The General and Market Specific Impacts of Airport De-Hubbing on Airfares

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Abstract

This paper studies the effects of de-hubbing, the process by which an airline closes hub operations at a certain airport, on airfares. In studying five cases of de-hubbing that occured between 2000 and 2019, I first examine the consequences that de-hubbing has on airfares from flights departing from the former hub airports. Second, I analyze the effects on airfares in markets out of former hub airports that lost nonstop commercial air service due to de-hubbing. Largely consistent with previous studies, I find that average airfares decrease post-de-hubbing at former hub airports where there is an increase in low-cost carrier presence post-de-hubbing. However, I find no statistically significant shift in average airfare at hub airports where there is no substantial increase in low-cost carrier operations post-de-hubbing. Additionally in city-pair markets where nonstop departing service is discontinued post de-hubbing, compared with overall airfare trends for the former hub, I find either no significant difference or a negative change in average airfare, indicating that downward trends in airfare at former hubs may be less prevalent in markets that lose nonstop service.

I. Introduction

Since the Airline Deregulation Act of 1978, many legacy air carriers have established considerable parts of their route networks across hub-and-spoke systems. Legacy airlines, also known as network or full-service carriers, include airlines such as American Airlines and United Airlines, while also historically included airlines such as TWA or Northwest. Colloquially, airline hubs are often characterized as airports with sufficiently large levels of traffic, or perhaps as airports of a sufficient size dominated by one carrier. However, airline hubs are often also characterized by the role that they play within the airline's larger route network, acting as nodes that connect passengers from one destination to another. In the hub-and-spoke mode, airlines route passengers from "spoke" origin airports through hub airports that serve as intermediate stops before sending them on another flight to then arrive at their final destination airport, other "spokes" of the route network. Although some airlines only operate one single hub, the largest legacy US carriers historically have functioned with multiple hubs. A key benefit of hub-and-spoke networks is that they open up numerous combinations of one-stop city pairs that are usually economically unfeasible to serve nonstop. Thus, legacy airlines often optimize their key operating airports to be tailored toward connecting passengers. Accordingly, airlines often create "banks" of flights at their hubs that arrive and depart within a relatively short period of time to minimize connecting times for passengers. In this paper, I examine the consequences on airfares for passengers originating from former hub airports that occur when airlines shut down specific hubs within their network. This process is often called de-hubbing.

De-hubbing can occur for various reasons, such as the unprofitability of a hub, the shutdown or restructuring of an airline, or because of an overlap with another hub of the same airline that makes the presence of two geographically similar hubs inefficient. The latter case often arises after two airlines merge, when operations from two previously competing hubs in a relatively close geographic area are, largely for efficiency purposes, consolidated at a single airport. Although local traffic plays a significant role at most hubs, because of the importance of connecting traffic, airport hubs, by definition, most often have more departures and available seats than can be filled by local traffic alone. Thus, when airlines choose to shut down a hub at airports that have disproportionally large quantities of connecting passengers (compared with the number of local passengers) unless another airline decides to fill in and create a new hub in its place or expand an existing hub at the same airport, the total supply of flights and seats offered out of the former hub airport will generally decrease. In this paper, I largely attempt to analyze the effects of this apparent negative supply shock that occurs during de-hubbing.

Not all airlines operate hub-and-spoke networks; instead, some airlines operate point-to-point networks. In pure point-to-point route networks, airlines do not operate any connecting traffic. All passengers fly directly between their originating city and destination, all on one nonstop flight. Most airlines in the United States that operate point-to-point networks are low-cost carriers (LCCs), which generally operate with lower operating costs than legacy carriers and often offer lower fares than legacy carriers. Nevertheless, the contrast between hub-and-spoke networks and point-to-point networks is often unclear. Airlines, such as Southwest, with primarily point-to-point route networks often have airports with significant operations that can counter the size of many airport hubs of legacy carriers. Historically, such airports, often termed "focus cities," have not primarily had network schedules predominantly established around providing connections. Regardless, many low-cost airlines eventually began allowing passengers to book connecting flights on a single reservation, thus blurring the difference between hub-and-spoke and point-to-point networks.

In this paper, while I only examine airports that were hubs of legacy carriers, I do consider the entry of low-cost carriers into airports that formerly were hubs of legacy carriers. After de-hubbing occurs, low-cost carriers commonly increase service at the former hub airport (Tan and Samuel, 2016) and sometimes operate routes that were discontinued by the former hub carrier. However, given that low-cost carriers generally carry less connecting traffic, most new routes taken up by LCCs are to destinations with only the most nonstop demand from the former hub airport.

For this paper, I will be broadly defining airport de-hubbing as when a legacy airline significantly reduces its presence, in both the number of departures and the number of departing seats,[1] at a major airport where the airline had a significant market share. In a later section, I provide a more detailed definition of de-hubbing for this paper. I consider five instances where airlines shut down hub services at airports between the years 2000 and 2019[2]. These former airline-airport hub operations include United Airlines at Cleveland Hopkins International Airport (CLE), Delta Air Lines at Cincinnati/Northern Kentucky International Airport (CVG), Delta Air Lines at Memphis International Airport (MEM), US Airways at Pittsburgh International Airport (PIT), and American Airlines at St. Louis Lambert International Airport (STL). Although I do not specifically explore the causes of each airline to de-hub these particular airports, four of the five instances occur within five years after the hub airline merged with another airline. In each case of de-hubbing, the surviving airline had at least one other hub located within 400 miles of

[1] I define the number of seats on a particular airline to be the number of seats available on all departing flights on that airline (and in the case of legacy carriers, their regional affiliates) within a particular period of time.
[2] Although there were instances of de-hubbing that occurred before 2000, I only consider recent examples as market characteristics of the aviation industry rapidly change, making it hard to compare instances of de-hubbing that occur with a multi-decade gap in between them.

the hub that was shut down. Thus, it is conceivable that newfound proximity to other hubs gained after mergers play some role in the decision to shut down airport hubs.

I perform two analyses that measure the consequences of de-hubbing on airfares. The first trial attempts to determine the monetary consequences of de-hubbing on passengers in the hub city by comparing average airfares from flights departing the hub airport of interest before and after de-hubbing. The second trial seeks to determine whether airfare changes occur in markets where nonstop flights were discontinued post-de-hubbing and how this price difference compares with the results from Trial 1. While before de-hubbing, passengers flying on routes considered for Trial 2 would have the option of flying nonstop to the destination city, post-de-hubbing, such travelers must fly through a separate hub to reach the destination. Inherently, de-hubbing results in greater inconveniences to passengers who live in the metro area of the hub airport due to the discontinuation of some nonstop flights from the hub airport, which is a characteristic of de-hubbing (Redondi, Malighetti, and Paleari, 2010). However, to my knowledge, there has been no paper that has attempted to quantify the consequences on market airfares caused by the discontinuation of nonstop service. Specifically, in Trial 2, I randomly choose ten airports that lost nonstop service to each of the five hub airports[3] and then measure the weighted average market fares from each hub airport to their respective ten destination airports both before and after de-hubbing. Given that LCCs generally operate point-to-point networks and did not take up nonstop service in any of the markets considered in Trial 2, this trial is furthermore meant to analyze the impacts of de-hubbing in markets only minimally influenced by LCC service or competition. In both trials I use difference-in-difference (DID) regressions that compare the respective average airfares from flights originating at the former

[3] I define an airport to lose service during de-hubbing when in the prior year, there were more than 75 nonstop flights to the destination airport, while following de-hubbing, there are less than 75 nonstop flights per year.

hub airport with national airfare averages as the control. Also, I further compare difference-in-difference analysis results from both trials with one another to ascertain whether there are substantially different trends in airfare in markets that lose nonstop service after de-hubbing.

In Trial 1, I find that de-hubbing contributes either to a non-significant change or a decrease in average airfares at all former hub airports considered. Specifically, at CLE, MEM, and PIT, de-hubbing contributes to an overall statistically significant decrease in average airfares, whereas at CVG and STL, I was not able to ascertain a statistically significant increase or decrease in average airfares caused by de-hubbing. I additionally find a direct correlation between airports with a decrease in average airfares after de-hubbing and airports with an increase in LCC operations post-de-hubbing. This indicates that LCC market entry into airports with former hub operations may help cause a decrease in average fares at such airports. In Trial 2 I find that de-hubbing contributes to a statistically significant decline in average market airfares to airports that lost nonstop service at CLE and PIT, a statistically significant increase in average airfare at STL, and no statistically significant change in average airfare at CVG and MEM. These results reveal that in markets from hubs to airports that lose nonstop service post-de-hubbing (and thus are also only minimally influenced by LCC market entry), changes in average airfare are either not significantly different from or less negative than the total average changes in airfare out of the hub airport (found in Trial 1).

II. Literature Review

Although there is a larger literature that examines the role of airport hubs in the broader airline industry, there is a smaller literature that considers the effects of de-hubbing. Multiple papers have been written that determine the presence of a hub premium, a phenomenon that posits that hub carriers can charge higher fares to passengers traveling either to or from one of an airline's hubs as an endpoint. This concept was developed by Borenstein (1989), who determined that airfares are often higher when an airline possesses an unusually high market share, which occurs often at hub airports. Further studies have focused on hub premiums, many of which corroborate Borenstein's original results. Recently Chen and Lei (2017) determine the existence of a hub premium within the Chinese domestic market, although only determine a hub airfare premium in premium cabin classes, not in economy class, which is an interesting concept that I believe merits further study in other markets. It is possible that the existence of hub airfare premiums at airports can influence changes in airfare post-dehubbing. Redondi, Malighetti, and Paleari (2010) are the first to my knowledge to study the phenomenon of de-hubbing itself. They propose metrics to quantify de-hubbing by measuring the reduction in viable connections possible at a hub airport and find that de-hubbing most often leads to a long-term reduction in the number of seats and destinations.

Less emphasis in the literature has been given specifically to the influence of de-hubbing on airfares, although two recent papers have studied this phenomenon. Many of the methods I use in this paper are modeled after two recent studies that also attempt to measure the effects of de-hubbing on airfare. First, Tam and Samuel (2015) measure the effects that multiple instances of de-hubbing have on airports within the United States between 1993 and 2009. They propose a theoretical model which posits that airfares increase or decrease post-de-hubbing depending on whether there is market presence by low-cost carriers. They examine seven airports that were each de-hubbed by various airlines: BNA, CVG, DEN, DFW, EWR, RDU, and STL. Also, they empirically determine that post-de-hubbing, airports with low-cost carrier presence experience airfare decreases, whereas airports without low-cost carrier presence experience airfare increases, validating their theoretical model. Additionally, Young (2018) examines multiple impacts of United Airlines' de-hubbing at CLE in 2014. Given that there is a large LCC presence at CLE, Young finds results consistent with Tam and Samuel (2015), as there is a significant decrease in average airfare that occurs at CLE post-dehubbing.

This paper contributes to the existing literature by analyzing the effects of de-hubbing on airfares departing former hub airports in more recent instances both previously studied and not before examined in this context. Additionally, I provide the first analysis to my knowledge regarding the impacts that de-hubbing has in markets where nonstop service is lost after de-hubbing.

III. Data

Primary Data Sources

In this paper, I utilize two datasets: the T-100 Segment (All Carriers) dataset and the Airline Origin & Destination Survey (DB1B both of which are published by the Bureau of Transportation Statistics, a part of the United States Department of Transportation. The T-100 Segment (All Carriers) dataset contains information concerning the number of scheduled flights, available seats, and passengers flown on a particular airline on a particular nonstop origin and destination pair within each month. Furthermore, I utilize the DB1B Market dataset, a random 10% survey of all domestic airfare data. Observations in the DB1B dataset provide the airfare of passengers on a single reservation flying between their origin and final destination, regardless of whether connecting flights are included or if they are traveling on a one-way or round-trip ticket. The dataset includes additional information such as the operating air carrier and the market miles flown on the itinerary.

In using the DB1B dataset, similar to Tan and Samuel (2015), I discard any observations where the reported airfare is either less than $25 or greater than $1,500, as it is believed that most of these observations either are purchases with frequent flier miles, are incorrectly coded, or represent another anomalous occurrence. Furthermore, I use the T-100 dataset to determine when the hub airlines de-hubbed the airports of interest and thus also discern relevant before- and after- de-hubbing periods to study. I subsequently use airfare data from the DB1B dataset to compare airfares between the before and after de-hubbing periods. In addition I use the T-100 dataset to investigate changes in low-cost carrier capacity at the hub airports. I use these data to propose possible explanations for disparities in airfare changes between hub airports studied. I collect quarterly data from both datasets from the years 2000 to 2019 for all airports[4].

Time Periods Considered

Next, I define the periods I consider each airport to be de-hubbed. Although some airlines officially state when they regard airports as not being hubs anymore, there is often no statistical uniformity regarding the time an airport is officially considered to no longer be a hub by the airline. Thus, it is important to define rules-based criteria to determine which airports can qualify as having been hubs in the first place and to consistently ascertain time periods where they can be considered to no longer be hubs.

I first establish multiple criteria for an airport to qualify as a hub. Since low-cost carriers operate business models that most often do not utilize conventional hubs, I only consider legacy, non-low-cost, carriers and their hubs as potential candidates for study. To exclude airline decreases in traffic at smaller airports that are not hubs, I only consider airports to be candidates

[4] I additionally include data from Q4 of 1999 for STL because this specific quarter was the first quarter in the 16-quarter pre-de-hubbing period. I did not collect DB1B quarterly data from this quarter from any other airports because the 16-quarter pre-de-hubbing period does not extend to this time at any other hub airport considered.

for de-hubbing if the airport is among the top 50 airports in the United States in terms of enplanements before de-hubbing occurs.[5] Additionally, to account for possible large percentage decreases in capacity by airlines with a small market share at major airports, I only consider an airline-airport combination to be a hub candidate if the airline operates at least a 20% market share in seats at the airport during the time before de-hubbing.

In this paper, I use a similar method to Tan and Samuel (2015) in deciding when to regard an airport as being de-hubbed and how to use those periods to determine the effects on airfare. Broadly, I compare average airfares from quarters before the airport was de-hubbed with average airfares from quarters after the airport was de-hubbed. To account for the transition from hub to non-hub where airfare data from a specific quarter may not clearly fit as occurring before or after the hub was still in place, I do not consider the airfares from the principal de-hubbing period. Aside from restrictions I describe later, I define the principal period of de-hubbing to be the four consecutive quarters in which there is the greatest decrease in the airline's departing seats offered. I consider the four-quarter total decrease in seat capacity to account for any standard seasonal changes in capacity. Average airfares from the 16 quarters before and after the 4-quarter principal de-hubbing period, taken from the DB1B dataset, are then compared to reveal impacts on airfare. I use the relatively longer period of 16 quarters, compared with periods used in previous studies, before and after the principal de-hubbing period to account for varied rates between airports used in the process of shutting down the hub (a process that may indeed begin before and end after the four quarter periods determined). Another reason I use data from the 16 quarters before and after the principal de-hubbing period is to account for the entry of low-cost

[5] I utilize the Enplanements at All Commercial Service Airports (by Rank) lists from each year, published by the Federal Aviation Administration to determine whether each airport was in the top 50 largest airports of the United States prior to de-hubbing.

carriers (LCCs) at the airport, which commonly occurs at airports after de-hubbing. However, since market saturation for LCCs at former hub airports does not occur on short time periods, I must consider a longer period for LCC operations to commence and service to increase. At most airports that I observe in this paper, the majority of post-de-hubbing LCC growth occurs during the 16 quarters directly following de-hubbing. I provide a brief remark on the role of LCCs in a later section.

As a prerequisite for the timeframe qualifying as being a potential 4-quarter principal de-hubbing period, I consider an airport to be de-hubbed only when an airline decreases both 50% of seats and 50% of departures at the airport when comparing the 16 quarters before with the 16 quarters after the principal de-hubbing period. Thus, in choosing the best period determined to be the principal de-hubbing period, the single greatest decrease in seats or departures does not necessarily qualify as the principal de-hubbing period. The importance of this criterion is perhaps best demonstrated by the example of CVG. While the four-quarter period with the greatest decrease in available seats from the hub airline is between 2005 Q3 and 2006 Q2, there was neither a 50% decrease in departures nor available departing seats when comparing the change in average departures and seats in the 16 quarters before the principal de-hubbing period with the 16 quarters after the principal de-hubbing period. Although during this period Delta drastically reduced its capacity at the CVG hub, the sheer size of CVG before this period as one of the largest hubs in the United States resulted only in the hub being downsized and not having its hub status eliminated. Thus, since not every significant decrease in capacity results in the airport losing its hub status, it is important to consider the percentage decreases in departures and available departing seats before and after principal de-hubbing periods, not just the overall change in capacity offered.

All five of the airline-airport hub complexes that I study meet all the criteria propose above. While the process of de-hubbing is not uniform, through the criteria provided, I believe I can separate airport operations of a former hub airline into a pre-de-hubbing and post-de-hubbing period. Graphs measuring the change in total, approximate hub airline, and low-cost carrier departures and available departing seats are presented in Figures 1 and 2 in the Appendix. The quarters used as the principal de-hubbing periods and the 16 quarters before and after that period are listed below in Table 1.

Table 1: Quarters Considered For Hub Airport Analysis

Airline	Principal Dehub Period	16 Quarters Before Dehub	16 Quarters After Dehub
CLE	2014 Q1 - 2014 Q4	2010 Q1 - 2013 Q4	2015 Q1 - 2018 Q4
CVG	2008 Q4 - 2009 Q3	2004 Q4 - 2008 Q3	2009 Q4 - 2013 Q3
MEM	2012 Q1 - 2012 Q4	2008 Q1 - 2011 Q4	2013 Q1 - 2016 Q4
PIT	2004 Q4 - 2005 Q3	2000 Q4 2004 Q3	2005 Q4 - 2009 Q3
STL	2003 Q4 - 2004 Q3	1999 Q4 - 2003 Q3	2004 Q4 - 2008 Q3

Note: The Principal Dehub Period is the 4-Quarter period in which there is the greatest decrease in average hub-carrier departing seats in the 16-Quarter period directly succeeding it, compared with the 16-Quarter period directly preceeding it, so long as hub-carrier departures and departing seats both decrease by greater than 50% in the following 16-Quarter period, compared with the preceeding 16-Quarter period.

Effects of Low-Cost Carriers (LCCs) on Airfares

I further consider the potential effects of low-cost carriers on airfare in markets originating from hub airports and examine whether there is a correlation between change in airfare and entry of low-cost carriers at airports directly following de-hubbing. Low-cost carriers, which fly with lower operating costs than legacy carriers, often sell comparable city-pair tickets with lower airfares than legacy carriers. Thus, when low-cost carriers enter a market, there is often a greater potential for average airfares to decrease than in markets without market entry from low-cost carriers. Tan and Samuel (2015) develop a theoretical model which predicts that the low-cost carrier market entry results in lower average airfares at former hubs.

In addition to analyzing the average changes in the number of departures and departing seats flown by the hub airline at the airport, I also consider the average changes in the number of departing flights and seats from low-cost carriers during the same periods. I use two metrics to determine whether LCCs significantly increase operations at the former hub airport post-dehubbing. The first is the percentage increase in average quarterly LCC seats at the hub airports, and the second is the comparison between the percentage of total average quarterly departing seats operated by LCCs at the hub airport both before and after de-hubbing. I use both metrics to mitigate potential issues that occur if only one of the two statistics were considered. For instance, the average increase in quarterly LCC seats can appear disproportionately large due to low initial levels of LCC service, while the LCC average of total departing seats can appear disproportionately large due to a large decrease in total departing seats offered at the airport, which is common post-de-hubbing. I define a significant increase in LCC presence at an airport (in comparing the 16-quarter post-dehubbing period with the 16-quarter pre-dehubbing period) to occur when there is an average increase departing LCC seats of greater than 100%, combined with an increase in the LCC average percentage of total seats by at least ten percentage points. Through this method, I attempt to ascertain whether airports with a greater increase in LCC departures and seats post-dehubbing correlate with a greater decrease in airfare. For each airport, I only include LCCs that operate regular commercial service to that specific airport in the complete 20-year period of data considered. The airlines I consider for each airport to be LCCs are presented in Table 2 below.

Table 2: Low-Cost Carriers Considered with Regular Service To Hub Airports

Hub Airport	CLE	CVG	MEM	PIT	STL
LCC Carriers	AirTran Airways Allegiant Air Frontier Airlines JetBlue Airways Southwest Airlines Co. Spirit Air Lines WOW Air	AirTran Airways Allegiant Air Frontier Airlines Southwest Airlines Sun Country Airlines WOW Air	AirTran Airways Allegiant Air Frontier Airlines Southwest Airlines	AirTran Airways Allegiant Air Frontier Airlines JetBlue Airways Southwest Airlines Co. Spirit Air Lines Sun Country Airlines WOW Air	AirTran Airways Allegiant Air Frontier Airlines Southwest Airlines Sun Country Airlines WOW Air

Hub Airlines, Their Predecessors, & Their Regional Affiliates

Within the airports that I consider, three occur where the airline operating the hub underwent a merger and thus transferred hub operations to the surviving airline post-merger. Such instances include the TWA hub at STL, which was transferred to American Airlines after their merger, the Northwest Airlines hub at MEM, which was transferred to Delta Air Lines after their merger, and the Continental Airlines hub at CLE, which was transferred to United Airlines after their merger. Since hub operations most often did not undergo radical transformation immediately following each merger, I treat the hub airline pre-merger and the new post-merger hub airline as the same when collecting data. In practice, when analyzing T-100 data to determine the number of departures and departing seats of the hub airline, I include information from both the pre-merger and post-merger hub airlines in my total hub carrier data as one.

Regional carriers play significant roles at nearly all hubs of US airlines. Instead of owning and operating regional-sized aircraft – generally those with capacities of greater than 19 and less than 76 – nearly all legacy US carriers contract out such operations to regional air carriers. Such regional airlines (e.g., Mesa Airlines, SkyWest Airlines) operate on behalf of the main legacy carrier under an affiliated brand name of the legacy carrier (e.g., Delta Connection, United Express, etc.). However, such regional carriers often perform services for numerous legacy carriers (e.g., SkyWest operates flights for both Delta Connection and United Express). Given that regional operations often contribute to a substantial portion (sometimes even the majority) of departures of the primary airline's hub operations, and since tickets on regional carriers are sold by the legacy carrier and thus contribute to the legacy airlines' hub complexes, I believe that it is necessary to account for passengers traveling on regional carriers when considering an airline's total hub operations. Accounting for regional carriers is especially important since legacy carriers often add or discontinue regional flights at different rates from mainline flights, which can influence measurements of when the hub carrier decreased capacity the most.

To account for the regional carrier operations of the specific mainline hub carriers, I determine which regional carriers operated for the hub carrier at the hub airport during the period considered. I collect information about which specific regional carriers operate for a specific legacy carrier from the legacy carriers' current and archived web pages. This method does present a methodological challenge since some regional carriers operate for more than one legacy carrier, and such data is not discriminated between within the T-100 dataset. Thus, hub-airline-specific information used includes some data from regional carriers operating for other mainline carriers and is likely an overestimation of each hub carrier's number of departures and seats at a given airport. However, since no other legacy carriers with their affiliated regional affiliates operated competing hubs or significant rivaling operations at the same airports at the same time as the hub airline considered, I believe that the error in determining overall trends of total hub airline capacity is minimal and less than had I not included regional carrier data at all. Similar to how I consider predecessor airlines in my hub carrier data for each airport, I include information from regional carriers for each airline at each airport, along with data from mainline hub airline operations, as one. Table 3, a list of the regional carriers operating for the legacy carrier that I consider for each airport is detailed below.

Table 3: Airlines Considered As Part of Hub Airline Group

Airports	CLE	CVG	MEM	PIT	STL
Primary Legacy Carrier(s)	Continental Airlines (pre-2012 merger) United Airlines (post-2012 merger)	Delta Air Lines	Northwest Airlines (pre-2010 merger) Delta Air Lines (post-2010 merger)	US Airways (pre-2015 merger) American Airlines (post-2015 merger)	Trans World Airlines/TWA (pre- American Airlines (post-2001 merger)
Regional Brand(s) of Legacy Carrier	Continental Connection (pre-2012 merger) Continental Express (pre-2012 merger) United Express (post-2012 merger)	Delta Connection	Northwest Airlink (pre-2010 merger) Delta Connection (post-2010 merger)	US Airways Express (pre-2015 merger) American Eagle (post-2015 merger)	Trans World Express (pre-2001 merger) AmericanConnection (post-2001 merger) American Eagle (post-2001 merger)
Affiliated Regional Carriers Opertating For Legacy Regional Brands Considered At Specific Hub Airports	Chautauqua Airlines Colgan Air CommuteAir ExpressJet Airlines ExpressJet Airlines GoJet Airlines Mesa Airlines Inc. Republic Airline Silver Airways SkyWest Airlines Trans States Airlines	Chautauqua Airlines Comair Inc. Compass Airlines Endeavor Air ExpressJet Airlines ExpressJet Airlines Freedom Airlines Independence Air Mesaba Airlines SkyWest Airlines	Chautauqua Airlines Comair Compass Airlines Endeavor Air ExpressJet Airlines ExpressJet Airlines Mesaba Airlines Shuttle America SkyWest Airlines	Air Wisconsin Airlines Allegheny Airlines Chautauqua Airlines Colgan Air Envoy Air Mesa Airlines Piedmont Airlines PSA Airlines Republic Airline Trans States Airlines	Chautauqua Airlines Envoy Air Piedmont Airlines PSA Airlines Regions Air Republic Airline Trans States Airlines

Brief Discussion of CVG Data

Given the drastic relative changes in airfare at CVG that occurred both directly before and after the de-hubbing period, I briefly examine the circumstances surrounding CVG separately. CVG is unique compared to the other four airports that I analyze in that the de-hubbing process by Delta was particularly drawn out. Delta initiated its greatest reduction in both departures and departing seats in 2005, which correlates with a direct subsequent increase in average fares at CVG. Tan and Samuel (2015) find that this initial period of capacity reduction by Delta led to a 36.8% increase in average airfare at CVG. However, despite this 2005 decline in flights being the greatest single capacity reduction within 4 quarters by Delta at CVG, this initial duration of capacity reduction does not meet my criteria of 50% reductions in both departures and available departing seats. CVG remained a Delta hub after this initial reduction in flights, roughly the size of Northwest/Delta’s hub at MEM (in terms of departures and departing seats) at its respective peak in operations. Thus, I do not consider Delta's original reduction in capacity to be the foremost instance when Delta de-hubbed CVG. Rather, I consider the primary instance where Delta de-hubbed CVG to be between Q4 of 2008 and Q3 of 2009, in which Delta had the greatest decrease in seats and simultaneously had a greater than 50% decrease in both departing seats and departures in the 16 quarters after this period, compared with the 16 quarters before. Although CVG arguably remained a small hub for Delta following this specific capacity reduction, I believe Delta's gradual decrease in capacity following this instance in the following decade provides no clearer precise 4-Quarter period where one could consider Delta to have de-hubbed CVG.

Furthermore, although there was no significant market entry of LCCs directly following the principal period of de-hubbing at CVG that occurred between 2008 and 2009, between 2014 and 2018, LCCs did significantly increase their operational presence at CVG. Between Q1 of 2014 and Q1 of 2018, the percentage of departing seats flown by LCCs increased from 4.21% to 34.16%. This significant growth in flights by LCCs correlated with a statistically significant decrease in relative average airfare out of CVG. While the market entry of LCCs at CVG likely contributed to lower average airfares, because this period of LCC market entry falls significantly after the bulk of Delta's reduction in both flights and seats at CVG, it is unclear whether one can directly attribute this later decrease in airfare to be a direct consequence of Delta's de-hubbing. While it is plausible that Delta's closure of its CVG hub resulted in the long-term market entry of LCCs at CVG, and therefore likely caused a long-term decrease in average airfare, it is challenging to determine any causality in this situation given the extensive delay between Delta's de-hubbing and the LCC entry. Thus, for this specific paper, I will not further examine changes in capacity or airfare outside of the periods I determined for consideration.

IV. Empirical Analysis

Overview

I use difference-in-difference regressions to determine the overall effects of de-hubbing on airfares in both trials. In each of the trials, I utilize the natural logged average airfare as the dependent variable. The other three variables, as described later, are independent dummy variables indicating the time period of the data taken (before or after de-hubbing) and whether the data represents the quarterly national average airfare or whether it represents the quarterly hub-airport-specific average airfare. In Trial 1, I compare the total quarterly average airfares at hub airports from departing passengers with quarterly national average airfares found. I then use a difference-in-difference regression to compare both sets of airfares from the 16 quarters pre-dehubbing with the average airfares from the 16 quarters post-dehubbing. Next, I use regressions to ascertain the direct effects that de-hubbing has on the average price of tickets departing from former hub airports.

Likewise, in Trial 2, I use a difference-in-difference regression to compare the average airfares from the 16 quarters pre-dehubbing with 16 succeeding de-hubbing. The main difference in Trial 2 is that the dependent variable, also ln(airfare), uses distinct data that measures the average market airfares per quarter from the selected hub to ten randomly chosen airports that lost nonstop service post-de-hubbing. The primary goal of Trial 2 is to measure how airfares change in markets that lose nonstop service post-de-hubbing. The secondary goal asked in Trial 2 is to ascertain the effect on airfare that the inherent supply decrease of de-hubbing has when excluding the effects of LCCs. Trial 2 captures this effect because most LCCs operate primarily with a point-to-point route network and not a hub and spoke network where connecting traffic is most prevalent. Given that post-de-hubbing there are no nonstop flights between the hub airport and the specific 10 airports with nonstop service lost, passengers wanting to fly between the hub airport and the specific destination airports would likely have to fly legacy carriers both before de-hubbing (either on the nonstop legacy hub airline flight or connecting on a different legacy carrier) and post-de-hubbing (connecting on a legacy carrier).

The difference-in-difference regression model adheres to the following equation:

$$\text{[Equation 1]: } \ln(\text{airfare}_{at}) = \alpha_1 + \beta_1(\textit{dehub}_t) + \beta_2(\textit{airport}_a) + \beta_3(\textit{dehub}_t \ x \ \textit{airport}_a) + \varepsilon_{at},$$

where ln(airfare) is the natural logged market average airfare in time t of either national or hub-specific airfares (denoted by a), *dehub* is a dummy variable stating whether the time period is either before or after de-hubbing has occurred, *airport* is a dummy variable stating whether the data is the national airfare average or the average airfare of flights departing from the hub airport, and *dehub x airport* is the combination of *dehub* and *airport.* The term ε_{at} denotes error. The variable *dehub x airport*[6] is the primary variable of interest and represents the difference in the differences of the mean average airfares before and after de-hubbing, when comparing the national average airfare with the average departing airfares at the hub airport. More generally, the variable *dehub x airport* represents the calculated change in the logged average airfare occurring due to the entire de-hubbing process.

[6] The variable of interest in this difference-in-difference analysis, *dehub x airport* is the difference between the airport-specific mean logged average airfare before airport-specific de-hubbing and the airport-specific mean logged average airfare after airport-specific de-hubbing, subtracted from the difference between the US average mean logged average airfare before airport-specific de-hubbing and US average mean logged average airfare after airport-specific de-hubbing.

Trial 1 Results

Table 7 reports the results from the difference-in-difference regression comparing the mean prices before and after de-hubbing of flights departing out of the hub airport with the average from all domestic flights The variable of interest, *dehub x airport*, is negative and statistically significant (p<.05) at three airports, CLE, MEM, and PIT, and is negative and statistically insignificant (p>.05) at two airports, CVG and STL. These results suggest that de-hubbing contributed to causing airport-specific 11.9%, 10.1%, and 14.5% decreases (see Table 10) in average airfare at CLE, MEM, and PIT, respectively. Thus, de-hubbing appears to either decrease or have no statistically significant effect on average airfares for passengers departing former hub airports. Results from all five DID regressions completed in Trial 1 (one from each hub airport) measuring the changes in airfare theorized to be caused by de-hubbing are presented in Table 4 below.

Table 4: Trial 1 Difference-in-Difference Regression Results
(Dependent Variable: ln(airfare))

	Airport (Standard Error)									
Variable	CLE		CVG		MEM		PIT		STL	
(Intercept)	5.531***	(0.011)	5.422***	(0.027)	5.520***	(0.012)	5.371***	(0.013)	5.395***	(0.014)
dehub	0.0304*	(0.015)	0.086*	(0.038)	0.044**	(0.016)	0.055**	(0.019)	0.013	(0.019)
airport	0.0419**	(0.015)	0.211***	(0.038)	0.096***	(0.016)	0.026	(0.019)	-0.028	(0.019)
dehub x airport	-0.124***	(0.021)	-0.092	(0.054)	-0.105***	(0.023)	-0.150***	(0.026)	-0.012	(0.027)

** p<.05, **p<.01, ***p<.0001*

Note: This table reports the results from difference-in-difference regressions measuring the change in logged average airfare caused by de-hubbing. The equation used is outlined in Equation 1. Data points used for this regression are at the quarter level and are averages of individual data points collected from DB1B datasets that are at the route-carrier-year-quarter level and measure individual observations of tickets bought by passengers.

To further analyze this data, I calculate the change in LCC departures and departing seats, the percentage change in departures and departing seats, along with the total LCC percentage of departures and departing seats at each hub airport in question. I also include this exact data for each hub airline. Summary statistics of this data found are presented in Tables 5-7 below.

Table 5: Change & Percentage Change in Average Quarterly Departing Seats and Departures Before and After De-Hubbing*

Airport	Data	Average LCC Seats Before/After Dehub	Average LCC Departures Before/After Dehub	Approx. Average Hub Carrier Seats Before/After Dehub	Approx. Average Hub Carrier Departures Before/After Dehub
CLE	Change	366,495	2,117	-613,752	-10,994
	% Change	217.49%	174.69%	-57.77%	-68.04%
CVG	Change	3,027	19	-1,914,054	-27,716
	% Change	1602.25%	1433.33%	-66.79%	-68.26%
MEM	Change	56,358	335	-1,107,113	-16,311
	% Change	119.42%	83.29%	-76.40%	-80.47%
PIT	Change	305,460	2,307	-1,902,179	-15,408
	% Change	497.56%	426.88%	-70.40%	-58.60%
STL	Change	-40,907	-299	-2,670,995	-18,554
	% Change	-4.52%	-4.46%	-68.06%	-51.63%

Table 6: Average Quarterly Available Departing Seats from Hub Airports**

Airport	Time Period	Average Quarterly Available Seats (All Airlines)	Average Quarterly LCC Tot. Seats	LCC Avg. % of Tot Seats	Approx. Average Quarterly Hub Carrier Tot. Seats	Approx. Average Hub
CLE	Before De-Hubbing	1,483,934	168,511.13	11.36%	1,062,340	71.59%
	After De-Hubbing	1,354,243	535,006.13	39.51%	448,588	33.12%
CVG	Before De-Hubbing	3,041,704	188.94	0.01%	2,865,755	94.22%
	After De-Hubbing	1,133,889	3,216.19	0.28%	951,701	83.93%
MEM	Before De-Hubbing	1,648,559	47,193.25	2.86%	1,449,050	87.90%
	After De-Hubbing	645,488	103,551.06	16.04%	341,937	52.97%
PIT	Before De-Hubbing	3,241,806	61,391.13	1.89%	2,702,087	83.35%
	After De-Hubbing	1,615,513	366,851.44	22.71%	799,908	49.51%
STL	Before De-Hubbing	5,347,334	905,762.44	16.94%	3,924,570	73.39%
	After De-Hubbing	2,624,268	864,855.56	32.96%	1,253,575	47.77%

Table 7: Average Quarterly Departing Flights from Hub Airport***

Airport	Time Period	Average Departures (All Airlines)	Average Quarterly LCC Departures	LCC Avg. % of Tot Departures	Approx. Average Quarterly Hub Carrier Departures	Approx. Average Hub
CLE	Before De-Hubbing	21,430	1,211.81	5.65%	16,160	75.41%
	After De-Hubbing	13,136	3,328.75	25.34%	5,165	39.32%
CVG	Before De-Hubbing	44,243	1.31	0.00%	40,605	91.78%
	After De-Hubbing	18,194	20.13	0.11%	12,889	70.84%
MEM	Before De-Hubbing	38,407	402.50	1.05%	20,269	52.77%
	After De-Hubbing	24,065	737.75	3.07%	3,958	16.45%
PIT	Before De-Hubbing	34,952	540.31	1.55%	26,294	75.23%
	After De-Hubbing	20,617	2,846.81	13.81%	10,887	52.81%
STL	Before De-Hubbing	48,322	6,719.19	13.90%	35,935	74.37%
	After De-Hubbing	30,660	6,419.75	20.94%	17,381	56.69%

** Compares the average airfares in the 16 quarters prior to with the 16 quarters after the 4 principal quarters of de-hubbing (see Table 1)*

*** Compares the average available departing seats in the 16 quarters prior to with the 16 quarters after the 4 principal quarters of de-hubbing (see Table 1)*

**** Compares the average number of departures in the 16 quarters prior to with the 16 quarters after the 4 principal quarters of de-hubbing (see Table 1)*

I find a direct correlation between airports with simultaneous increases in both total LCC capacity at the airport and LCC percentage of total flights and airports with statistically significant decreases in average departing airfare. Particularly, in the period following de-hubbing compared with the period before de-hubbing, the average LCC departing seats per quarter increases by 217.49% at CLE, 119.42% at MEM, and 497.56% at PIT, while the LCC percentage of total departing seats increases from 11.36% to 39.51% at CLE, 2.86% to 16.04% at MEM% and 1.89% to 22.71% at PIT. All three airports meet both criteria presented in an earlier section specifying what I determine to be a significant increase in LCC operations (a 100% increase in average quarterly departing seats and an increase in average quarterly percentage of total departing seats by 10 percentage points).

Although there is a 1,602% increase in LCC departing seats at CVG, the LCC percentage of total departing seats only increases from .01% to .28%. The large percentage increase in LCC departing seats compared with the small increase in the percentage of total departing seats at CVG indicates that although the LCC presence at CVG was negligible before de-hubbing, the actual increase in seats subsequently following de-hubbing was minimal since LCCs did not operate significant scheduled services before de-hubbing. Conversely, there is a 4.52% decrease in LCC departing seats at STL and an increase in the LCC average percentage of total departing seats from 16.94% to 32.96%. This disproportionally large increase in total departing seats, combined with a small decrease in average quarterly LCC departing seats, is largely due to the relatively large original presence of LCCs at STL before de-hubbing, combined with the abrupt closure of American's hub at STL. In both instances, despite one individual metric suggesting a large increase in LCC service at both former hub airports, the actual increase in LCC presence at both airports was either minimal or negative.

While de-hubbing does not always result in lower average airfares out of former hub airports, in the instances where there is significant LCC market entry at the former hub airport (CLE, MEM, and PIT), average airfares out of the airport decrease significantly. Since at most airports studied, significant LCC entry occurred directly following de-hubbing, de-hubbing possibly can be a direct cause of LCC market entry, as to fill the void left by the former hub airline. Thus, consistent with former papers previously referenced, de-hubbing appears to cause a decrease in total average airfares when there is an increase in LCC presence.

Trial 2 Results

In Trial 2, as previously described, I use a difference-in-difference regression to analyze the effects that de-hubbing has on the weighted average airfare to ten randomly selected destination airports that permanently lost nonstop service directly after the period of de-hubbing. The ten destination airports randomly chosen for each hub airport are listed in Table 8.

Table 8: 10 Randomly Chosen Domestic Airports With Nonstop Service Permanently Discontinued After De-Hubbing

	Originating Hub Airport				
10 Destination Airports	CLE	CVG	MEM	PIT	STL
Airport 1	ERI	ATW	AMA	BTV	ANC
Airport 2	FKL	COS	CLE	CAK	FSD
Airport 3	GRR	DAY	GPT	GRR	HNL
Airport 4	GSP	FSD	HSV	GSP	LNK
Airport 5	MCI	GRB	ICT	ITH	MLI
Airport 6	MDT	LAN	JAX	LEX	OGG
Airport 7	MSN	OKC	LFT	MCI	ONT
Airport 8	PWM	PDX	MLU	ROA	SBN
Airport 9	SDF	PVD	MOB	SBN	SHV
Airport 10	SYR	SNA	MSN	TOL	SJU

At two airports, CLE and PIT, I find statistically significant decreases in airfare to the ten respective destination airports with nonstop service lost, at one airport, STL, I find a statistically significant increase in average airfare, while at two airports, CVG and MEM, I find no statistically significant change in airfare. Thus, I find no general conclusion as to whether average airfares increase or decrease in markets that lose nonstop service during the period of de-hubbing. Table 9 summarizes the results of my five regressions for each hub airport for Trial 2 and is presented below.

Table 9: Trial 2 Difference-in-Difference Regression Results
(Dependent Variable: ln(airfare))

Variable	Airport (Standard Error) CLE		CVG		MEM		PIT		STL	
(Intercept)	5.531***	(0.011)	5.422***	(0.028)	5.520***	(0.013)	5.371***	(0.020)	5.395***	(0.014)
dehub	0.0304	(0.015)	0.086*	(0.039)	0.044*	(0.018)	0.039562	(0.028)	0.013706	(0.020)
airport	0.044**	(0.015)	0.269***	(0.039)	0.107***	(0.018)	0.00452	(0.028)	0.253***	(0.020)
dehub x airport	-0.071**	(0.022)	-0.10286	(0.055)	-0.02311	(0.026)	-0.138**	(0.039)	0.061*	(0.029)

** p<.05, **p<.01, ***p<.0001*

Note: This table reports the results from difference-in-difference regressions measuring the change in logged average airfare caused by de-hubbing. The equation used is outlined in Equation 1. Data points used for this regression are at the quarter level and are averages of individual data points collected from DB1B datasets that are at the route-carrier-year-quarter level and measure individual observations of tickets bought by passengers.

Additionally, I compare the results from the general regressions measuring the change in the average airfare to all destinations (Trial 1) out of the hub airport with the results found measuring the changes in the average airfare to its specific ten destination airports (Trial 2). At two out of the five hub airports studied, CLE and MEM, I find that the decrease in airfare that occurs at the ten randomly selected airports is significantly less negative than the general average airfare departing from the former hub airports. Specifically, there is a significant 11.93% decrease in airfares to all destinations compared with a significant 6.82% decrease in airfares to its specific ten destination airports at CLE, and a significant 10.09% decrease in airfares to all destinations compared with a non-significant 1.91% decrease in airfares to its specific ten destination airports at MEM. Meanwhile, at STL, there is a statistically significant positive 6.73% change in airfare when considering airfares to the ten airports with discontinued nonstop service, as opposed to a 1.30% non-statistically significant decrease in airfare when considering all departing airfares. These results are roughly in line with my hypothesis; since there is a permanent significant supply decrease at all included markets in each of the ten markets per airport, and since there are limited effects from LCCs on these individual markets, I originally predicted that in these ten markets per airport, there would be a less negative or more positive change in average airfare. Table 10, a summary listing the calculated percentage changes in average quarterly airfare that seemingly occurs because of changes because of de-hubbing is presented below.

Table 10: Percentage Change in Average Airfare

	Originating Hub Airport				
Destination Airports	CLE	CVG	MEM	PIT	STL
All Destinations	-11.93%	-8.77%	-10.09%	-14.50%	-1.30%
10 Airports With Discontinued Service Post-Dehub	-6.82%	-9.13%	-1.91%	-13.10%	6.73%

Note: This table reports the percentage changes in average airfare observed through a Difference-in-Difference regression, theorized to be caused by changes in hub airline and LCC capacity that occur during and after de-hubbing. Statistical significance of changes in airfare are presented in the dehub x airfare *variable in tables 7 and 9.*

At CVG and PIT, there is not a statistically significant difference between the changes in average airfare post-de-hubbing when comparing the differences in average airfare to all destinations (Trial 1) with the differences in average airfare to the ten airports with discontinued nonstop service (Trial 2). Specifically, there is a non-significant 8.77% decrease in airfares to all destinations and a non-significant 9.13% decrease in airfares to its specific ten destination airports at CVG, while there is a significant 14.50% decrease in airfares to all destinations and a significant 13.10% decrease in airfares to its specific ten destination airports at PIT.

Thus, with comparison to average national airfares as the control variable in a difference-in-difference analysis, my results from Trial 2 overall do not indicate any consistent trend as to whether average airfares increase, decrease, or remain the same in markets that lose nonstop service post-de-hubbing. However, changes in average airfare in markets that lose nonstop service appear to be either less negative than or identical to the changes in average airfare when considering all flights out of former hub airports.

V. Possible Sources of Error in Data Collection & Analysis

Given the lack of uniformity in the length and scale by which airlines choose to pursue when closing an airport hub, any method which analyzes the effects of de-hubbing inevitably provides difficulties in comparing multiple example airports with one another. First, although I set uniform lengths of time used that I consider for examples of de-hubbing, this method is not perfect as reductions in hub services that ultimately lead to full de-hubbing can occur at vastly different timescales between airports. Additionally, the difference in the scale of capacity reductions that occur between different de-hubbing processes could also influence the degree of airfare changes that occur during periods of the same length. This issue is especially pertinent when considering CVG, where Delta decreased hub operations at a much slower rate than other airlines did at other hubs. However, any alternative methods would likely provide other issues that could also impact results. For instance, were I to examine periods with varied lengths which had similar percentage reductions in capacity by each hub airline in question, other issues, such as the supplemental emphasis on the effects of LCCs at airports where longer periods are considered, may disproportionately influence results. Nevertheless, it may be worthwhile in the future to conduct a study that compares before-and-after periods of de-hubbing not measured by a specific length of time but measured by periods with consistent decreases or percentage decreases in capacity between former hub airports.

Second, I aggregate individual airfare data into quarter-level averages and use those 16 data points per airport or national average-specific time period, meaning that I use 64 data points per regression. Since airfare data from each quarter is given equal weight in individual regressions, disproportional extra weight is given to individual airfare data points in quarters with less overall DB1B data (fewer passengers traveling), while less weight is given to data points in quarters with more overall data (more passengers traveling). Third, I do not account for national average income and other macroeconomic factors specific to individual cities or regions which have the potential to influence airfares in specific cities and markets. Fourth, as aforementioned, since I include regional carriers in my hub airline level data, for each hub airline, I overestimate the number of departures and available departing seats for each airport. While this provides some source of error, I believe that the alternative of not accounting for regional affiliates of legacy carriers provides a greater potential for error.

I additionally make multiple assumptions for Trial 2. First, I assume little to no variance in quantity demanded because of the change in supply in the removal of nonstop service because of de-hubbing to the ten airports randomly chosen. Instead of choosing to fly from the hub airport to their final destination which lost nonstop service through another third, likely hub, airport it is possible that the loss of nonstop service hinders flight demand in a particular market. This influence of supply on market demand could occur because potential customers decide to use another mode of transportation other than a connecting flight (such as driving themselves or rail) or because individuals instead might choose to travel elsewhere to a destination that continued having nonstop air service. Additionally, I do not account for specific changes associated with average price changes related to the ten specific cities in comparison to the average domestic airfares of the whole nation, which still serves as the control data. This problem, while still existent in Trial 1, is conceivably exacerbated in Trial 2. While Trial 1 includes airfares to all domestic markets from the hub airport, which are more likely to follow the same airfare trends as the rest of the country, Trial 2 only includes market data to randomly selected ten airports, of which each airport may experience vastly different changes in average airfare completely unrelated to the loss of nonstop service to the one hub airport considered.

VI. Conclusion

The shutdown of specific hubs is an inevitable occurrence within legacy airline hub-and-spoke networks. In this paper, I utilize hub carrier capacity data to determine the specific periods that can best be thought of as the primary period of de-hubbing. I then use airfare data in markets departing the hub airport, compared with national domestic airfare data, within the respective periods before and after de-hubbing, to determine the impacts that de-hubbing has on airfares for passengers originating out of specific former hub airports. I then compare this data with capacity data from low-cost carriers to determine a correlation between low-cost carrier market entry and price changes post-de-hubbing. Additionally, I perform a similar analysis that measures the effects that de-hubbing has on airfares in markets to destinations that had nonstop service discontinued after the hub was shut down.

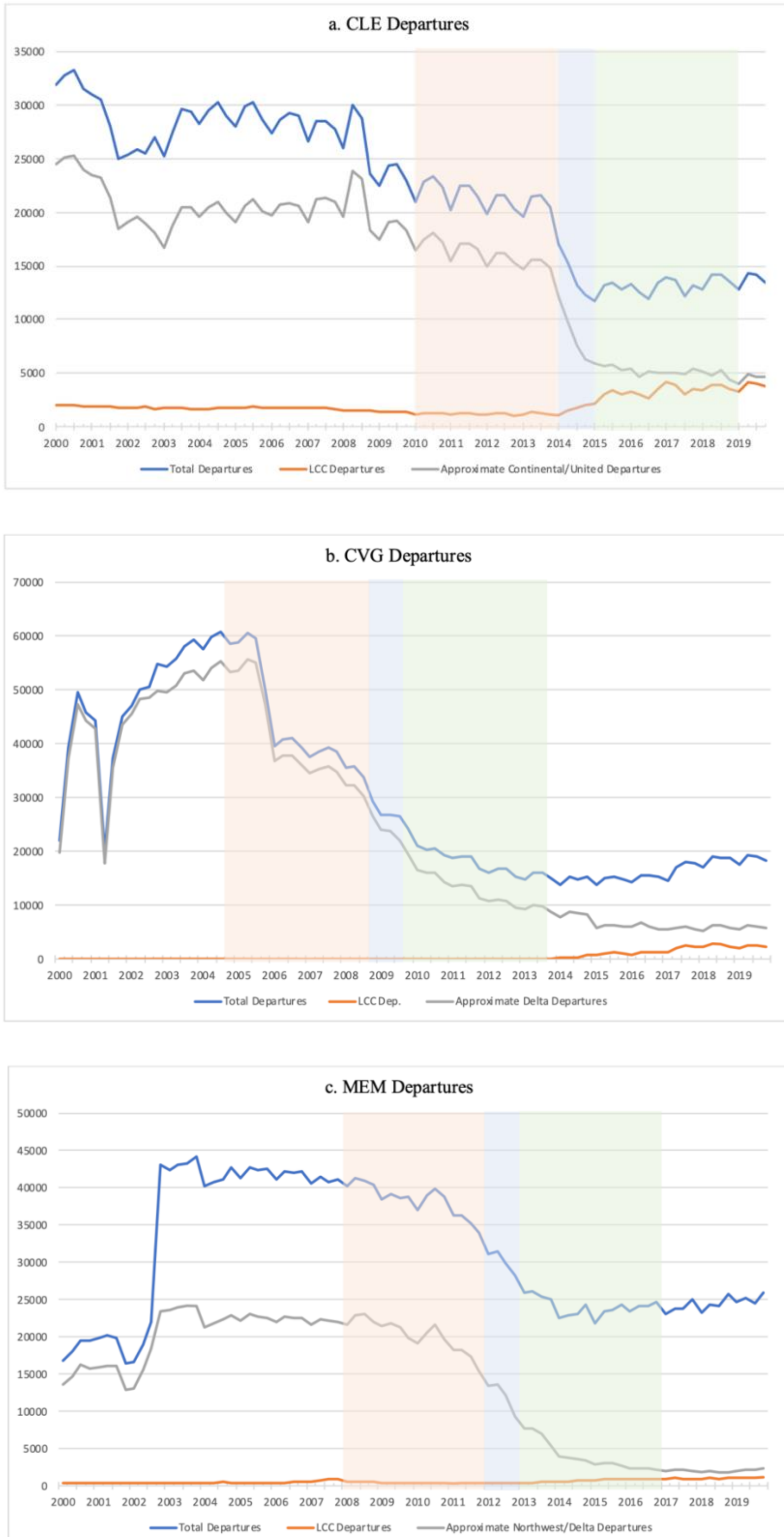
In Trial 1, I find that only at airports with a substantial increase in low-cost carrier presence post-de-hubbing (CLE, MEM, and PIT), is there a statistically significant decrease in average airfare that occurs post-de-hubbing, while I find no significant changes in average airfare caused by de-hubbing at the other two (CVG and STL). Thus, de-hubbing appears to either have no effect on or bring down average airfares at former hub airports, with the outcome reliant on whether there is low-cost carrier entry post-de-hubbing. In Trial 2, I measure the effects of de-hubbing on airfare in markets that have a small low-cost carrier presence either before or after de-hubbing. I find no specific pattern as to whether airfares increase or decrease in markets that lost nonstop service after de-hubbing. However, at three out of the five former hub airports (CLE, MEM, and STL), I find that in comparison to total changes in average airfares out of each respective airport, markets with nonstop service discontinued post-de-hubbing experience a less negative change in airfares. At the other two hub airports (CVG and PIT), I find no significant difference between the relative changes in airfare. Thus, markets with nonstop service discontinued post-de-hubbing, compared with all markets departing the hub airport, appear to either experience identical or less negative changes in average airfare.

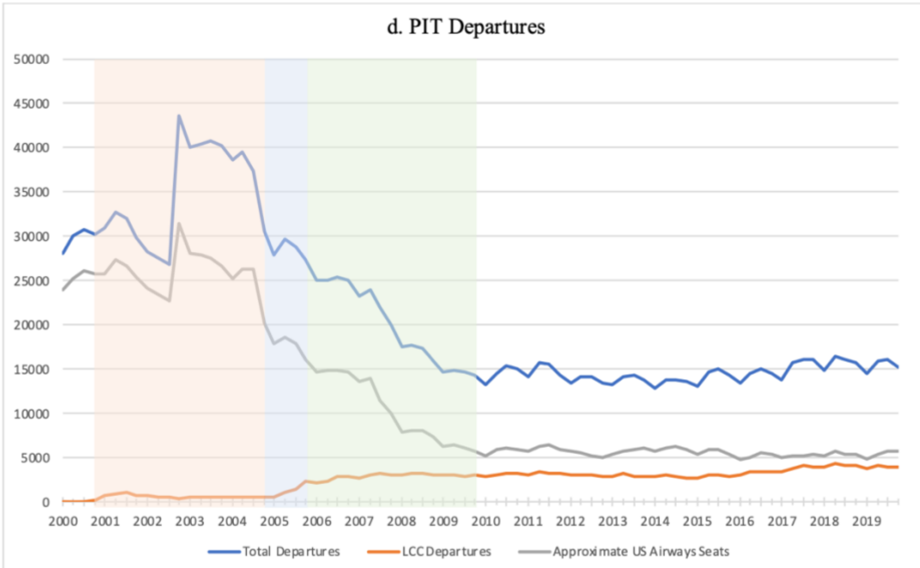
My results from Trial 1 mostly corroborate the results found in the existing literature regarding the effects of airfare on de-hubbing. Although the results from Tan and Samuel (2015) suggest that a statistically significant decrease in airfares post-de-hubbing occurs at all airports with a significant low-cost presence both before and after de-hubbing, my results are only able to corroborate a significant post-de-hubbing decrease in airfare at airports where there is a significant increase in low-cost carrier post-de-hubbing. Although I use distinct trial airports and time periods, my results do not suggest an increase in general airfares occurring at any airports post-de-hubbing. Additionally, my results support the findings from Young (2018) that determine a statistically significant decrease in average airfare at CLE following de-hubbing. My results from Trial 2 are the first of my knowledge to consider the effects on average airfare in city pair markets that lost nonstop service post-de-hubbing.

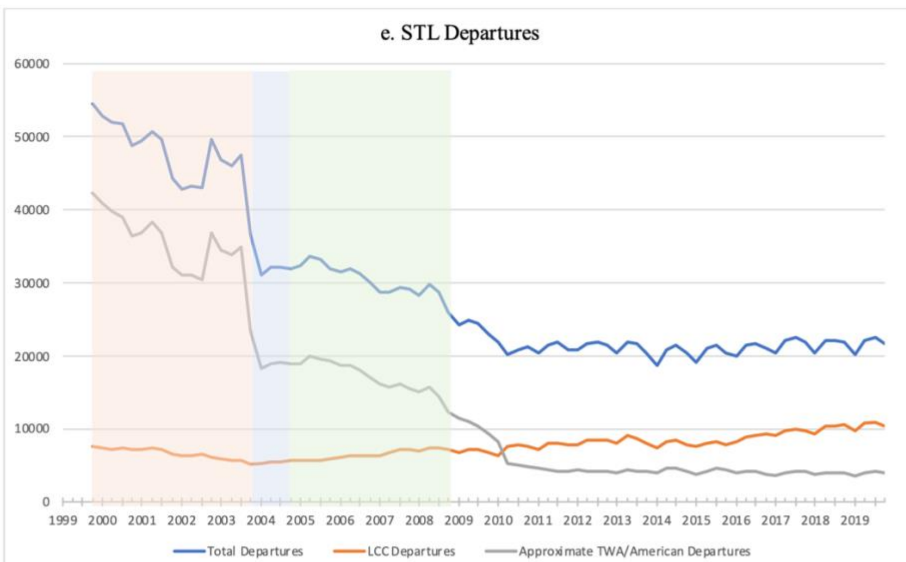
This paper suggests multiple areas of future research. First, although I do not concentrate on the change that occurs after de-hubbing in average airfares on specific airlines and within specific markets, it may be interesting to research the effects on airfare for specific airlines. This type of study would observe whether the loss of market power influences the average airfares on the former hub airline departing from the former hub airport. It may also be worthwhile to analyze the changes in airfare that occur in markets where there is increased LCC presence post-de-hubbing compared with markets that experience no nonstop LCC presence. Additionally, future papers may be interested in analyzing the effects on airfare and convenience (such as average total travel time) that occur in the markets with historically the most connecting traffic through the former hub airport.

VII. Appendix

Figure 1: Hub Airport Number of Departures Per Quarter[i]

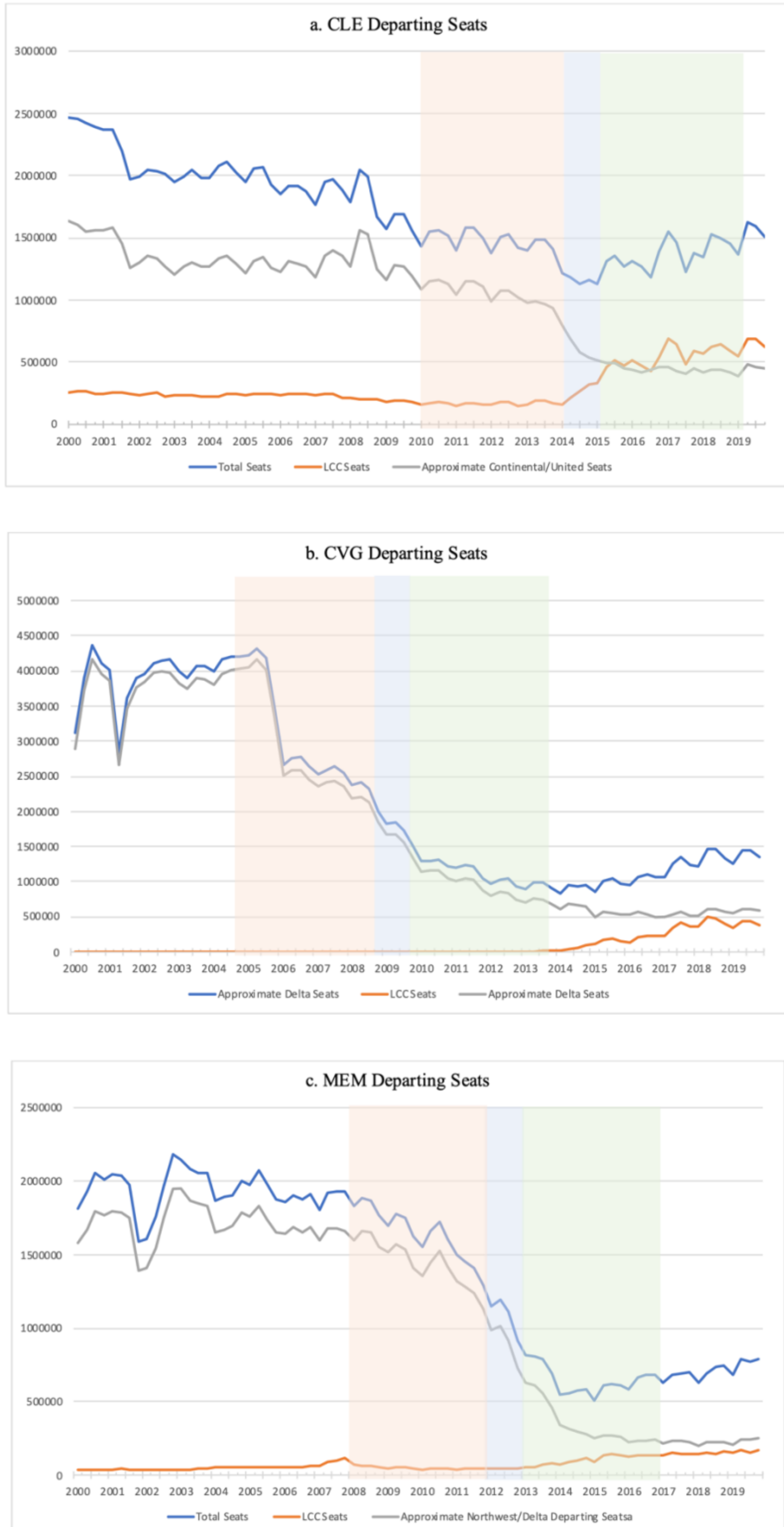


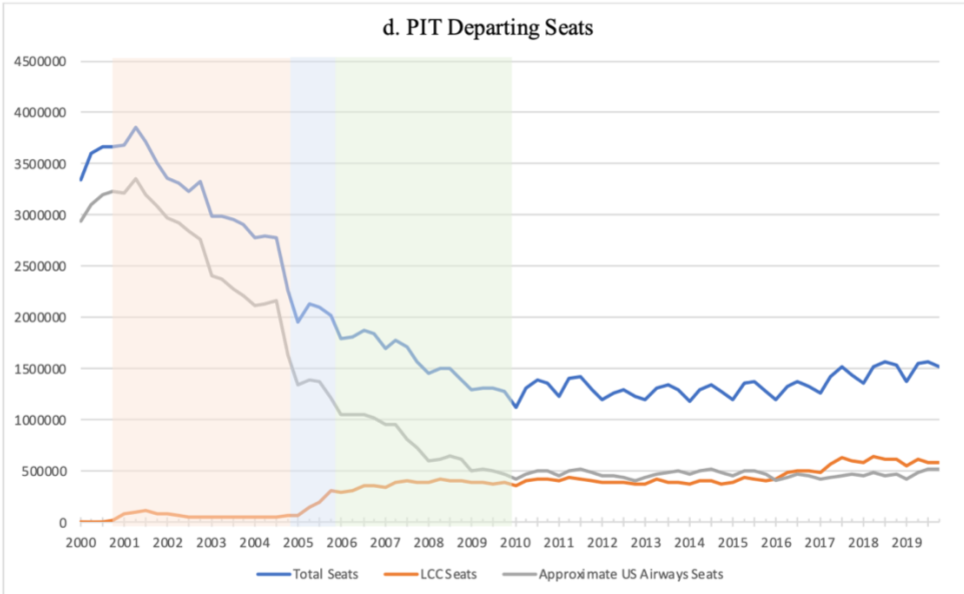




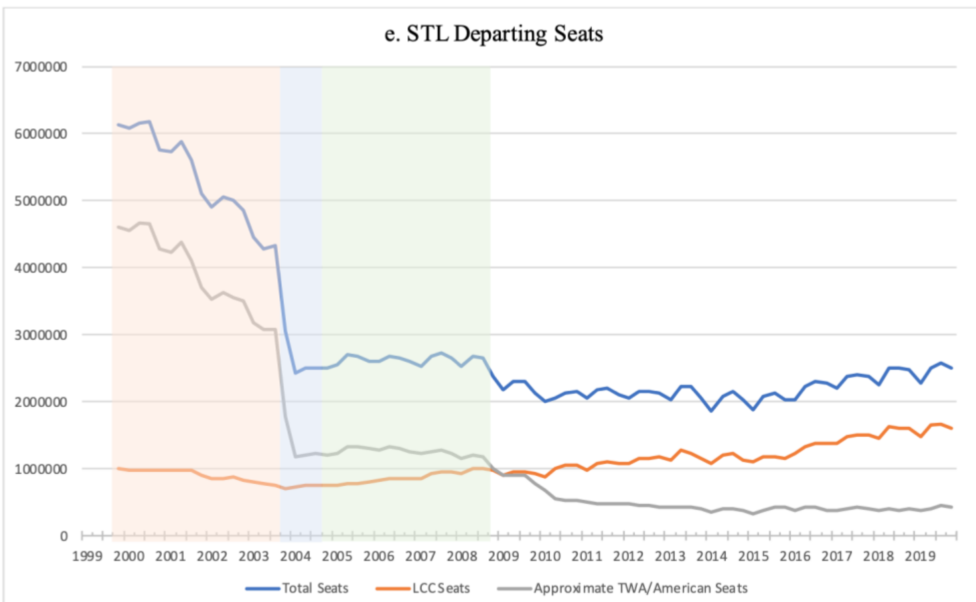
[ii] The red shaded area denotes the 16-quarter pre-de-hubbing period, the blue shaded area denotes the 4-quarter principal de-hubbing period, while the green shaded area denotes the 16-quarter post-de-hubbing period. The 16-quarter pre-de-hubbing and post de-hubbing periods are compared when analyzing airfare data.

Figure 2: Hub Airport Number of Departing Seats Per Quarter





d. PIT Departing Seats
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Total Seats
LCC Seats
Approximate US Airways Seats



e. STL Departing Seats
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Total Seats
LCC Seats
Approximate TWA/American Seats

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