does not allow us to clearly demarcate the geographic boundaries of leakage. Without clear geographic (and therefore, governance) boundaries, data collection efforts are stymied; thus, the study of interregional airport passenger leakage is caught in a vicious feedback loop (Fig. 2).

Secondly, interregional leakage in the U.S. is mainly facilitated by private vehicle, as highways and air transport largely facilitate interregional travel in North America. This leads to two further implications. First, models of MAS passenger choice are not directly applicable to the study of airport leakage, as these models typically consider that airport ground access options are a driver of airport choice. Second, a region that experiences significant air passenger leakage is also seeing those air passengers driving on intercity highways (often an interstate freeway in the U.S.). These air passengers may potentially take a measurable share of volumes on freeways (Ryerson & Kim, 2017), which have experienced huge growth since the 2008 economic downturn (Jin & Rafferty, 2017). As a result, there is incentive for state and federal DOTs to understand airport passenger leakage traffic on state and interstate facilities, and also give more attention towards understanding the connectivity and complementary of the intercity transportation system – particularly in the U.S. context where public transport provision is largely absent interregionally (although airport bus services are sometimes provided in heavy leakage corridors, such as Tucson to Phoenix International Airport). Increased co-operation between DOTs and airport authorities may encourage high-quality data collection (as per the first point) and more integrated, intermodal approaches to intercity transportation planning.

Table 1 provides a summary of the literature discussed in this section in chronological order.

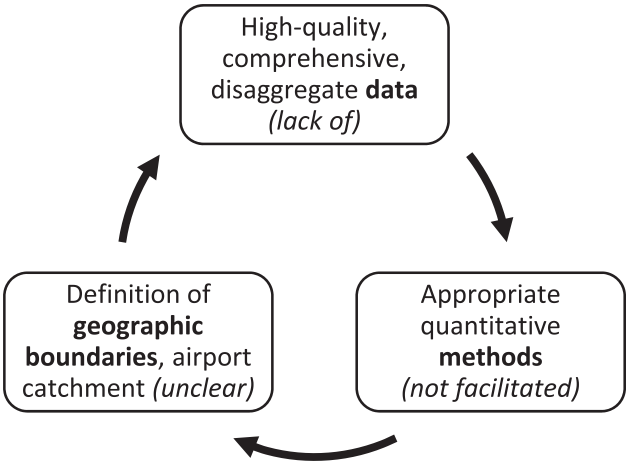

Fig. 2. Vicious feedback loop in the study of airport market leakage.

Table 1
Studies on interregional airport passenger leakage.

Study authors (publication year)	Geographic scope	Approx. driving distances[a]	Methods used	Traveller survey data?	Data source[b]	Key findings
Innes and Doucet (1990)	Province of New Brunswick, Canada (3 airports)	94, 125, 133 miles between airports	Multinomial logit (airport choice)	Yes	SDC	Travellers highly prefer jet aircraft and direct travel
Suzuki and Audino (2003)	14 U.S. airport pairs	–	Log-linear regression (2SLS)	No	PA	Passenger volumes and fares at local and possible leakage (large) airport related
Suzuki et al. (2003)	Des Moines (DSM), leakage to MCI, MSP, OMA (U.S.)	200, 250, 150 miles	Multinomial logit (airport choice)	Yes	SDC	Passenger leakage exists to BWI
Fuellhart (2003)	Harrisburg, PHL, leakage to BWI (U.S.)	97, 100 miles	Linear regression	No	PA	Travellers prefer airports with lower airfares, more non-stop services
Suzuki et al. (2004)	DSM, leakage to MCI, MSP, OMA (U.S.)	200, 250, 150 miles	Nested logit (airport choice)	Yes	SDC	Airlines serving DSM should reduce airfares to increase demand (and profits)
Phillips et al. (2005)	State of Wyoming (U.S.)	Avg. of 261 miles	Two-stage linear regression	Yes	SDC	More leakage with higher additional fare for connecting flight from local to hub airport; greater driving distances to hub airport reduce leakage
Zhang and Xie (2005)	Golden Triangle Regional Airport (GTR) leakage to MEM, JAN, BHM (U.S.)	170, 150, 80 miles	Logistic regression (of airport usage)	Yes	SDC	Factors influencing airport choice include: airfare, flight schedules, distance to airports, previous experiences with local (leakage) airport
Blackstone et al. (2006)	Philadelphia (PHL), leakage to BWI, Newark (EWR), JFK (U.S.)	100, 94, 115 miles	Probit model	Yes	SDC	Higher incomes increased probability of using EWR or BWI; higher likelihood of leaking if ground travel distance was important consideration
Fuellhart (2007)	Harrisburg, leakage to BWI (U.S.)	97 miles	Linear regression	No	SDC	BWI's lower airfares promote leakage from MDT's core market catchment
Suzuki (2007)	DSM, leakage to MCI, MSP, OMA (U.S.)	200, 250, 150 miles	2-step nested logit (airport choice)	Yes	SDC	Model demonstrates improved fit over Suzuki et al. (2004)
Lian and Rønnevik (2011)	Norway	84-850 miles	Logistic regression (binary airport choice)	Yes	PA	Fares and direct/connecting services impacted leakage levels; lower fares and greater car ownership enlarged catchment areas of main airports
de Luca (2012)	Campania Region: Naples, leakage to Rome airports (Italy)	131, 150 miles	Multinomial, cross-nested, mixed logit (airport choice)	Yes	SDC	Frequent flyers likely to use closest airport; increased likelihood of leakage with personal vehicle availability and higher incomes (but only when better flight frequencies available)
Fu and Kim (2016)	20 U.S. airport pairs	54-202 miles	Log-linear regression (2SLS)	No	PA	Lower airfares at hub airports have greater impact on airport choice of larger travelling groups

[a] Driving distances from local airport to large hub airport, unless otherwise indicated.
[b] (PA = publicly available, or SDC = purchased/sponsored data collection).

6. Concluding remarks & future research needs

We have provided an examination of the literature on interregional airport passenger leakage – from small and medium airports to large, out-of-region hub airports – within the U.S. context. We have covered methodological approaches, data, and major findings of studies on this topic with respect to interregional passenger leakage by personal vehicle (the mode traditionally associated with leakage in the U.S.). This topic has seen limited attention in the literature, largely due to lack of data and unclear definitions of airport passenger catchment beyond regional boundaries. Given the direction of U.S. aviation, namely, a deepening bifurcation between large hub airports with many flights and small/medium airports with dwindling flight service (Fuellhart et al., 2016), we expect that interregional airport passenger leakage will continue. Recent concerns with leakage have prompted operators of small and medium airports, in concert with local governments, to offer incentive programs to airlines to continue and/or grow their services (Ryerson, 2016b). Based on our review, we make some key research recommendations.

Firstly, we emphasize the need to collect data on intercity travel trends. Data would enable further modeling applications to interregional airport passenger leakage, the ability to provide empirically-based (and shifting) definitions of airport catchment, and stay abreast of changing trends in all these areas. Collected data might consist of survey data, passive data on travel patterns (i.e. intercity modal shares from anonymous cell phone data (Hui, Wang, Kim, & Qiu, 2017)), and others. Participation by local, state, and federal agencies – in addition to airport authorities – will be critical in gathering useful data. Application of discrete choice modelling methodologies should yield information such as demand elasticities (with respect to the key factors driving airport choice), critical distance, fare, and trip duration breakpoints, and value-of-time and willingness-to-pay estimates. These important values are largely absent from the limited literature on interregional leakage, despite that the key factors driving the choice to "leak" have been identified and quantified. These values are critical for precise targeting of the airline incentive programs mentioned above. Also important for the design of these incentive programs are equilibrium models focusing on the relationship between supply and demand, and airline competition. Although plentiful in the MAS literature, Suzuki et al. (2004) were the only authors to touch on airline pricing strategies and their implications in an interregional airport passenger leakage context. Future studies might explicitly look at airline strategies under competition with other airlines at the local leakage airport, at the large substitute airport, or both. Through data collection, we further highlight the need to revisit the definition of airport catchment. Rather than framing the interregional air passenger leakage problem as such, the definition of airport catchment should be revised to extend beyond regional boundaries, supporting multimodal transportation network planning at a mega-region level (Coogan et al., 2010). Precise definition of air passenger market catchment is instrumental in identifying leakage and designing targeted measures to combat it.

Secondly, a region that experiences significant air passenger leakage is also seeing those air passengers driving on intercity corridors (often an interstate freeway in the U.S.). These air passengers may take a measurable share of volumes on freeways, which have also experienced huge growth since the economic downturn of 2008 (Jin & Rafferty, 2017). As a result, there is incentive for state and federal DOTs to understand airport passenger leakage traffic on state and interstate facilities. More broadly, we feel that there should be more attention towards understanding the inherent connectivity and complementarity of the intercity transportation system. This is particularly true in the U.S. context where public transport provision is largely absent interregionally, despite clear empirical evidence of mega-regions based on commuter travel patterns (Dash Nelson & Rae, 2016). We have historically treated air and highway transportation as separate and disparate systems, instead of taking an intermodal approach such as those in Europe and Asia (Allard & Moura, 2016). There exists explicit competition between driving and flying in particular corridors – choices that are driven by the intercity transportation services themselves, as well as urban form. Increased co-operation between DOTs and airport authorities may encourage high-quality data collection and more integrated, intermodal approaches to intercity transportation planning.

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References

Adler, N., Pels, E., & Nash, C. (2010). High-speed rail and air transport competition: Game engineering as tool for cost-benefit analysis. *Transportation Research B, 44*(7), 812–833.

Allard, R. F., & Moura, F. (2016). The incorporation of passenger connectivity and intermodal considerations in intercity transport planning. *Transport Reviews, 36*(2), 251–277.

Ashford, N., & Bencheman, M. (1987). Passengers' choice of airport: An application of the multinomial logit model. *Transportation Research Record, 1147*, 1–5.

Basar, G., & Bhat, C. (2004). A Parameterized consideration set model for airport Choice: An application to the san Francisco Bay area. *Transportation Research B: Methodological, 38*(10), 889–904.

Blackstone, E. A., Buck, A. J., & Hakim, S. (2006). Determinants of airport choice in a multi-airport region. *Atlantic Economic Journal, 34*(3), 313–326.

Borenstein, S., & Netz, J. (1999). Why do all the flights leave at 8 am?: Competition and departure-time differentiation in airline markets. *International Journal of Industrial Organization, 17*, 611–640.

Brueckner, J. K. (2003). Airline traffic and urban economic development. *Urban Studies, 40*(8), 1455–1469.

Brueckner, J. K., Lee, D., & Singer, E. S. (2013). Airline competition and domestic US airfares: A comprehensive reappraisal. *Economics of Transportation, 2*, 1–17.

Button, K., Doh, S., & Yuan, J. (2010). The role of small airports in economic development. *Journal of Airport Management, 4*(2), 125–136.

Button, K., & Taylor, S. (2000). International air transportation and economic development. *Journal of Air Transport Management, 6*(4), 209–222.

Chester, M., & Ryerson, M. S. (2014). Grand challenges for high-speed rail environmental assessment in the United States. *Transportation Research A: Policy and Practice, 61*, 15–26.

Clewlow, R., Sussman, J., & Balakrishnan, H. (2012). Interaction of high-speed rail and Aviation: Exploring air-rail connectivity. In *Transportation Research Record Annual Meeting* (p. 15). Washington DC: National Academies.

Cohas, F. J., Belobaba, P. P., & Simpson, R. W. (1995). Competitive fare and frequency effects in airport market share modeling. *Journal of Air Transport Management, 2*(1), 33–45.

Coogan, M. A. (2012). *Quantifying the scale of air/rail complementarity and air/rail competition in Europe and the United States*. Washington, D.C.: Transportation Research Board.

Coogan, M. A., Hansen, M., Ryerson, M. S., Kiernan, L., Last, J., Marchi, R. F., et al. (2010). *ACRP report 31: Innovative approaches to addressing aviation capacity issues in Coastal Mega-regions*. Washington, D.C.: National Academies.

Cunningham, L. F., & Eckard, E. W. (1987). U.S. small community air service subsidies: Essential or superfluous? *Journal of Transport Economics and Policy, 21*, 255–277.

Dash Nelson, G., & Rae, A. (2016). An economic geography of the United States: From commutes to megaregions. *PLoS ONE, 11*(11), 1–23. e0166083, Retrieved from: https://doi.org/10.1371/journal.pone.0166083.

Edmonton Airports. (1998). *1998 annual report*. Retrieved 03 10, 2017, from: http://corporate.flyeia.com/sites/default/files/Files/Reports%20and%20Publications/46.pdf.

Elwakil, O. S., Windle, R. J., & Dresner, M. E. (2013). Transborder demand leakage and the US–Canadian air passenger market. *Transportation Research E: Logistics and Transportation Review, 57*, 45–57.

Erhardt, G. D., Freedman, J., Stryker, A., Fujioka, H., & Anderson, R. (2007). *Ohio long-distance travel model. Transportation research record (2003)*.

FAA. (2016, 03 03). *Airport categories*. Retrieved from Federal Aviation Administration: https://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/categories/.

Figueiredo Monteiro, A. B., & Hansen, M. (1996). Improvements to airport ground access and behavior of multiple airport system: BART extension to san Francisco international airport. *Transportation Research Record: Journal of the Transportation Research Board, 1562*, 38–47.

Fröhlich, K., & Niemeier, H. (2011). The importance of spatial economics for assessing airport competition. *Journal of Air Transport Management, 17*(1), 44–48.

Fuellhart, K. (2003). Inter-metropolitan airport substitution by consumers in an asymmetrical airfare environment: Harrisburg, Philadelphia and Baltimore. *Journal of Transport Geography, 11*, 285–296.

Fuellhart, K. (2007). Airport catchment and leakage in a multi-airport region: The case of Harrisburg international. *Journal of Transport Geography, 15*(4), 231–244.

Fuellhart, K., Ooms, K., Derudder, B., & O'Connor, K. (2016). Patterns of US air transport across the economic unevenness of 2003–2013. *Journal of Maps, 12*(5), 1253–1257.

Fu, Q., & Kim, A. M. (2016). Supply-and-demand models for exploring relationships between smaller airports and neighboring hub airports in the U.S. *Journal of Air Transport Management, 52*, 67–79.

GAO. (2014). *Aviation: Impact of fuel price increases on the aviation industry*. U.S. Government Accountability Office. Retrieved 11 28, 2016, from: http://www.gao.gov/products/GAO-14-331.

Goetz, A. R., & Vowles, T. M. (2009). The good, the bad, and the ugly: 30 years of US airline deregulation. *Journal of Transport Geography, 17*(4), 251–263.

Governing: the States and Localities. (2013, May 20). *Air service in steep decline at small and mid-sized city airports. Governing the states and Localities*. Retrieved from: http://www.governing.com/news/local/gov-air-service-steep-decline-small-city-airports.html.

Graham, A. (2013). Understanding the low cost carrier and airport relationship: A critical analysis of the salient issues. *Tourism Management, 36*, 66–76.

Green, R. K. (2007). Airports and economic development. *Real Estate Economics, 35*(1), 91–112.

Grubesic, T. H., Matisziw, T. C., & Murray, A. T. (2012). Assessing geographic coverage of the essential air service program. *Socio-economic Planning Sciences, Modeling Public Sector Facility Location Problems, 46*, 124–135.

Grubesic, T. H., & Wei, F. (2012). Evaluating the efficiency of the essential air service program in the United States. *Transportation Research Part A: Policy and Practice, 46*(10), 1562–1573.

Gupta, S., Vovsha, P., & Donnelly, R. M. (2008). Air passenger preferences for choice of airport and ground access mode in the New York City metropolitan region. *Transportation Research Record: Journal of the Transportation Research Board, 2042*(1), 3–11.

Hanlon, J. (1989). Hub operations and airline competition. *Tourism Management, 10*(2), 111–124.

Hansen, M. (1995). Positive feedback model of multiple-airport systems. *Journal of Transportation Engineering, 121*(6), 453–460.

Harvey, G. (1987). Airport choice in a multiple airport region. *Transportation Research A: General, 21*(6), 439–449.

Hess, S. (2004). A model for the joint analysis of airport, airline, and access-mode choice for passengers departing from the San Francisco Bay Area. In *European transport conference* (Strasbourg, France).

Hess, S. (2005). Analysing air-travel choice behaviour in the greater London area. In *45th congress of the European regional science association*. http://www-sre.wu.ac.at/ersa/ersaconfs/ersa05/papers/736.pdf.

Hess, S., & Polak, J. W. (2006). Airport, airline and access mode choice in the San Francisco Bay area. *Papers in Regional Science, 85*(4), 543–567.

Hess, S., & Polak, J. W. (2010). Airport choice behaviour: Findings from three separate studies. In P. Forsyth, D. Gillen, J. Müller, & H.-M. Niemeier (Eds.), *Airport Competition: The European experience* (pp. 177–196). Aldershot: Ashgate.

Hihara, K. (2012). An analysis of an airport–airline relationship under a risk sharing contract. *Transportation Research Part E: Logistics and Transportation Review, 48*(5), 978–992.

Hui, T. Y., Wang, C., Kim, A. M., & Qiu, T. (2017). *Investigating the use of anonymous cellular phone data to determine intercity travel volumes and modes. Transportation research board*. Washington, D.C.: National Academies.

Innes, J. D., & Doucet, D. H. (1990). Effects of access distance and level of service on airport choice. *Journal of Transportation Engineering, 116*(4), 507–516.

Ishii, J., Jun, S., & Van Dender, K. (2009). Air travel choices in multi-airport markets. *Journal of Urban Economics, 65*(2), 216–227.

Jang, B. (2010, November 29). *Edmonton airport looks to stem passenger leakage to Calgary*. Toronto, ON, Canada: The Globe and Mail. Retrieved 10 23, 2015, from: www.theglobeandmail.com/report-on-business/edmonton-airport-looks-to-stem-passenger-leakage-to-calgary/article1316259/.

Jin, J., & Rafferty, P. (2017). Does congestion negatively affect income growth and employment growth? Empirical evidence from US metropolitan regions. *Transport Policy, 55*, 1–8.

Jou, R.-C., Hensher, D. A., & Hsu, T.-L. (2011). Airport ground access mode choice behavior after the Introduction of A New mode: A case study of Taoyuan international airport in Taiwan. *Transportation Research E, 47*(3), 371–381.

Kaemmerle, K. C. (1991). Estimating the demand for small community air service. *Transportation Research Part A: General, 25*(2), 101–112.

Kanafani, A., & Abbas, M. S. (1987). Local air service and economic impact of small airports. *Journal of Transportation Engineering, 113*(1), 42–55.

Kimley-Horn & Associates, Inc. (2012a). *Airport air service profile: Orlando-sanford International airport*.

Kimley-Horn & Associates, Inc. (2012b). *Airport air service Profile: Miami International airport*.

Lee, J.-H., & Chang, J. S. (2006). Effects of high-speed rail service on shares of intercity passenger ridership in South Korea. *Transportation Research Record, 1943*, 31–42.

Leigh Fisher. (2012, 09 19). *Airline service and leakage study: Savannah/Hilton Head International airport*. Retrieved 03 10, 2017, from: http://savannahairport.com/pub/files/pdf/SAV-HHI-9-19-12-Presentation.pdf.

Levinson, D. M., Gillen, D., & Kanafani, A. (1998). The social costs of intercity transportation: A review and comparison of air and highway. *Transport Reviews, 18*(3), 215–240.

Lian, J. I., & Rønnevik, J. (2011). Airport competition—regional airports losing ground to main airports. *Journal of Transport Geography, 19*(1), 85–92.

Lieshout, R. (2012). Measuring the size of an airport's catchment area. *Journal of Transport Geography, 25*, 27–34.

Loo, B. P. (2008). Passengers' airport choice within multi-airport regions (MARs): Some insights from a stated preference survey at Hong Kong international airport. *Journal of Transport Geography, 16*(2), 117–125.

de Luca, S. (2012). Modelling airport choice behaviour for direct flights, connecting flights and different travel plans. *Journal of Transport Geography, 22*, 148–163.

Malina, R., Albers, S., & Kroll, N. (2012). Airport incentive Programmes: A European Perspective. *Transport Reviews, 32*(4), 435–453.

de Neufville, R., & Odoni, A. (2003). *Airport Systems: Planning, design and management*. New York: McGraw-Hill, Inc.

Pels, E., Nijkamp, P., & Rietveld, P. (2000). Airport and airline competition for passengers departing from a large metropolitan area. *Journal of Urban Economics, 48*(1), 29–45.

Pels, E., Nijkamp, P., & Rietveld, P. (2001). Airport and airline choice in a multiple airport Region: An empirical analysis for the san Francisco Bay area. *Regional Studies, 35*(1), 1–9.

Pels, E., Nijkamp, P., & Rietveld, P. (2003). Access to and competition between airports: A case study for the san Francisco Bay area. *Transportation Research Part A: Policy and Practice, 37*(1), 71–83.

Phillips, O. R., Weatherford, L. R., Mason, C. F., & Kunce, M. (2005). Passenger leaks and the fate of small community air service. *Economic Inquiry, 43*(4), 785–794.

Resource Systems Group, Inc. (2015). *Airport cooperative research program report 118: Integrating aviation and passenger rail planning*. Washington, D.C.: National Academy of Sciences.

Riga International Airport. (2009). *Airport erminology*. Retrieved from Riga International Airport: http://www.riga-airport.com/en/main/newsroom/aviation-terms.

Ryerson, M. S. (2016a). An analytical approach to documenting air carrier incentive programs in airport sustainability plans. *Transportation Research Record: Journal of the Transportation Research Board, 2569*, 1–15.

Ryerson, M. S. (2016b). Incentivize it and they will Come? How some of the busiest U.S. Airports are building air service with incentive programs. *Journal of the American Planning Association, 82*(4), 303–315.

Ryerson, M. S., & Kim, H. (2013). Integrating airline operational practices into passenger airline hub definition. *Journal of Transport Geography, 31*, 84–93.

Ryerson, M. S., & Kim, A. M. (2017). A Drive for Better Air Service: How air service imbalances across neighboring regions integrate air and highway demands. *Transportation Research A* (in press).

Shapiro, P. S. (1997). Intermodal ground access to airports: A planning guide - a good start. In *Sixth TRB conference on the application of transportation planning methods* (pp. 114–121) (Dearborn).

Sharkey, J. (2015). *Smaller airports struggle against big airports' lures*. New York, NY, United States: New York Times. Retrieved June 2015, from New York Times: http://www.nytimes.com/2015/03/17/business/smaller-airports-struggle-for-a-place-on-the-route-map.html?_r=1.

Sheard, N. (2014). Airports and urban sectoral employment. *Journal of Urban Economics, 80*, 133–152.

Skinner, R. E. (1976). Airport choice: An empirical study. *Transportation Engineering Journal, 102*(4), 871–883.

Suau-Sanchez, P., Burghouwt, G., & Pallares-Barbera, M. (2014). An appraisal of the CORINE land cover database in airport catchment area analysis using a GIS approach. *Journal of Air Transport Management, 34*, 12–16.

Suzuki, Y. (2007). Modeling and testing the "two-step" decision process of travelers in airport and airline choices. *Transportation Research Part E: Logistics and Transportation Review, 43*(1), 1–20.

Suzuki, Y., & Audino, M. J. (2003). The effect of airfares on airport leakage in single-airport regions. *Transportation Journal*, 31–41.

Suzuki, Y., Crum, M. R., & Audino, M. J. (2003). Airport choice, leakage, and experience in single-airport regions. *Journal of Transportation Engineering, 129*(2), 212–218.

Suzuki, Y., Crum, M. R., & Audino, M. J. (2004). Airport leakage and airline pricing strategy in single-airport regions. *Transportation Research Part E: Logistics and Transportation Review, 40*(1), 19–37.

Tam, M. L., Tam, M. L., & Lam, W. H. (2005). Analysis of airport access mode choice: A case study in Hong Kong. *Journal of the Eastern Asia Society for Transportation Studies, 6*, 708–723.

Tierney, S., & Kuby, M. (2008). Airline and airport choice by passengers in multi-airport regions: The effect of Southwest Airlines. *Professional Geographer, 60*(1), 15–32.

Vowles, T. M. (2001). The "Southwest Effect" in multi-airport regions. *Journal of Air Transport Management, 7*(4), 251–258.

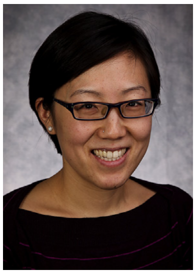
VTPI. (2016, October). *Transportation cost and benefit Analysis: Techniques, estimates and implications*. Victoria Transport Policy Institute. Retrieved October 27, 2016, from: http://www.vtpi.org/tca/.

Wei, W., & Hansen, M. (2005). Impact of aircraft size and seat availability on airlines' demand and market share in duopoly markets. *Transportation Research Part E, 41*, 315–327.

Windle, R., & Dresner, M. (1995). Airport choice in multiple-airport regions. *Journal of Transportation Engineering, 121*(4), 332–337.

Wittman, M. D. (2014). Public funding of airport incentives in the United States: The efficacy of the small community air service development grant program. *Transport Policy, 35*, 220–228.

Zhang, Y., & Xie, Y. (2005). Small community airport choice behavior analysis: A case study of GTR. *Journal of Air Transport Management, 11*(6), 442–447.



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A drive for better air service: How air service imbalances across neighboring regions integrate air and highway demands

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ABSTRACT

Between 2000 and 2010, newly merged U.S. airlines decreased service to airports in small and mid-sized metropolitan regions, opting to consolidate their operations at high-value airport hubs (passenger transfer points). At this point travelers living in small and mid-sized regions likely began leaking, or abandoning their local airport to take flights from hub airports offering more convenient flight options. The extent of this practice, however, is not well established. Our study asks to what extent airline consolidation deepened the divide in service levels between airports that are 100–300 miles apart, and seeks to estimate the magnitude of air traveler leakage at small and medium airports across the U.S. We estimate that travelers living in small and mid-sized metropolitan regions have the incentive to "leak" from their airport to a distant, better-served airport. Our estimates suggest that 15.7%–31.8% of the total passengers living proximate to a small or mid-sized airport have the incentive to leak. Our estimates range from 10.8% to 33.0% for travelers facing a non-stop itinerary from their local airport and 33.3%–85.1% for travelers facing a connecting itinerary. The potential leaked passengers contribute 1–2.75% of average daily highway traffic at heavily congested portions of the interstate highways connecting airports and up to 10–12% of traffic on low density portions of the highway. Our study illustrates the relationship between interregional surface transportation and the aviation system by estimating the number of travelers who may choose to travel long distances by car to access a relatively busier, larger airport with better service. The results of this study help to shape the evolving role of airport managers in controlling demand and delay at major hub airports and in building and managing air service and smaller airports across the U.S.

1. Introduction

Airport owners and operators (often called "airport sponsors," typically cities or sub-or multi-state authorities), Metropolitan Planning Organizations (MPOs), and state transportation agencies have long come together to plan local roads, rail transit systems, and highways proximate to airports to facilitate local mobility and reduce congestion. Hub airports with high levels of air service can be large trip generators for a region; consider that Los Angeles International Airport is the largest trip generator in the LA region (Giuliano et al., 2010; Gordon and Richardson, 1996). Thus, planning airport access for passengers and employees within an airport's catchment area, or in a region with multiple airports (comprising a Multiple Airport System), is a critical role for airports in managing local congestion and promoting airport access.

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Since the 2000 s, however, significant changes in the aviation system have possibly extended the geography over which passengers engage in an airport choice decision. When seven major U.S. network airlines merged into three in the 2000 s, the newly merged airlines consolidated their networks: they concentrated flights at their key hubs and reduced flights in smaller, marginally profitable markets (Fuellhart et al., 2016; Ryerson and Kim, 2013). It is therefore possible that airports that serve as airline hubs, with their relatively higher levels of air service, were able to expand their catchment areas by attracting more passengers residing in the catchment areas of relatively smaller airports that lost service due to airline mergers. The practice of a traveler choosing a substitute airport – typically one that is 100–300 miles away from their local airport – is broadly referred to as a traveler "leaking" to another airport.

Airports and supporting infrastructures are enormous public investments, made in anticipation of better serving existing and potential future travel demands. In essence, in planning airports, planners seek to match the transportation supply to the market demand as best as possible, to maximize the efficient usage of public monies. Therefore, airport managers as well as federal, regional, and highway planners should be concerned with airport market leakage. Leakage indicates the fluidity with which travelers' substitute air and surface transportation over a wide geography possibly leading to an imbalance in infrastructure use. In addition, stemming the concentration of airport demand on a few airports, rather than spreading this demand out to a number of regional airports, renders the aviation system vulnerable to outages at large airports and creates more demand for airport infrastructure in already constrained urban locations. Passengers leaking to a large airport in a neighboring city could depress air demand at a local airport, thus perpetuating a vicious cycle of flight levels being reduced and airfares going up, encouraging more passenger leakage, and so on. Airport market leakage is also an indication of fleeing economic development. As travelers abandon their local airport, they are reducing the flow of revenue to their airport from parking fees, concessions, and ticket taxes. In short, leaking travelers contribute to the deepening of the divide of the economic development potential, both direct and indirect, across cities (Harrison and Hoyler, 2015).

In the following study, we seek to uncover a) the factors that could have encouraged leakage in specific air markets in the U.S. (i.e., changes in relative air service and air fare levels at airports 100–300 miles apart since the mid-2000 s) and b) the leakage magnitude, specifically the number of air travelers with a higher likelihood of choosing a distant, larger airport than their local airport. We scale the magnitude as a function of the current surface transportation flows and the airport demands such that the scale of the leakage through the past eight years is established. The results of this study help to shape the evolving role of airport managers in controlling demand and delay at hub airports and in building and managing air service at smaller airports across the U.S.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature, including the precipitating events in the aviation system that led to possible service and fare imbalances at relatively larger and relatively smaller airports and the body of literature that directly addresses traveler airport and airport access mode choice and airport market leakage. In Section 3 we present our study geographies and evaluate the relative changes in service and airfares at the airports over our study geographies. In Section 4 we present our methodology and estimate the quantity of passengers leaking to a distant airport and present our findings, for our study geographies, on the number of travelers leaked from a relatively small to a relatively large airport. These estimates enable us to compare the volume of traffic generated by leaked passengers and existing highway volumes on the most-likely traffic route of each passenger. In Section 5 we explore the implications of airport market leakage and then conclude with a discussion about the role of airports in managing their changing congestion levels and catchment areas.

2. Literature review

2.1. An environment ripe for airport market leakage

Between 2008 and 2013, six major U.S. carriers merged into three – United Airlines with Continental Airlines (2010), Delta Air Lines with Northwest Airlines (2008), and American Airlines with US Airways (2013) – during a period of large variations in fuel price and economic recession. These newly merged airlines consolidated their networks and hub operations and established fewer, more concentrated airline hubs (Ryerson and Kim, 2013). Hub airports situated in the largest cities saw their air service strengthen while airports in smaller metropolitan areas lost significant service (Brueckner et al., 2013). Fuellhart et al. (2016) find that between 2003 and 2013, hub airports situated in the largest cities (particularly in the Northeast corridor) and leisure regions such as Florida and the southeast saw increases in their air service, while airports in smaller metropolitan areas (airports roughly between the top 50–75 of U.S. airports by passengers carried, particularly in areas such as the Rust Belt, Appalachia, Mississippi Valley, and parts of Idaho, Montana, and the rest of the Intermountain West) lost significant air service. The authors develop a map displaying the change in departures, passenger levels, and available seats and find that airports within 100–300 miles of the busiest airports in the Southeast, the South, the Midwest, and the West (such the small airports proximate to the hub airports of San Francisco and Los Angeles CA; Dallas Fort Worth and Houston TX; Atlanta GA; Charlotte NC; Phoenix AZ) lost passengers and flight frequency while these metrics increased at the hub airports. These findings indicate the widening discrepancies between 2003 and 2013 in flight frequency, number of destinations served, and airfares at airports with significant service versus those without.

The service imbalances have caused airports that lost service to actively seek out new air service. Airport sponsors do not directly control airline or passenger demand; they have, however, have long sought to attract airlines to their airports, believing that air services stimulate regional economic development (Brueckner, 2003; Button et al., 2010; Button and Taylor, 2000; Green, 2007; Sheard, 2014). In fact, air service is viewed as so critical to a local economy that many airport sponsors provide incentive packages funded by airport revenue to retain and build new service, in the U.S. and throughout the world (Hihara, 2012; Malina et al., 2012; Ryerson, 2016a, 2016b; Smyth et al., 2012). Incentives may also be used at relatively small airports with little service to reduce airfare. While airlines may be able to command a premium for travel from their hubs (Borenstein, 1989; Borenstein and Rose, 2007), airlines also raise fares when there is reduced competition in a market (Brueckner et al., 1992); as a result, many airports in smaller metropolitan areas experience relatively higher airfares due to reduced competition. Despite the potential for incentives to reduce fares at high-fare smaller airports and also build regional economic development in relatively small metropolitan areas, Ryerson (2016b) found that the airports most successful in recruiting and retaining new air service through incentives are the largest of the airports that already serve as airline hubs, rather than the small or medium airports that are struggling with very little service. Despite their efforts, incentives for new service at the small and medium airports to provide new flight services – and thus capture more local demand – have not been successful enough in stemming service losses and possible increases in airfare at these relatively smaller airports.

2.2. Airport market leakage: definitions and scope

An airport market, or catchment, is the land area from which passengers are expected to originate and use the services of a particular airport. A traveler could decide to use their local airport for their air trip, and from that airport travel to their destination on a non-stop flight or a connecting flight through a hub airport. An air traveler could also decide to “leak” to an out-of-region airport and access a large hub airport (typically by driving). From the hub airport the traveler will likely travel by a non-stop flight to their destination (de Luca, 2012). The motivations of an air traveler to leak to a distant market are linked to the spatial characteristics of airport markets, as well as differences in airfares and schedule frequency across airports.

It is clear that the concept of a local vs. neighboring out of region airport is linked to the definition of catchment. However, there is no general industry-wide consensus on how to define and measure catchment. Researchers have drawn concentric circles around airports (Fröhlich and Niemeier, 2011), used population data and functions of distance to estimate airport catchments in regions with multiple airports (Fuellhart, 2007; Kaemmerle, 1991; Suau-Sanchez et al., 2014), and used logit and other functional forms to estimate passenger choice of airports (located within a single region) based on the key variables known to influence airport choice (access time/cost, airfares, air travel time) (Hsu and Wu, 1997; Lieshout, 2012). The definition of airport catchment and the definition of a traveler leaking from one airport catchment to another are intrinsically linked; if an air passenger within an airport’s catchment chooses to travel to a substitute airport for their air travel, this passenger is “leaking” from their airport market to another (Suzuki et al., 2003).

Air passengers may leak to a large airport as that airport has more air service than their local airport. The categories of airports defined by the FAA are as follows: large airports carry at least 1% of all annual passenger boardings at U.S. Airports; medium airports carry at least 0.25% but less than 1% of annual passenger boardings; small airports carry at least 0.05% but less than 0.25% of annual passenger boardings; and non-primary airports carry at least 10,000 passengers but less than 0.05% of annual passenger boardings (Federal Aviation Administration, 2014). Consider that large airports (including the hub airports of Atlanta, Chicago, New York, and Los Angeles) have substantial runway and airport infrastructure and many serve as transfer points for passengers and freight. Airports that fit in the category of large serve between 7.9 and 46.6 million passengers per year. Medium airports enplane between 1.9 and 6.1 million passengers per year and do not serve as hubs for a major airline; thus they tend to have a mix of flights that travel directly to a large hub to facilitate connecting traffic and some non-stop service to other, non-hub markets. Small airports enplane between 400,000 and 1.8 million passengers per year and serve significantly fewer flights compared with large and medium airports. Small airports tend to have mostly service to large hub airports, enabling connections to a wide range of destinations but not offering non-stop service themselves.

2.3. Multiple airport systems and airport market leakage: differences and similarities

The key difference between a traveler leaking to an out of region airport versus choosing between multiple airports within a multiple airport system is the location of the traveler’s true origin (home, work, etc.) in or outside the origin airport catchment. If a traveler is located within the catchment area of more than one airport and they choose to travel from one such airport, then they are making a choice within a multiple airport system (MAS): a system of commercial airports that serve a single metropolitan region, classified at least as small – airports roughly between the top 50 to 75 of U.S. airports by passengers carried – by the Federal Aviation Administration (FAA) (de Neufville and Odoni, 2013). Scholars have established that travelers residing in a MAS choose airport and flight itineraries jointly, optimizing a set of options (Pels et al., 2003), including the choice of airport based on low cost airline services (de Neufville, 2006; Tierney and Kuby, 2008; Vowles, 2001). Others have identified the importance of ground access characteristics on a traveler’s choice of airport, including the effects of distance and traffic congestion (Innes and Doucet, 1990), availability of rail transit connections (Hansen, 1995; Monteiro and Hansen, 1996; Shapiro, 1997) and physical barriers and characteristics (Pels et al., 2003; Windle and Dresner, 1995).

Metropolitan Planning Organizations (MPOs) and airport sponsors in regions with a MAS regularly engage in planning local surface access to the system of airports. The Port Authority of New York and New Jersey has long worked with the Regional Planning Agency and spearheaded the development of the AirTrain, a transit service connecting the two hub airports in the NY metropolitan area with the surface transit system (Zupan et al., 2011). Massport (2013), the operator of Boston Logan International Airport, collects regular Air Passenger Surveys to understand the modes by which passengers access their airport. The Regional Airport Planning Committee (RAPC, 2011) under the Metropolitan Transportation Commission of the San Francisco Bay Area, surveys passengers at the three international airports in the region to study airport access mode choice and the spatial distribution of home origins for passengers at all three airports.

With interregional airport market leakage, air passengers considered to be within the catchment of one small or medium airport choose to travel by surface transportation (typically driving) to a large airport, often one that serves as an airline hub. While this phenomenon is well understood for travelers living in a rural area with an airport with very low service levels such that it falls below the top 75 airports by passenger count (Grubesic and Wei, 2012), literature on passengers located in the catchments of small and medium airports leaking to large airports is nascent. The literature does establish that air travelers within the catchment of a small airport "leak" across regions in order to take advantage of better, more convenient flight options, lower airfares, and other amenities at a larger (substitute) airport – features that can override the added cost of driving long distances to access air travel. The majority of airport market leakage studies apply regression models to publicly available data of passenger volumes and service attributes such as airfares and flight frequencies, to show correlation between these features (Fu and Kim, 2016; Fuellhart, 2003; Lian and Rønnevik, 2011; Phillips et al., 2005; Suzuki et al., 2003; Zhang and Xie, 2005). There are far fewer studies that use primary survey data to study traveler airport choice between local and substitute airport pairs (de Luca, 2012; Fuellhart, 2007; Suzuki et al., 2003, 2004).

Among the most comprehensive studies using primary data is de Luca (2012), who investigated the airport choice of residents of Italy's Campania Region, which includes Naples and is adjacent to Rome. The author collected stated preference data via intercept surveys of Campania residents, to understand their choices between the Naples airport (local) and two Roman airports (one large international hub, one smaller), and motivations for doing so. The author estimated utility functions to look at two choice situations: one where the traveler considers a non-stop flight (to any destination) from the local or one of the substitute airports, and another where the traveler considers either a non-stop flight or a connecting flight from the local or substitute airports. The passenger utility for a non-stop flight itinerary from any of the three airports is set as a function of airfare, flight frequency, and ground access distance between either the substitute or the local airport and the destination. The passenger utility function that allows comparisons between connecting and non-stop flight itineraries from the local or substitute airports is a function of air travel time, which includes any dwell (connecting) time, ground access travel time, and airfare.

The prevalence of data for airport access studies and the dearth of data for airport market leakage studies indicate the strength of integrated airport and surface transportation planning institutions. Local airport access in a MAS is a topic that airports and MPOs have identified as important for decades; as such, it receives focus, scrutiny, and resources for study. In contrast, airport market leakage is poorly understood. While some airports (such as Orlando Sanford, as documented by Kimley-Horn and Associates, Inc., 2012) engage in leakage studies, the data or (oftentimes) the studies are not made publicly available. Moreover, the results of airport market leakage studies are not integrated into surface transportation plans. The TRB Special Report 320 on Interregional Travel in 2016 noted that there is a lack of data on long-distance travel, stemming from the lack of coordinated funding and planning institutions that cover groups of neighboring cities or megaregions. The urban transportation planning community also laments the lack of institutions for megaregional planning (Dewar and Epstein, 2007; Innes et al., 2010).

3. Methodology and data collection

3.1. Choosing the study markets

We choose to focus on a specific subset of airports: small and medium airports within 70–300 miles of a large airport in regions of the country. We looked for U.S. airports ranked in the top 30–75 of enplaned passengers, meaning they are designated by the Federal Aviation Administration as small or medium airports and are within 70–300 miles of a large (top 30 airport by enplaned passengers) designated as a hub by a U.S. airline. We choose airport pairs (small/medium airport and proximate large airport) that are 1) made up of one small or medium airport and one large airport; 2) located in separate Metropolitan Statistical Areas; 3) at least 70 miles apart and no more than 300 miles apart. We eliminate airport pairs for which the small or medium airport is within 300 miles of two large airports, since it would be difficult to isolate the leakage volumes to each of the large airports (as evidenced by Hess et al. (2013)).[1]

We choose the range of up to 300 miles based on the existing literature. Studies have estimated and found airport market leakage in the range of 200 miles (Kimley-Horn and Associates, Inc., 2012). Suzuki et al. (2003) studied and found leakage from Des Moines, IA to hub airports up to 230 miles away. Studies by Phillips et al. (2005) and Suzuki et al. (2004) estimated and found airport market leakage for markets separated by 250–260 miles. Given the changes in the aviation industry since these studies were conducted (prior to 2005), we broaden the leakage range to be up to 300 miles.[2]

Twelve airport pairs and four substitute airports meet our requirements and are the focus of our study (Fig. 1). Our sample includes four large airline hubs: the major airports in the cities of Atlanta, Charlotte, Phoenix, and Dallas/Fort Worth and one to five local airports surrounding each hub. We collect data on these airports from 2007 to 2015; we choose this date range to cover the change in air service immediately prior to the wave of airline mergers and the economic recession through the present day.

3.2. Collecting, matching, and mapping data

We collect data on air service, airfares, travel distances to air destinations, and surface ground access distances for our local and substitute airports. For each airport (substitute or local), we collect the list of destinations for which a connecting and a non-stop

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[1] Knoxville Airport is within 300 miles of Charlotte Airport yet the travel time is relatively high, as the two airports are connected by I-40 which runs through the mountains of east Tennessee/west North Carolina.

[2] Informal conversations with airport managers also provide support.

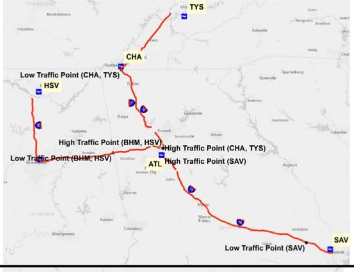
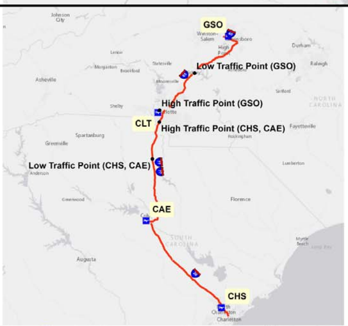
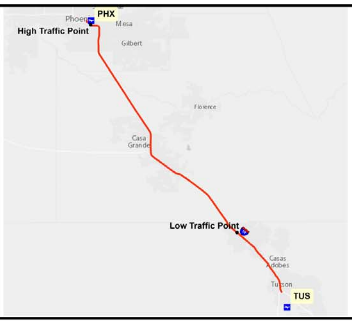
Local Airport	Substitute Airport and Megaregion	Distance, local to substitute airport (miles)	Interstate Connection	Map
Chattanooga Metropolitan (CHA)	Atlanta (ATL), Piedmont Atlantic Megaregion	123	I-75	
Huntsville (HSV)		201	I-20	
Birmingham (BHM)		152	I-20	
Savannah (SAV)		240	I-16	
Knoxville (TYS)		224	I-75	
Columbia Metropolitan (CAE)	Charlotte Douglas (CLT), Piedmont Atlantic Megaregion	105	I-77	
Charleston (CHS)		204	I-77	
Greensboro (GSO)		102	I-85	
Oklahoma City (OKC)	Dallas/Fort Worth (DFW), Texas Triangle and Gulf Coast	195	I-35	
Shreveport Regional (SHV)		202	I-20	
Tucson (TUS)	Phoenix (PHX), Arizona Sun Corridor	117	I-10	

Fig. 1. Local and substitute airport pairs, including their interstate connections.

itinerary was purchased from the Bureau of Transportation Statistics (BTS) Airline Origin and Destination Survey (DB1B, a 10% sample of all air itineraries purchased); we retain the connecting and non-stop itinerary information in separate lists for each airport. Finally, we collect the number of non-stop flights per quarter and the total in-flight time from the BTS Air Carrier Statistics (T-100), and the average airfare per ticket in each quarter from DB1B for each non-stop and connecting flight itinerary.

We assume that the ground distance a traveler must cover to access their local airport is the driving distance (network distance) to the local airport from the center of the metropolitan area. We assume that the ground distance a traveler must cover to access the substitute airport is the network distance between the local and the substitute airport. We derive a door-to-door airport access time from the network distances by assuming speeds of 30 mph (local) or 55 mph (highway).

It is important to note that while the values for ground distance we will use in the model formulation discussed below reflect leaking passengers driving to either their local or substitute airport, there are several leakage corridors where bus services have been

Table 1
Summary statistics of departures per year at the substitute airport and departures at the local airport as a percentage of departures at the substitute airport.

(a) Atlanta and local airports

Year	Departures per year	Departures at the local airport as a percentage of departures at the substitute airport				
	Atlanta (ATL)	Birmingham (BHM)	Knoxville (TYS)	Savannah (SAV)	Huntsville (HSV)	Chattanooga (CHA)
2007	472,369	5.68%	4.72%	3.40%	2.99%	1.75%
2011	445,553	5.10%	4.47%	3.17%	3.04%	1.66%
2015	426,365	4.43%	3.89%	3.33%	2.24%	1.71%

(b) Charlotte and local airports

Year	Departures per year	Departures at the local airport as a percentage of departures at the substitute airport		
	Charlotte (CLT)	Greensboro (GSO)	Columbia metropolitan (CAE)	Charleston (CHS)
2007	227189	11.09%	7.11%	9.22%
2011	245243	7.55%	5.10%	8.43%
2015	250222	6.29%	4.26%	9.01%

(c) Dallas and local airports

Year	Departures per year	Departures at the local airport as a percentage of departures at the substitute airport	
	Dallas (DFW)	Shreveport (SHV)	Oklahoma city (OKC)
2007	321106	3.14%	9.40%
2011	305210	2.56%	8.37%
2015	322070	2.18%	7.20%

(d) *Phoenix and local airport*

Year	Departures per year	Departures at the local airport as a percentage of departures at the substitute airport
	Phoenix (PHX)	Tucson (TUS)
2007	223623	13.50%
2011	200513	12.74%
2015	189177	12.26%

improved or expanded to serve these passengers. For instance, in the Arizona Sun corridor, several bus companies provide service from Tucson directly to Phoenix International Airport. However, intercity bus services to airports (existence and uptake by passengers), as well as intercity rail services, continue to be the exception rather than the norm (Augustin et al., 2014; Kanafani and Abbas, 1987; Sperry et al., 2012). Our results will represent the likelihood that a particular traveler will choose either the substitute or the local airport if driving is their mode of access; a traveler may, in practice then, choose to take another mode.

3.3. Changes in air transportation supply in the study markets

We compare the local and substitute airport on the following key metrics over the study period: domestic passengers (and split across airlines); international and domestic departures; and airfare. We do so to understand 1) the quantity of air service, and the quality of that air service, across airports and regions, and 2) the change in the distribution and quality of air service over time. These comparisons begin with Table 1, which captures the departures per year at the substitute and local airports, with the departures per year at the local airport shown as a percentage of the departures at the substitute airport.

Overall, it is clear that the substitute, hub airports overwhelm the local airports in terms of the number of departures. Consider that Atlanta airport experienced fluctuations of 40,000 departures per year during the study period, roughly 9% of the total departures in 2015; these minor fluctuations are roughly double the number of total departures at the local airports (the local airports have between 8000 and 27,000 departures per year). The differences in the number of departures are less dramatic for the other substitute/local airport pairs yet the gap is still stark, with the large hubs typically having 10 times the departures compared to local airports. There is variability in the number of departures in both the hub and local airports. This variability could be attributed to an airline introducing a new route and then cancelling that route, flights added or reduced at the substitute airport, or airlines using larger aircraft and thus consolidating flights into fewer departures. The variability over time trend mirrors the national trend in the supply of air service. Airlines significantly reduced their supply of flights at the local airports and increased airfares at the local airport after the recession and the peak in fuel prices in 2008. Post 2008, flight levels have grown tentatively at small and medium

Table 2
Summary statistics of passengers in 2015 at the local and substitute airport and the distribution of passengers across the airlines serving the local and substitute airports.

Airport	Passengers on all flights in 1000s (percentage in parenthesis is the ratio of local over substitute airport enplaned passengers)	Percent of Passengers at Each Local Airport Carried by Each Airline						
		Major Airlines		Low Cost Airline	Regional Airlines			Other
		American	Delta	Southwest	PSA	ExpressJet	Envoy Air	
Atlanta	87867		73.5%	10.4%				16.1%
Chattanooga	778.4 (0.9%)		22.4%			34.8%		42.8%
Knoxville	1676 (1.9%)				18.8%	26.6%		54.6%
Birmingham	2645 (3.0%)		28.4%	33.2%				38.5%
Savannah	1958.4 (2.2%)		37.6%		18.3%			44.1%
Huntsville	1038.78 (1.2%)		36.3%			20.2%		43.5%
Charlotte	40877	60.9%	3.8%	35.3%				
Columbia	1067 (2.6%)		23.1%	41.2%		35.6%		
Charleston	3329 (8.1%)	17.6%	27.0%	55.4%				
Greensboro	1683 (4.1%)		24.8%	58.1%		17.2%		
Dallas	55631	67.3%					7.9%	24.8%
Oklahoma City	3585 (6.4%)	11.1%		36.0%				52.9%
Shreveport	583.94 (1.0%)		7.8%			76.0%		16.1%
Phoenix	31681	52.2%		43.4%		4.4%		
Tucson	11802 (37%)	5.9%		8.3%		85.7%		

airports (Fuellhart et al., 2016).

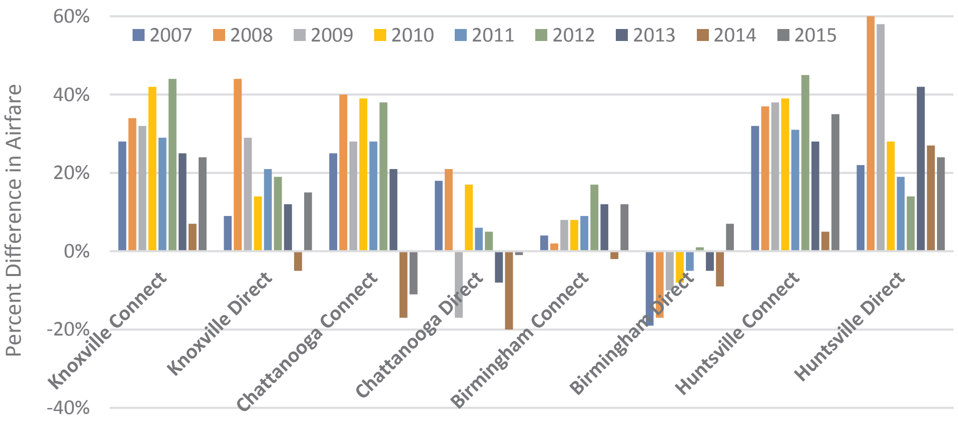
As passengers and departures are strongly correlated (found by Ryerson and Kim, 2013 and Shaw, 1993), the same trends hold for passengers. The distribution of passengers across airlines (Table 2) sheds light on the different characters and offerings of each airport. Consider Atlanta: 70% of the passengers are served by the major hub airline, Delta Air Lines. The next largest airline by passenger volume is Southwest Airlines, a low-cost carrier. Atlanta therefore has both the character of a major hub airport with many unique international and domestic destinations and an airport that offers relatively low-fare point to point service. Phoenix, another hub airport, has almost an equal divide between the passengers carried on the hub airline (American Airlines) and on Southwest Airlines. Dallas and Charlotte are more traditional hubs, with a major carrier (American Airlines in both cases) dominating the service. For the local airports, the passengers are mostly carried on small regional airlines operating connecting service for the major hub airlines. Only Oklahoma City, Charleston, and Tucson have their second largest airline (in terms of passengers carried) as Southwest Airlines. This is notable as much of the conventional wisdom is that low cost carriers favor secondary airports (Tierney and Kuby, 2008; Vowles, 2001).

To compare airfare (Fig. 2), we estimate the percent difference in fares for itineraries from the local and substitute airport with the same destination (discarding destinations served by the substitute airport that are not directly served by the local destination). We do so comparing 1) non-stop itineraries from the local and the substitute airports and 2) connecting itineraries from local airports and non-stop itineraries from substitute airports. We take a weighted average of each percent difference across destinations for each local-substitute airport pair.

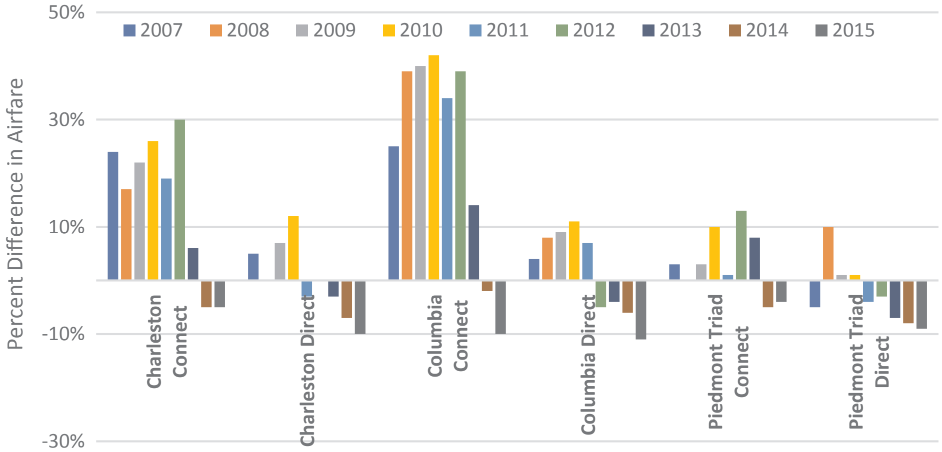
Overall, as seen in Fig. 2, airfares at the local airports are between 20% lower and 60% higher compared with those at their substitute airports across our study airport pairs. Airfares at local airports are mostly – and overwhelmingly in some cases – higher than those offered at their substitute airports. Airfares for connecting itineraries at the local airport generally appear to be higher than for non-stop flights at their substitute airports, in some cases 20–60% higher. Airfares for direct itineraries at the local airport are between 20% lower and 10% higher than those at the substitute airport. While direct flights from local airports might be relatively commensurately priced with those from the substitute airports. There is a great deal of variability (and volatility) across the study years of 2007–2015 in terms of fares, with fares at the local airports, compared to the substitute airports, tending to be their highest from 2007 to 2012.

4. Estimating local airport market share and airport market leakage

For each local-substitute airport pair, we predict the passenger market share for travel to a destination from the local versus substitute airport for travelers beginning their trip proximate to the local airport. We do this by applying a simple binary logit model, under the assumption that air travelers in the local airport market catchment will choose to depart from either the local or substitute airport. We use this estimate to, in turn, calculate the estimated number of passengers “leaked” from the local airport market catchment in each year of the study period across all identified travel destinations. We predict market share for air service provided at the local airport for all destinations served by the local airport, both via direct service and connecting service.



a) Atlanta and Local Airports



b) Charlotte and Local Airports

Fig. 2. Difference in average airfare between local and substitute airports.

To calculate utilities, and ultimately, market shares of the local airport for direct and connecting travel, we collect the values of the utility function variables from the publicly available data described in the previous section. Calculating the utilities also requires the coefficients on the variables that enter into the utility function: coefficients that explain the impacts of airfare, frequency, time, and distance on airport choice. Using relevant literature, we collect coefficient values and explore the sensitivity of the results to these coefficients through scenario analysis.

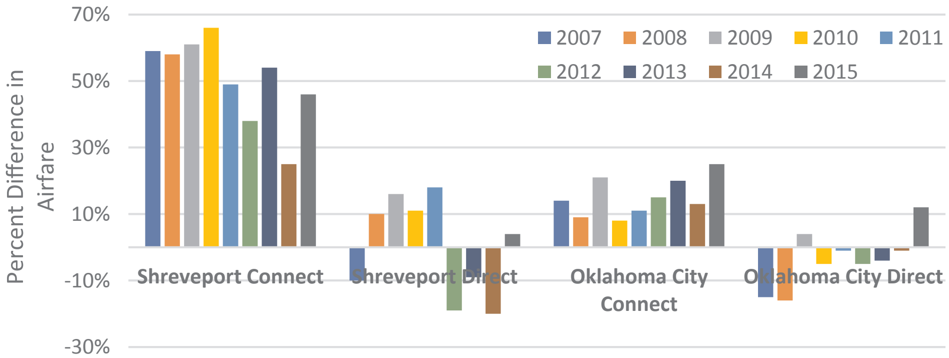
4.1. Models of local airport market share

Let i be a single airport, either substitute or local, that is contained in the set I which includes all study airports ($i \in I$). Let s and ℓ, $s,\ell \subseteq I$ be elements that represent a substitute or local airport, respectively. In our sample set, there are 12 local airports and four substitute airports, rendering 12 unique s–ℓ pairs. For each s–ℓ pair, we estimate the likelihood that a passenger located proximate to ℓ headed to destination $j, j \in J$ either 1) chooses a non-stop itinerary to j from ℓ compared with a non-stop itinerary from s and 2) chooses a connecting itinerary to j from ℓ vs. a non-stop itinerary from s.

For each s–ℓ pair, we predict the market share of s for an average traveler in its catchment, and calculate the estimated number of leaked passengers every year from the catchment of $s \ \forall \ j$. We present a disaggregate choice model that predicts, for a given traveler choosing between s and ℓ for each s–ℓ pair, the likelihood that a passenger will choose to travel from s. Upon establishing this model, we use it to 1) predict the market share of the local airport ℓ for an average traveler in the local airport catchment and 2) calculate the estimated number of leaked passengers every year from the local airport (ℓ) market catchment. If we assume that air travelers will choose to depart from ℓ or s, we can calculate the aggregate market share for ℓ using a binary logit model.

Consider the model structure proposed by de Luca (2012) to study the airport choice of residents of Italy's Campania Region. de Luca (2012) estimated utility models for the choice of traveling non-stop from each of the three airports (1 local and 2 substitute), as well as traveling either non-stop or with connection. We have adapted de Luca's utility function for non-stop itineraries to estimate

c) Dallas and Local Airports



d) Phoenix and Local Airport

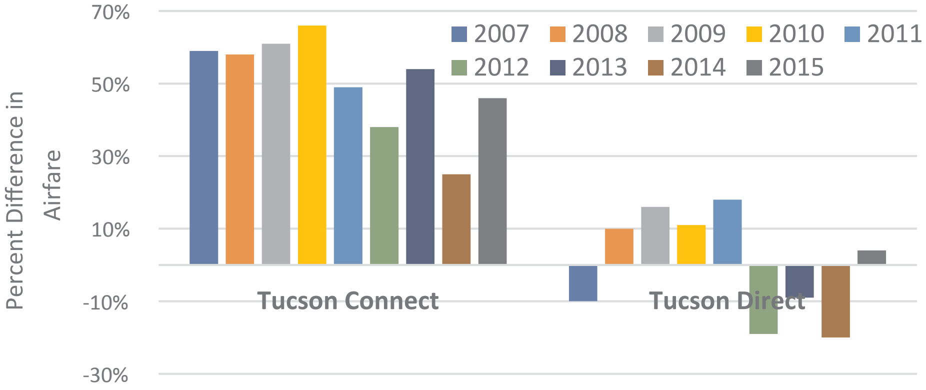


Fig. 2. (*continued*)

the market share of travelers in the catchment of the local airport seeking to travel to destinations served directly from the local airport. We use the more flexible utility function (that includes the air travel time variable) to estimate the market share of travelers in the catchment of the local airport seeking to travel to a destination by connecting trip.

Based on de Luca's model, in our work we specify two choice situations that could be available to an air traveler traveling to destination j: 1. Travel non-stop from local airport ℓ or substitute airport s, or 2. Travel with a connecting flight from ℓ or non-stop from substitute airport s. These are meant to capture travel situations where a traveler either has non-stop options from both airports, or a non-stop option from the substitute airport but only a connecting option from the local.

A traveler's utility for a non-stop flight itinerary from either ℓ or s to j ($U^n_{\ell j}$ and U^n_{sj} from Eq. (1)) is a function of airfare, flight frequency, and ground access distance (Eq. (1)). Eq. (2) shows the utility for a passenger considering a connecting itinerary from the local airport ℓ or non-stop itinerary from the substitute airport s ($U^c_{\ell j}$ and U^c_{sj}), which is a function of air travel time (including any dwell, or connecting, time), ground access travel time, and flight frequency. Although we consider non-stop itineraries from the substitute airport in both choice situations, we have specified a different equation for the choice to travel from s for each choice situation, because of the different variables that have been found by de Luca (2012) to influence choice in situation 2 (Eq. (2)) versus those of situation 1 (Eq. (1)). While de Luca specified the function in a flexible manner, to allow for air travel time and ground access travel time variables to enter into the utility function non-linearly, other studies based on U.S. data have found that non-linear specifications are not significant in airport choice (Hess et al., 2007). Therefore, we use de Luca's functional form (2012), but assuming a linear utility function.

We calculate airport market share in each of the two situations above. Eq. (3) represents the market share of the local airport ℓ where non-stop flights are available from both airports to j, $MS^n_{\ell j}$; Eq. (4) represents the market share of the local airport ℓ where a connecting flight is available from ℓ but nonstop is available from substitute airport s.

The market share models are then used to estimate $T^n_{\ell j}$, the number of travelers that have "leaked" from the local airport ℓ to the substitute s who choose between non-stop itineraries to j at both airports, and $T^c_{\ell j}$, the number of travelers that have "leaked" from ℓ to s who choose between a connecting itinerary from ℓ and a non-stop itinerary from s to j, shown in Eqs. (5) and (6).

$$U^n_{ij} = V^n_{ij} + \varepsilon^n_{ij} = \alpha F^n_{ij} + \beta\log(f^n_{ij}) + \gamma\log(g_i) + \varepsilon^n_{ij}, i = \ell \ or \ s \tag{1}$$

$$U^c_{ij} = V^c_{ij} + \varepsilon^c_{ij} = \zeta F^c_{ij} + \pi\log(t_{ij}) + \theta\log(m_i) + \varepsilon^c_{ij}, i = \ell \ or \ s \tag{2}$$

$$MS^{n}_{\ell j} = \frac{e^{V^{n}_{\ell j}}}{e^{V^{n}_{\ell j}} + e^{V^{n}_{sj}}} \tag{3}$$

$$MS^{c}_{\ell j} = \frac{e^{V^{c}_{\ell j}}}{e^{V^{c}_{\ell j}} + e^{V^{c}_{sj}}} \tag{4}$$

$$T^{n}_{\ell j} = \frac{P^{n}_{\ell j}}{MS^{n}_{\ell j}} - P^{n}_{\ell j}; T^{n}_{\ell} = \sum_{j} T^{n}_{\ell j} \tag{5}$$

$$T^{c}_{\ell j} = \frac{P^{c}_{\ell j}}{MS^{c}_{\ell j}} - P^{c}_{\ell j}; T^{c}_{\ell} = \sum_{j} T^{c}_{\ell j} \tag{6}$$

where:

i	is the departure airport; $i = \ell$ is the local airport while $i = s$ is the substitute airport
j	is the destination airport.
c	connecting itinerary
n	nonstop itinerary
U^{n}_{ij}	is the utility of choosing Airport i to travel to destination airport j on non-stop (n) itineraries from both airports
U^{c}_{ij}	is the utility of choosing Airport i to travel to j on a connecting (n) itinerary (from airport ℓ) or non-stop itinerary (from airport s)
V^{n}_{ij},V^{c}_{ij}	is the deterministic utility of choosing airport i in situation 1 (n: non-stop from both) or situation 2 (c: nonstop from s, connecting from ℓ)
ε^{n}_{ij},ε^{c}_{ij}	is the stochastic error term
F^{n}_{ij},F^{c}_{ij}	is the average airfare (in hundreds of US dollars) from airport i to j
f^{n}_{ij}	is the flight frequency from airport to j, choice situation 1 (non-stop from both ℓ or s)
t_{ij}	is the travel time (in-flight time + dwell time) from airport i to j
g_i	is the average ground access distance to airport i
m_i	is the average ground access time to airport i
α,β,γ,ζ,π,θ	are coefficients
$P^{n}_{\ell j}$,$P^{c}_{\ell j}$	is the number of passengers traveling from ℓ to j on non-stop and connecting itineraries (c)
$MS^{n}_{\ell j}$,$MS^{c}_{\ell j}$	is the market share for airport ℓ (compared with s), on non-stop (n) or connecting (c) itineraries to j
$T^{n}_{\ell j}$,$T^{c}_{\ell j}$	is the number of passengers that leak from airport ℓ to s, on non-stop (n) or connecting (c) itineraries to j

4.2. Choice of coefficients for market share model inputs

To calculate utilities and ultimately market shares using the model of Eqs. (1)–(6), we need the values of the variables in the utility functions as well as the values for the parameters on airfare, frequency, travel time, ground access distance, and ground access time (α,β,π,γ and θ, respectively).

de Luca (2012) produced estimates of the coefficients; we use these coefficients as well as coefficients two standard errors around the base value, representing upper and lower bound coefficient values. We explore the meaning of the base values of the coefficients, as well as the sensitivities of the choice probabilities to the base values – for example, observing how the choice probabilities are impacted when passengers place a higher than average value on airfare, or travel distance. Exploring the sensitivities of the results to the coefficient values is critical given that we are not empirically estimating the coefficient values but rather applying these coefficient values to estimate and bound airport market leakage. Air travel survey data that would populate the coefficients on the model explored in this research is not readily available and would require an extensive data collection effort. Before executing a large survey, we sought intuition about whether this problem may be one significant and important enough to warrant such an effort. Hence, we used de Luca's coefficients as a guide, around which we estimate the sensitivity of the results, to gain some understanding of the possible scale of the airport leakage problem. A finding that airport market leakage is of great significance would be a call for a larger, more long-term line of research inquiry for the entire field.

We begin by presenting the values of the coefficient estimates that we will use in the market share modeling (Table 3). The values labeled as "base" are from the utility functions estimated by de Luca (2012). To explore sensitivities to the base values – for example, in a scenario where passengers place a higher than average value on airfare, or travel distance, we add or subtract two standard errors from the base value. For the variables of airfare, flight frequency, and travel time, variables for which lower values at the local airport would favor the local airport, we subtract two standard deviations from the base values; for the variable of ground access distance and access time, we add two standard deviations. The "lower bound" coefficients all represent coefficients that would favor a passenger choosing their local airport. The lower bound value of the airfare coefficient means that a passenger does not value airfare highly: a passenger that values airfare highly is likely to be more predisposed to travel to the substitute airport. The lower bound value of distance indicates a passenger that values distance highly; this traveler thus has a higher likelihood of travel through the local airport.

Table 3
Coefficients estimated by de Luca (2012) for utility Eqs. (1) and (2).

	Coefficients used in Eq. (1) (standard error)			Coefficients used in Eq. (2) (standard error)		
	Airfare	Frequency	Ground access distance	Airfare	Travel time	Ground access time
	α	β	γ	ζ	π	θ
Units of coefficient (inverse)	Euros	No. of daily flights	Kilometers	Euros	Hours	Minutes
Base	−0.18	0.36	−0.85	−1.1	−0.047	−1.57
	(−0.08)	(0.13)	(−0.25)	(13)	(2.8)	(8.4)
Lower bound	−0.02	0.09	−1.35	−0.93	−0.01	−1.94

Note: The coefficient on airfare is in euros and distance in kilometers; going forward we assume the value of one euro to be equal to the value of one dollar across our study period which is consistent with the exchange rate in 2015.

The airfare elasticities that result from the base value estimates, for an airfare increase ranging from 10% to 50%, are reported by de Luca (2012) to be between −0.9 and −4.8 for the local airport. The elasticities of flight frequency, over the same percent increase range, are between 0.4 and 1.9. We can compare these values to those estimated by others in the literature. The International Air Transport Association (IATA) summarizes the literature up through 2005 and finds wide disagreement in elasticity estimates of air demand. From a synthesis of the literature, the authors estimate that the airfare elasticity for intra-Europe flights is -1.30 while price elasticity for U.S. domestic flights is -0.83. The study, however, asserts that the values found across the literature vary widely and that the demand is not necessarily consistently more elastic for intra-Europe flights compared to U.S. domestic flights. More recently, Brueckner (2009) assumes perfectly elastic demand to airfare without loss of generality. Granados et al. (2011) find perfect elasticity empirically for business travelers and leisure travelers, estimating the elasticity of demand to airfare being −1.03 to −1.1. Bhadra (2010) finds that, among metropolitan areas served by a small airport, that the airfare elasticity of demand is −1.3. Berry and Jia (2010) find that, compared with the late 1990 s, in 2006 the price elasticity of air travel demand increased by 8%; with their 2006 estimate for air fare price elasticity being −2.1.

5. Estimating airport market leakage

5.1. Passengers leaked from each airport catchment

Using the adapted de Luca model, we estimate the number of travelers who are likely to use the local airport, as well as the market share of the local airport for travel to different destinations. We estimate the number of travelers using the base coefficients, and then separate models varying one of the coefficients to its "lower bound" level. As the most conservative values result from varying the coefficients that capture ground access distance and time; we present the results when the coefficients on ground access distance and time represent "high" values of time as our lower bound.

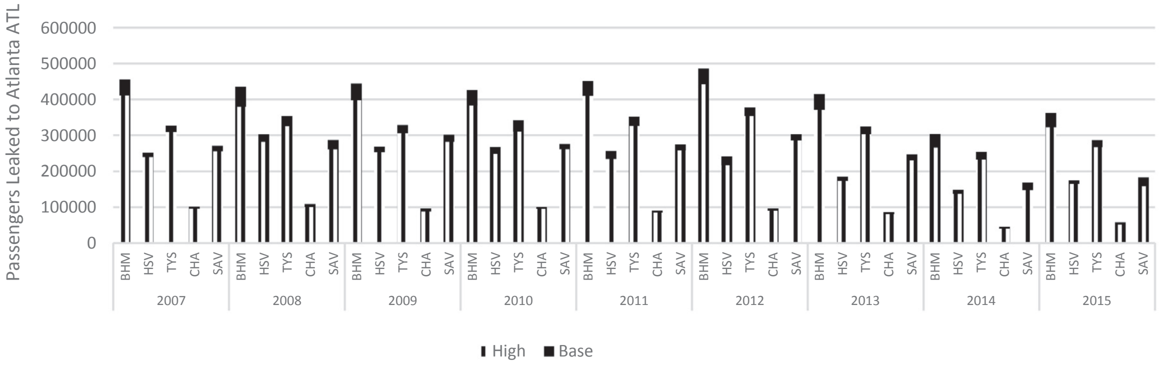
Fig. 3 presents the total number of passengers leaked from the local to the substitute airport and Fig. 4 presents the estimated total number of leaked passengers divided by the total number of passengers that could be considered to be within the local airport catchment per year (the sum of the total passengers at the local airport and the leaked passengers). Table 4 then breaks down the results of Fig. 4 by passengers looking for connecting flights and passengers looking for non-stop flights.

At each individual local airport, we see that approximately 58,000–700,000 travelers annually leak from a local airport to a large substitute airport, with a median value of 201,514 travelers in 2015. The implication is that each local airport is unable to capture and serve these passengers because, for these passengers, the service at the substitute airport is more attractive.

In Figs. 3 and 4 we see that the trends in the number of leaked passengers change over time, with the most marked changes occurring in the later years (about 2012–2015). The market shares for the local airports were at their lowest between 2008 and 2012, but they appear to rise between 2012 and 2015. This reflects the contraction of the aviation market from 2008 to 2012, when the airlines reduced their services, particularly in short haul markets. As flights were added after 2012 when the aviation market experienced some expansion, the market shares for local airports began to grow and the number of leaked passengers decreased. This trend of decreased market leakage for local airports in the Texas Triangle/Gulf Coast regions does not hold post-2013. In this region, Shreveport has fewer than 10,000 flights per year and Oklahoma City has 30,000 compared with Dallas Fort Worth's 320,000 (Fig. 2); in addition, the gap between air service frequencies at these airports has grown over time. Dallas strengthened its position as a hub not just relatively to the local airports but with actual growth in air service; this was to the detriment of the local airports.

To put the number of total travelers who may "leak" into further context, Fig. 4 includes the percent of leaked passengers from a local airport in a year divided by the total passengers carried by the local airport that year. We find this percentage to generally be in the 15.7%–31.8% range for the different airport pairs. The interpretation of this percentage is that each local airport is not capturing a possible 15.7%–31.8% more passengers than it carried/carries in any particular year. The numbers in Table 4 present the values in Fig. 4 broken down by non-stop and connecting travel. The median shares of passengers captured at local airports are 83.4% in 2015 for direct itineraries and 42.3% in 2015 for connecting itineraries. The local airport market shares for direct flights are well above the

a) Atlanta and Local Airports



b) Charlotte and Local Airports

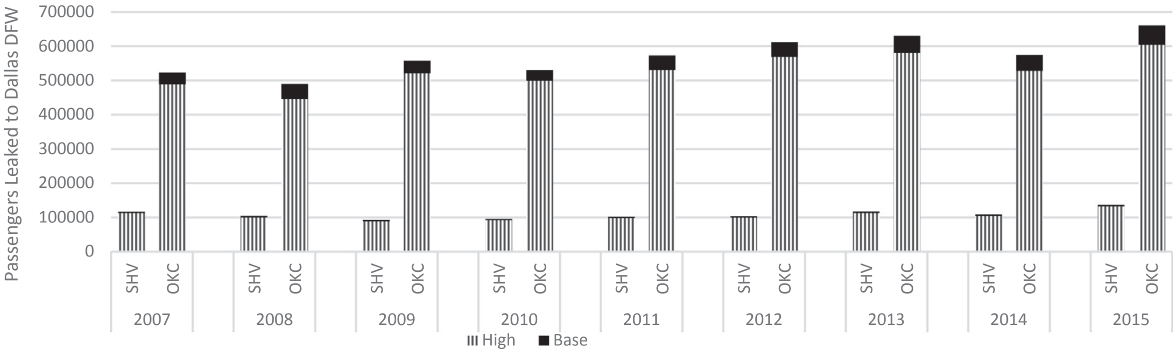


Fig. 3. Estimates of leaked passengers per year from the local to the substitute airport. (High = high values of time for coefficients, base = base value of time for coefficients.) Note that scales vary from graph to graph.

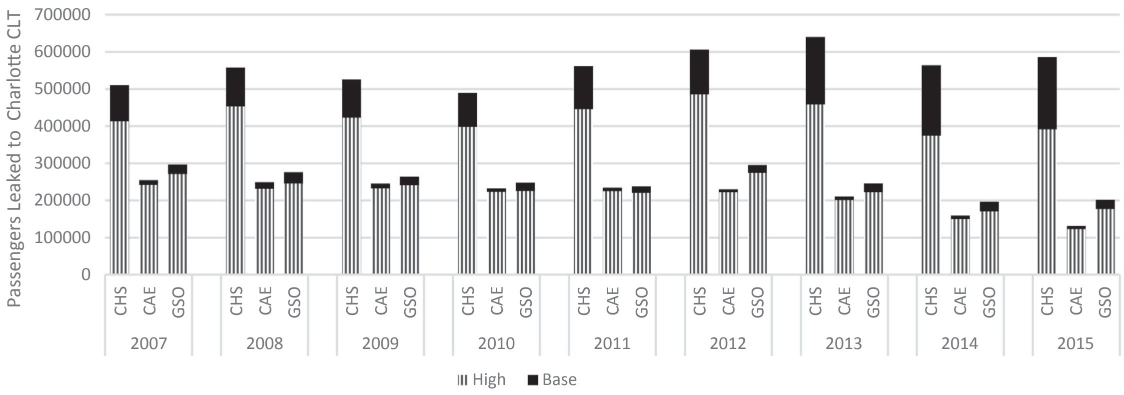
market shares for connecting travel. The local airport passenger market shares for direct flights are between 67.0% and 89.2%, with most values around 80%; for connecting flights this ranges between 15.0% and 66.7%, with most values in the 20%–30% range. In short, a local airport typically commands the largest share of their passenger catchment market when they offer the option of flying directly to destinations; when passengers must connect to their final destination, they are much less likely to use their local airport. The overall leakage is estimated to amount to between 15% and nearly 32%, which suggests that airport passenger leakage may be occurring at significant rates in the various regions of the U.S., which in turn suggests a substantial amount of travel (if not distance, then at least the time) spent on the ground accessing these major hub airports.

Overall, across all markets, local airports are able to retain 80% of travelers facing a direct flight but less than 50% of air travelers facing a connecting flight. There are few studies upon which to validate the results. Back in 1999, the Iowa Department of Transportation (1999) estimated that 31% of the total number of passengers originating in the Des Moines airport catchment (a local airport) leak to an out of region airport, results that are supported by the sensitivity analysis of market share for local airports by Fu and Kim (2016) in the U.S. and Lian and Rønnevik (2011) in Norway. In Canada, Edmonton International Airport estimated that 750,000 Edmonton-area residents flew through Calgary International Airport annually, a hub airport 179 miles south of downtown Edmonton (Jang, 2010).

5.2. Highway traffic due to airport market leakage

We estimate the proportion of traffic on interstate highways connecting local to substitute airports that may be attributed to travelers driving long distances between the catchment of the local airport to/from a substitute airport. To do so, we take the ratio of the travelers leaked to the substitute airport per day and the Average Annual Daily Traffic (AADT) on the major interstate highway that links the two airports. We collect Average Annual Daily Traffic (AADT) for two points along each interstate highway route connecting the substitute airport pairs from State DOT websites (see Fig. 1). The first is the lowest volume point on the corridor; the second is the highest volume point. Collecting two AADT values for each corridor, each year, allows us to identify an upper and lower bound of traffic between the local and substitute airport. Fig. 1 shows the locations we collected AADTs. We then divide the passengers leaked from the local to the substitute airport by the AADT. For local airports that share a route with another local airport to the substitute airport, we add the number of passengers leaked to the substitute from both local airports together to estimate a share of highway traffic attributed to both local airports.

c) *Dallas and Local Airports*



d) *Phoenix and Tucson (Local Airport)*

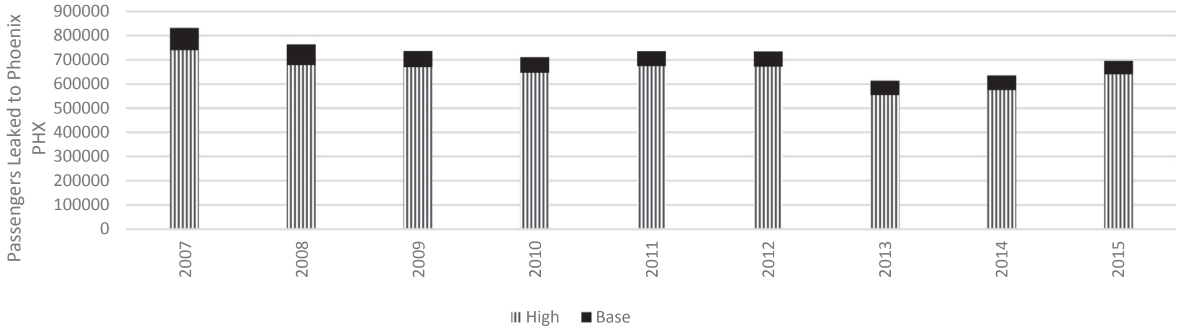


Fig. 3. (*continued*)

It should be noted that we assume that each passenger travels in their own vehicle for purposes of calculation. This assumption is supported by the data. DB1B, the 10% sample of all air itineraries purchased collected by the FAA, includes a variable capturing how many people are booked on a single itinerary. Analyzing that data reveals that, for all itineraries booked departing from our study airports, the 90th percentile of the number of passengers booked on an itinerary for each airport is 1, reflecting an individual traveling alone. It is certainly possible that people traveling together book individual itineraries. However, we present results assuming one passenger per vehicle and invite the reader to factor down the results given the load factor of the vehicle one might wish to assume.

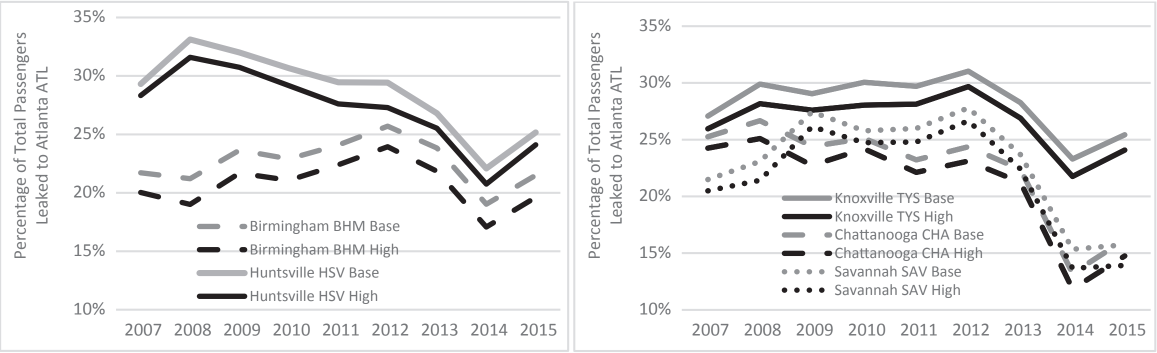
Table 5 shows the percent of daily traffic that might be able to be attributed to passengers leaking to a substitute airport in 2015. The results are organized by local and substitute airport pairs, either a single local-substitute pair or multiple local airports that might be connected to the substitute airport by the same highway, and two AADT levels (high and low points along the highway). The high AADT points represent segments of the highway that are very close to the large cities served by the substitute airport, while the low AADT points represent rural, less trafficked areas.

Across our study airport pairs, the percentage of traffic attributed to travelers driving to a substitute airport is generally between 0.05% and 12%, depending on the year and airport pair. The range between the high and the low AADT sections can be quite large across highways connecting the different airport pairs studied. The low AADT sections of highway clearly see the highest percentage of traffic attributable to airport market leakage, as these sections see relatively low levels of traffic. Low trafficked areas, such as those seen in the more rural areas of Arizona, South Carolina, Alabama, and Oklahoma, might see up to 10%–12% of their daily traffic coming from people driving to Dallas for air service. However, those same volumes from leaking passengers are less than 2% of the traffic in high traffic areas.

6. The implications of leaky markets

In the following section, in light of our empirical findings, we explore the implications and the future of airport market leakage. We begin with why transportation planners should be concerned with airport market leakage particularly in the areas of traffic, the environment, and economic development. We then explore how incentives for new air service could be exacerbating, rather than stemming, airport market leakage. We conclude with the future of airport market leakage with advances in vehicle technologies.

a) Atlanta and Local Airports (Local airports split between two graphs)



b) Charlotte and Local Airports

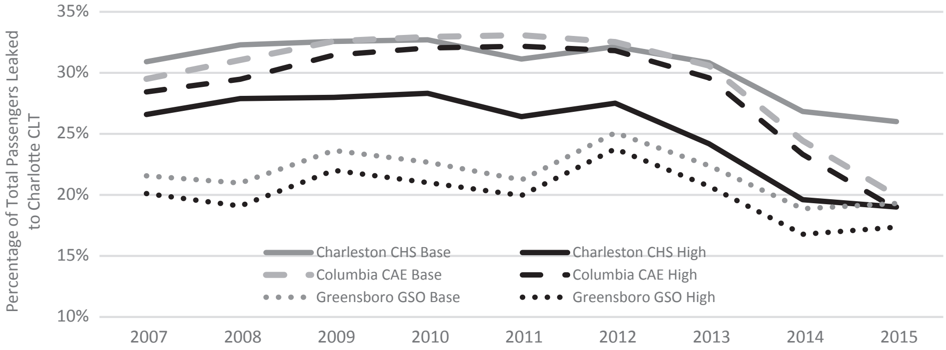


Fig. 4. Percent of potential local airport passengers estimated to leak to a substitute airport. (High = high values of time for coefficients, base = base value of time for coefficients.)

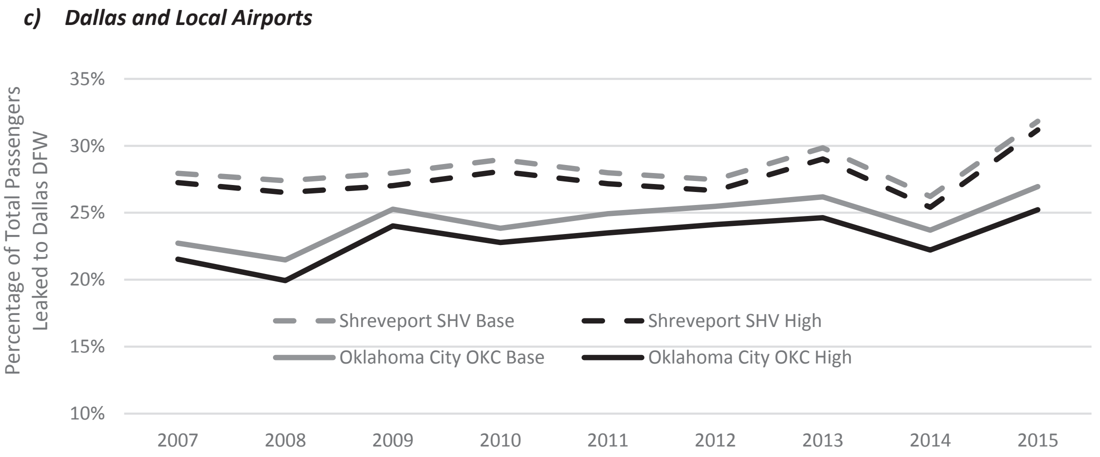
6.1. Megaregional trends: traffic, the environment, and economic development

The deepening in the divide in air service between neighboring regions may lead to increased traffic on the roads as travelers seek out lower airfares at distant airports. Our estimates indicate that, for most local and substitute airport pairs, 0.05%–12% of highway traffic can be attributed to travelers accessing large airports. These quantitative estimates of traffic due to airport market leakage establish the importance of integrated air and surface transportation planning. Our results suggest that the imbalance of air transportation service and usage in regions throughout the U.S. may be contributing to intercity highway volumes.

The imbalance of air transportation service between neighboring regions (or, within a megaregion) may exacerbate congestion in areas that are already congested. To put the percentages of AADT attributed to travelers accessing substitute airports in perspective, consider that reducing vehicle miles traveled by 1% or less is a major initiative of planners and policymakers; this seemingly small number can potentially have significant environmental (Chester and Horvath, 2009; Ryerson et al., 2015) and mobility benefits (Choo et al., 2005). Congestion acts as an access restriction to different opportunities (Levine et al., 2005); our findings point to how local mobility in major cities might be significantly impaired by interregional travel. And while airport travel may not coincide with typical morning and afternoon peak periods, megaregions are well known for their relatively flat congestion profiles and their growing congestion (Ross, 2012).

Added traffic in megaregions will also have environmental and economic development consequences. While in this study we do not do perform a full environmental accounting of airport market leakage, the possibility that travelers are opting to drive instead of fly could lead to an overall higher level of environmental emission from the transportation system. Consider that aircraft have a large fixed fuel consumption attributed to operating the flight; the fewer passengers on that aircraft, the higher the overall emissions per passenger (Levinson et al., 1997). Chester and Horvath (2009) find that the per passenger mile emissions of a conventional sedan are larger than those of a small aircraft used to connect a local airport to a hub or other local airport. A leaking passenger is thus substituting an air trip with a less environmentally efficient auto trip; it is therefore possible that an environmental efficient solution to highway traffic is to encourage more air service at local airports. A full environmental and social cost analysis would require a careful analysis of the added auto trip and possible reduced flights; moreover, it should also include the impacts of emissions on human health (which are dependent on geography per Nahlik et al. (2016)) as well as any differences in accident risk and likelihood (as highways have a higher accident risk per Levinson et al. (1997)).

Finally, the traffic due to airport market leakage is a very physical indication of fleeing economic development. As travelers



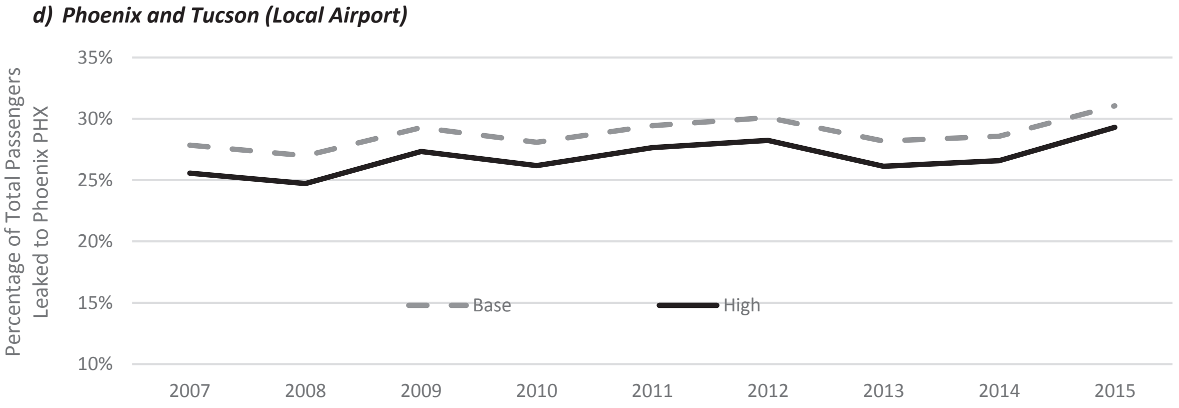


Fig. 4. (*continued*)

Table 4
Share of passengers within the local airport catchment that are estimated to prefer a flight option from the local airport.

Local airport	Local market share, direct flights	Local market share, connecting flights	% Total local passengers leaked
		Atlanta	
Knoxville	80.4%	32.1%	25.4%
Huntsville	83.3%	26.4%	25.2%
Birmingham	87.1%	42.3%	21.5%
Savannah	89.2%	59.9%	15.7%
Chattanooga	71.5%	66.7%	16.2%
		Charlotte	
Charleston	67.0%	58.6%	26.0%
Greensboro	81.7%	59.9%	19.3%
Columbia	84.2%	65.3%	19.9%
		Dallas	
Oklahoma City	85.0%	31.1%	26.9%
Shreveport	85.4%	15.0%	31.8%
		Phoenix	
Tucson	83.4%	26.1%	31.1%

abandon their local airport, they are reducing the flow of revenue to their airport from parking fees, concessions, and ticket taxes; in short, these travelers are furthering the divide between economic development potential, both direct and indirect, across cities within a megaregion (Harrison and Hoyler, 2015). Passengers leaking to a substitute airport could depress air demand at a local airport, thus perpetuating a vicious cycle of flight levels being reduced and airfares going up, thus encouraging more passenger leakage.

6.2. Air service incentives

Through an analysis of air service trends in Fig. 2, we compared how airports have grown or contracted during the study period;

Table 5
Data sources for highway AADT and estimates of highway traffic attributed to leaked passengers accessing a substitute airport in 2015.

Substitute airport	Local airport	Data source	Highway	Low AADT		High AADT	
				High	Base	High	Base
Atlanta	Chattanooga & Knoxville	Georgia DOT	I-75	2.53%	2.74%	1.34%	1.45%
Charlotte	Greensboro	NC DOT	I-85	1.31%	1.49%	0.91%	1.04%
Atlanta	Savannah	Georgia DOT	I-16	2.25%	2.60%	0.24%	0.27%
Dallas	Shreveport	TX DOT	I-20	2.56%	2.64%	1.00%	1.03%
Phoenix	Tucson	AZ DOT	I-10	8.57%	9.32%	1.49%	1.62%
Dallas	Oklahoma City	OK & TX DOT	I-35	11.04%	12.07%	2.18%	2.38%
Charlotte	Columbia & Charleston	SC DOT	I-77	7.23%	10.09%	1.97%	2.75%
Atlanta	Huntsville & Birmingham	Alabama DOT	I-20	8.12%	8.94%	1.62%	1.78%

through Fig. 3 we explored how these trends impact leakage. One of the mechanisms through which airports grow their air service is Air Service Incentive Programs (ASIPs). The FAA allows airport sponsors to fund an ASIP with their revenues collected from non-aeronautical sources and use them to waive the fees airlines pay to land aircraft and to rent gate space for one to two years, and/or pay for marketing programs, for airlines launching new air service at the airport. The goal of many ASIPs is to add non-stop flights to new destinations not previously directly connected to an airport, and to attract new carriers that can help reduce fares overall at an airport. Our findings provide strong justification that ASIPs at small and medium airports can help airport managers attract passengers from their local catchment by increasing the non-stop offerings to new destinations and by reducing fares. As local airports were able to retain roughly 80% of travelers who had the option of traveling non-stop from their local airport, ASIPs targeted at building air service to new destinations could be very helpful at stemming leakage. In addition, air service incentives that reduce airfare at a local airport could also help reduce the incentive for a passenger to leak.

While ASIPs could be helpful in stemming leakage at small and medium airports, Ryerson (2016b) finds that it is the larger airports, and not the small and medium airports, that maintain ASIPs and are able to recruit and retain new air service under these ASIPs. Among the airports in our study sample, it is Dallas that has been the most successful at recruiting new air service since 2010 (Dallas recruited flights to 22 new domestic and 11 new international routes between 2012 and 2015Q1 alone, experiencing some of the highest growth in new flight routes for large hub airports during that time). None of the local airports except Oklahoma City were confirmed to maintain an ASIP during this study period. However, maintaining an ASIP does not necessarily mean that an airport is successfully recruiting flights, and indeed Oklahoma City was unsuccessful in recruiting any new flights between 2012 and 2015Q1 with their ASIP. It is possible that the presence of an active air service incentive program at a large airport accelerated airport market leakage from neighboring small airports. This finding is particularly notable because the spirit of air service incentive programs – and the federal guidance permitting such programs – is to promote and build air service at medium and small airports (Ryerson, 2016a). It is possible that, when a hub airport actively expands their service offerings by incentivizing new routes, the local airports suffer the effects of more travelers leaking to the large hub airport.

6.3. *New vehicle technology and automation*

In a future with new vehicle technologies it is possible that travelers will value ground access distance or time very little. Scholars surmise that automation, from connected vehicles that assist drivers in finding the routes with the lowest traffic and maintain a safe distance from other vehicles to autonomous vehicles which perform the driving function, will reduce a traveler's effective value of time (Krueger et al., 2016; van den Berg and Verhoef, 2016). A long drive to access an airport with higher levels of service may be of little consequence to a traveler with an autonomous vehicle. If this is the case, and new vehicle technologies become widely available, the coefficient on ground access time and distance might trend toward zero, thus increasing the likelihood that a passenger leak to the substitute airport. If this is the case, then our base estimates are actually a lower bound rather than an upper bound on the potential for airport market leakage.

7. Conclusions

Our study finds the existence of airport market leakage from local airports to hub airports 100–300 miles apart. Our estimates suggest that 15.7%–31.8% of the total passengers living proximate to a small or mid-sized airport have the incentive to leak; the range 10.8%–33.0% for travelers facing a non-stop itinerary from their local airport and 33.3%–85.1% for travelers facing connecting travel. We find that passengers leaking from a local to a hub airport could contribute 1%–2.75% of average daily highway traffic at heavily congested portions of the interstate highways connecting airports and up to 10%–12% of traffic on low density portions of the highway.

Our research indicates the strength of the connection between the air and intercity surface transportation system and provides justification for integrated air-highway transportation planning. Policies and actions by airports and airlines at large airports have significant implications not just on neighboring local airports but on the interstate highway system; consider that the findings of our study indicate that one possible cure for congestion on the highway is to increase air service at a small local airport. Our findings on the significant link between the air and intercity transportation system open up a new area of inquiry in the field of intercity transportation. While there are institutions and scholars focused on the link between the local transportation system and airports, few focus on the concept of long-distance airport access and airport market leakage. Our study indicates that leaking from a local to a larger airport market is a widespread practice in which travelers engage and one that has a significant impact on the surface transportation system and the economic health of small metropolitan areas.

The results of this study help to shape the evolving role of airport managers in controlling demand and delay at major hub airports and in building and managing air service at smaller airports across the U.S. Small airport managers could stem market leakage by focusing not on building air service to connecting hub airports but to new, unique destinations. This is a challenging prospect, however, as small and medium airport managers have been markedly less successful in building new service in the recent years compared with large hub airports. The findings of our study also indicate the complexity of the challenges large airport managers face: they must balance providing air service for their region against starving neighboring regions of air service and causing increasing surface highway traffic. While we assert their role is complex, large airport managers are not necessarily concerned with surface traffic or the health of small airports. Large airport managers are well known for protecting their hub airline and trying to grow their airport to better serve – and retain – that hub airline.[3] While our findings help broaden the solution space over which an airport manager of a large airport may look to tackle congestion at a busy airport – namely, encourage air traffic at a local airport to stem leakage – it may take the intervention of federal regulators or a powerful megaregional planning body to actually encourage airport managers to consider the implications of their plans on the health of the broader aviation system.

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References

Augustin, K., Gerike, R., Martinez Sanchez, M.J., Ayala, C., 2014. Analysis of intercity bus markets on long distances in an established and a young market: The example of the U.S. and Germany. Res. Transportation Economics 48, 245–254. http://dx.doi.org/10.1016/j.retrec.2014.09.047.

Berry, S., Jia, P., 2010. Tracing the woes: an empirical analysis of the airline industry. Am. Econ. J.: Microecon. 2 (3), 1–43. http://dx.doi.org/10.1257/mic.2.3.1.

Bhadra, D., 2010. Air travel in small communities: an econometric framework and results. J. Transportation Res. Forum 43 (1). http://dx.doi.org/10.5399/osu/jtrf.43.1.711.

Borenstein, S., 1989. Hubs and high fares: dominance and market power in the U.S. airline industry. RAND J. Econ. 20 (3), 344–365.

Borenstein, S., Rose, N.L., 2007. How Airline Markets Work...Or Do They? Regulatory Reform in the Airline Industry (Working Paper No. 13452)Natl. Bureau Econ. Res. http://dx.doi.org/10.3386/w13452.

Brueckner, J.K., 2003. Airline traffic and urban economic development. Urban Studies 40 (8), 1455–1469. http://dx.doi.org/10.1080/0042098032000094388.

Brueckner, J.K., 2009. Price vs. quantity-based approaches to airport congestion management. J. Public Econ. 93 (5), 681–690. http://dx.doi.org/10.1016/j.jpubeco.2009.02.009.

Brueckner, J.K., Dyer, N.J., Spiller, P.T., 1992. Fare determination in airline hub-and-spoke networks. Rand J. Econ. 23 (3), 309–333. http://dx.doi.org/10.2307/2555865.

Brueckner, J.K., Lee, D., Singer, E.S., 2013. Airline competition and domestic US airfares: A comprehensive reappraisal. Econ. Transportation 2 (1), 1–17. http://dx.doi.org/10.1016/j.ecotra.2012.06.001.

Button, K., Doh, S., Yuan, J., 2010. The role of small airports in economic development. J. Airport Manage. 4 (2) Retrieved from http://trid.trb.org/view.aspx?id=924327.

Button, K., Taylor, S., 2000. International air transportation and economic development. J. Air Transport Manage. 6 (4), 209–222. http://dx.doi.org/10.1016/S0969-6997(00)00015-6.

Chester, M.V., Horvath, A., 2009. Environmental assessment of passenger transportation should include infrastructure and supply chains. Environ. Res. Lett. 4 (2), 24008. http://dx.doi.org/10.1088/1748-9326/4/2/024008.

Choo, S., Mokhtarian, P.L., Salomon, I., 2005. Does telecommuting reduce vehicle-miles traveled? An aggregate time series analysis for the U.S. Transportation 32 (1), 37–64. http://dx.doi.org/10.1007/s11116-004-3046-7.

de Luca, S., 2012. Modelling airport choice behaviour for direct flights, connecting flights and different travel plans. J. Transp. Geogr. 22, 148–163. http://dx.doi.org/10.1016/j.jtrangeo.2011.12.006.

de Neufville, R.F., 2006. Planning airport access in an era of low-cost airlines. J. Am. Planning Assoc. 72 (3), 347–356. http://dx.doi.org/10.1080/01944360608976756.

de Neufville, R., Odoni, A.R., 2013. Airport Systems: Planning, Design, and Management, second ed. McGraw-Hill, New York.

Dewar, M., Epstein, D., 2007. Planning for "Megaregions" in the United States. J. Planning Literature 22 (2), 108–124. http://dx.doi.org/10.1177/0885412207306615.

Federal Aviation Administration, 2014, October. Airport Categories – Airports [template]. Retrieved February 23, 2015, from http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/categories/.

Fröhlich, K., Niemeier, H.-M., 2011. The importance of spatial economics for assessing airport competition. J. Air Transport Manage. 17 (1), 44–48. http://dx.doi.org/10.1016/j.jairtraman.2010.10.010.

Fu, Q., Kim, A.M., 2016. Supply-and-demand models for exploring relationships between smaller airports and neighboring hub airports in the U.S. J. Air Transport Manage. 52, 67–79. http://dx.doi.org/10.1016/j.jairtraman.2015.12.008.

Fuellhart, K., 2003. Inter-metropolitan airport substitution by consumers in an asymmetrical airfare environment: Harrisburg, Philadelphia and Baltimore. J. Transp. Geogr. 11 (4), 285–296. http://dx.doi.org/10.1016/S0966-6923(03)00005-X.

Fuellhart, K., 2007. Airport catchment and leakage in a multi-airport region: The case of Harrisburg International. J. Transp. Geogr. 15 (4), 231–244. http://dx.doi.org/10.1016/j.jtrangeo.2006.08.001.

Fuellhart, K., Ooms, K., Derudder, B., O'Connor, K., 2016. Patterns of US air transport across the economic unevenness of 2003–2013. J. Maps 12 (5), 1253–1257. http://dx.doi.org/10.1080/17445647.2016.1152917.

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[3] Consider that Delta Air Lines continues to fight competition from local airports. In 2016 Delta agreed to extend their lease at their hub in Atlanta once the City committed, in writing, not to operate a second commercial airport .

Giuliano, G., Gordon, P., Pan, Q., Park, J., Wang, L., 2010. Estimating freight flows for metropolitan area highway networks using secondary data sources. Networks Spatial Econ. 10 (1), 73–91. http://dx.doi.org/10.1007/s11067-007-9024-9.

Gordon, P., Richardson, H.W., 1996. Beyond Polycentricity: The Dispersed Metropolis, Los Angeles, 1970–1990. J. Am. Planning Assoc. 62 (3), 289–295. http://dx.doi.org/10.1080/01944369608975695.

Granados, N., Gupta, A., Kauffman, R.J., 2011. Online and offline demand and price elasticities: evidence from the air travel industry. Inf. Syst. Res. 23 (1), 164–181. http://dx.doi.org/10.1287/isre.1100.0312.

Green, R.K., 2007. Airports and economic development. Real Estate Econ. 35 (1), 91–112. http://dx.doi.org/10.1111/j.1540-6229.2007.00183.x.

Grubesic, T.H., Wei, F., 2012. Evaluating the efficiency of the essential air service program in the United States. Transportation Res. Part A: Policy Practice 46 (10), 1562–1573. http://dx.doi.org/10.1016/j.tra.2012.08.004.

Hansen, M., 1995. Positive feedback model of multiple-airport systems. J. Transportation Eng. 121 (6), 453–460. http://dx.doi.org/10.1061/(ASCE)0733-947X(1995)121:6(453).

Harrison, J., Hoyler, M., 2015. Megaregions: Globalization's New Urban Form? Edward Elgar Publishing.

Hess, S., Adler, T., Polak, J.W., 2007. Modelling airport and airline choice behaviour with the use of stated preference survey data. Transportation Res. Part E: Logistics Transportation Rev. 43 (3), 221–233. http://dx.doi.org/10.1016/j.tre.2006.10.002.

Hess, S., Ryley, T., Davison, L., Adler, T., 2013. Improving the quality of demand forecasts through cross nested logit: a stated choice case study of airport, airline and access mode choice. Transportmetrica A: Transport Sci. 9 (4), 358–384. http://dx.doi.org/10.1080/18128602.2011.577758.

Hihara, K., 2012. An analysis of an airport–airline relationship under a risk sharing contract. Transportation Res. Part E: Logistics Transportation Rev. 48 (5), 978–992. http://dx.doi.org/10.1016/j.tre.2012.03.002.

Hsu, C., Wu, Y., 1997. The market size of a city-pair route at an airport. Ann. Reg. Sci. 31 (4), 391–409. http://dx.doi.org/10.1007/s001680050055.

Innes, J.D., Doucet, D.H., 1990. Effects of access distance and level of service on airport choice. J. Transportation Eng. 116 (4). http://dx.doi.org/10.1061/(ASCE)0733-947X(1990) 116:4(507).

Innes, J.E., Booher, D.E., Di Vittorio, S., 2010. Strategies for megaregion governance. J. Am. Planning Assoc. 77 (1), 55–67. http://dx.doi.org/10.1080/01944363.2011.533640.

Iowa Department of Transportation, 1999. Intercity Passenger Service Study. Committee on Air Service Report to the General Assembly. Retrieved from https://iowadot.gov/pdf_files/asc_report.pdf.

Jang, B., 2010. Edmonton airport looks to stem passenger leakage to Calgary, November 29. Retrieved from https://www.theglobeandmail.com/report-on-business/edmonton-airport-looks-to-stem-passenger-leakage-to-calgary/article1316259/.

Kaemmerle, K.C., 1991. Estimating the demand for small community air service. Transportation Res. Part A: General 25 (2), 101–112. http://dx.doi.org/10.1016/0191-2607(91)90129-E.

Kanafani, A., Abbas, M.S., 1987. Local air service and economic impact of small airports. J. Transportation Eng. 113 (1), 42–55. http://dx.doi.org/10.1061/(ASCE)0733-947X(1987) 113:1(42).

Kimley-Horn and Associates, Inc., 2012. Airport Air Service Profile: Orlando-Sanford International Airport.

Krueger, R., Rashidi, T.H., Rose, J.M., 2016. Preferences for shared autonomous vehicles. Transportation Res. Part C: Emerging Technol. 69, 343–355. http://dx.doi.org/10.1016/j.trc.2016.06.015.

Levine, J., Inam, A., Torng, G.-W., 2005. A choice-based rationale for land use and transportation alternatives evidence from Boston and Atlanta. J. Planning Educ. Res. 24 (3), 317–330. http://dx.doi.org/10.1177/0739456X04267714.

Levinson, D., Mathieu, J.M., Gillen, D., Kanafani, A., 1997. The full cost of high-speed rail: an engineering approach. Ann. Reg. Sci. 31 (2), 189–215. http://dx.doi.org/10.1007/s001680050045.

Lian, J.I., Rønnevik, J., 2011. Airport competition – Regional airports losing ground to main airports. J. Transp. Geogr. 19 (1), 85–92. http://dx.doi.org/10.1016/j.jtrangeo.2009.12.004.

Lieshout, R., 2012. Measuring the size of an airport's catchment area. J. Transp. Geogr. 25, 27–34. http://dx.doi.org/10.1016/j.jtrangeo.2012.07.004.

Malina, R., Albers, S., Kroll, N., 2012. Airport incentive programmes: a European perspective. Transport Rev. 32 (4), 435–453. http://dx.doi.org/10.1080/01441647.2012.684223.

Massport, 2013. Logan Airport Air Passenger Ground-Access Survey. Retrieved November 30, 2016, from https://www.massport.com/environment/environmental-reporting/air-passenger-survey/.

Monteiro, A.B., Hansen, M., 1996. Improvements to airport ground access and behavior of multiple airport system: BART extension to San Francisco international airport. Transportation Res. Rec.: J. Transportation Res. Board 1562, 38–47. http://dx.doi.org/10.3141/1562-05.

Nahlik, M.J., Chester, M.V., Ryerson, M.S., Fraser, A.M., 2016. Spatial differences and costs of emissions at U.S. Airport Hubs. Environ. Sci. Technol. doi: http://dx.doi.org/10.1021/acs.est.5b04491.

Pels, E., Nijkamp, P., Rietveld, P., 2003. Access to and competition between airports: a case study for the San Francisco Bay area. Transportation Res. Part A: Policy Practice 37 (1), 71–83. http://dx.doi.org/10.1016/S0965-8564(02)00007-1.

Phillips, O.R., Weatherford, L.R., Mason, C.F., Kunce, M., 2005. Passenger leaks and the fate of small community air service. Econ. Inq. 43 (4), 785–794. http://dx.doi.org/10.1093/ei/cbi055.

RAPC, 2011. Regional Airport System Planning Analysis: 2011 Update. Regional Airport Planning Committee, Retrieved from. http://www.mtc.ca.gov/planning/air_plan/RASPA-2011_update/Volume_1-Sept_2011_RASPA_Final_Report.pdf.

Ross, C., 2012. Megaregions: Planning for Global Competitiveness. Island Press.

Ryerson, M.S., 2016a. Building air service sustainability. Transportation Res. Rec.: J. Transportation Res. Board 2569, 1–15. http://dx.doi.org/10.3141/2569-01.

Ryerson, M.S., 2016b. Incentivize it and they will come? How some of the busiest U.S. airports are building air service with incentive programs. J. Am. Planning Assoc. 82 (4), 303–315. http://dx.doi.org/10.1080/01944363.2016.1215257.

Ryerson, M.S., Hansen, M., Hao, L., Seelhorst, M., 2015. Landing on empty: estimating the benefits from reducing fuel uplift in US Civil Aviation. Environ. Res. Lett. 10 (9), 94002. http://dx.doi.org/10.1088/1748-9326/10/9/094002.

Ryerson, M.S., Kim, H., 2013. Integrating airline operational practices into passenger airline hub definition. J. Transp. Geogr. 31, 84–93. http://dx.doi.org/10.1016/j.jtrangeo.2013.05.013.

Shapiro, P.S., 1997. Intermodal ground access to airports: a planning guide - a good start. In: Presented at the Sixth TRB Conference on the Application of Transportation Planning Methods. Retrieved from /view.aspx?id = 651266.

Shaw, S.-L., 1993. Hub structures of major US passenger airlines. J. Transp. Geogr. 1 (1), 47–58. http://dx.doi.org/10.1016/0966-6923(93)90037-Z.

Sheard, N., 2014. Airports and urban sectoral employment. J. Urban Econ. 80, 133–152. http://dx.doi.org/10.1016/j.jue.2014.01.002.

Smyth, A., Christodoulou, G., Dennis, N., AL-Azzawi, M., Campbell, J., 2012. Is air transport a necessity for social inclusion and economic development? J. Air Transport Manage. 22, 53–59. http://dx.doi.org/10.1016/j.jairtraman.2012.01.009.

Sperry, B., Larson, S., Leucinger, D., Janowiak, S., Morgan, C., 2012. Intercity passenger rail access to airports. Transportation Res. Rec.: J. Transportation Res. Board 2300, 22–30. http://dx.doi.org/10.3141/2300-03.

Suau-Sanchez, P., Burghouwt, G., Pallares-Barbera, M., 2014. An appraisal of the CORINE land cover database in airport catchment area analysis using a GIS approach. http://dx.doi.org/10.1016/j.jairtraman.2013.07.004.

Suzuki, Y., Crum, M.R., Audino, M.J., 2003. Airport choice, leakage, and experience in single-airport regions. J. Transportation Eng. 129 (2), 212–218. http://dx.doi.org/10.1061/(ASCE)0733-947X(2003) 129:2(212).

Suzuki, Y., Crum, M.R., Audino, M.J., 2004. Airport leakage and airline pricing strategy in single-airport regions. Transportation Res. Part E: Logistics Transportation Rev. 40 (1), 19–37. http://dx.doi.org/10.1016/S1366-5545(03)00055-3.

Tierney, S., Kuby, M., 2008. Airline and airport choice by passengers in multi-airport regions: the effect of southwest airlines. Professional Geographer 60 (1), 15–32. http://dx.doi.org/10.1080/00330120701715218.

van den Berg, V.A.C., Verhoef, E.T., 2016. Autonomous cars and dynamic bottleneck congestion: The effects on capacity, value of time and preference heterogeneity. Transportation Res. Part B: Methodological 94, 43–60. http://dx.doi.org/10.1016/j.trb.2016.08.018.

Vowles, T.M., 2001. The "Southwest Effect" in multi-airport regions. J. Air Transport Manage. 7 (4), 251–258. http://dx.doi.org/10.1016/S0969-6997(01)00013-8.

Windle, R., Dresner, M., 1995. Airport choice in multiple-airport regions. J. Transportation Eng. 121 (4). http://dx.doi.org/10.1061/(ASCE)0733-947X(1995)121:4(332).

Zhang, Y., Xie, Y., 2005. Small community airport choice behavior analysis: A case study of GTR. J. Air Transport Manage. 11 (6), 442–447. http://dx.doi.org/10.1016/j.jairtraman.2005.07.008.

Zupan, J.M., Barone, R.E., Lee, M.H., 2011. Upgrading to world class: The future of the New York region's airports. Regional Plan Association. Retrieved from www.rpa.org/pdf/RPA-Upgrading-to-World-Class.pdf.