Mergers and Product Quality:

A Silver Lining from De-Hubbing in the U.S. Airline Industry*

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Abstract

This paper investigates how de-hubbing, which occurs when an airline ceases hub operations, impacts product quality. Examining four cases of de-hubbing following U.S. airline mergers between 1998 and 2016, we analyze three product quality measures: on-time performance, travel time, and flight cancellations. In order to isolate a merger's impact on product quality, we compare the results of four de-hubbing events that followed a merger with three de-hubbing cases that occurred independently of a merger. We find a silver lining from mergers since product quality improvements are isolated to de-hubbing events which follow airline mergers rather than non-merger induced de-hubbing.

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1 Introduction

> "Our hub in Cleveland hasn't been profitable for over a decade, and has generated tens of millions of dollars of annual losses in recent years. We simply cannot continue to bear these losses." (former United CEO Jeff Smisek's letter to United's Cleveland employees, 1 February 2014).[1]

A series of mergers in the airline industry since 2004 has trimmed the number of major U.S. airlines from ten to just four large carriers which dominate the U.S. domestic market. These mergers have caused carriers to re-evaluate their route network structure in search of efficiency gains. A frequent consequence of an airline merger is the decision to reduce the number of hub airports, a phenomenon called "de-hubbing". Since 1998, there have been four cases in the U.S. where an airport has been de-hubbed after an airline merger. This paper examines the impact that these de-hubbing events have had on product quality. While companies commonly cite synergies and efficiency gains as justifications for merging, this paper provides a retrospective look at whether mergers generate efficiency gains or losses. Our measure of efficiency is the daily operational performance of the airline in terms of on-time performance, such as flight delays, travel times, and flight cancellations.

This research has public policy implications given the testimony by Gerald L. Dillingham, the Director of Civil Aviation for the Government Accounting Office (GAO), to the Subcommittee on Aviation Operations regarding the U.S. Airways - American Airlines merger indicated that the GAO's evaluation of the merger is to determine "if the potential benefits for consumers outweigh the potential negative effects" (U.S. GAO-13-403T). Hence, this paper sheds some light on whether airline mergers and subsequent de-hubbing of an airport improves (or worsens) product quality for consumers.

Airlines seek to merge for both revenue and cost reasons. From a revenue viewpoint, the merged entity now has a more valuable network of flight offerings and the potential for having

[1] Mutzabaugh, Ben. (2014, February 2). "United Airlines axing its hub in Cleveland", *USA Today*.

greater market power from having one less competitor in overlapping markets. For example, US Airways estimated that the annual financial benefits to shareholders following the consummation of the American and US Airways merger completed in 2015 would be $1.4 billion with the majority of these benefits coming from additional revenue due to improvements in network connectivity, a more valuable frequent flier network, and optimization in the use of aircraft (GAO-13-403T). From a cost standpoint, a merged company can also provide potential cost savings. US Airways executives expect the American Airlines and US Airways merger to generate $640 million in annual cost savings by reducing or eliminating duplicative operating costs, including inefficient (or redundant) hubs or routes (GAO-13-403T).

Due to the consistency in which de-hubbing of airports has occurred following previous airline mergers, the state attorney generals of Arizona, Florida, Michigan, Tennessee, Pennsylvania, Virginia, and District of Columbia filed lawsuits in opposition to the US Airways - American Airlines merger out of fear that their state could potentially suffer substantial job losses at existing hub airports. In their Amended Complaint, these attorney generals provide an economic rationale for de-hubbing following the US Airways - America West merger when they quote the Chief Financial Officer for US Airways in 2010:[2]

> "We believe in the hub system. I just think that there's too many hubs. If you look across the country, you can probably pick a few that are smaller hubs and maybe duplicative to other hubs that airlines have that they could probably get out of. In our example, we merged with US Airways [and] … what we have done over time which is unfortunate for the cities, but we couldn't hold a hub in Pittsburgh and we couldn't hold a hub in Las Vegas. So over time we have consolidated and condensed our operation back, which is really important, condensed it back to our major hubs."

As a condition for allowing American and US Airways to merge, the AMR Corporation reached a settlement agreement with the U.S. Department of Justice and state attorney generals to "maintain

[2]The Amended Complaint can be found at: `https://www.justice.gov/atr/case-document/file/514521/download`.

its hubs in Charlotte, New York (Kennedy), Los Angeles, Miami, Chicago (O'Hare), Philadelphia, and Phoenix consistent with historical operations for a period of three years" (AMR Corporation press release, 12 November 2013).[3] Hence, the possibility still exists that American may close one of its existing hub airports after three years (beginning in 2016:Q4). Consequently, this research on mergers and product quality following de-hubbing is of particular interest for travelers at existing American Airlines hub airports.

There has been considerable research into the economics behind the hub-and-spoke networks frequently utilized in the airline industry. Major carriers have been shown to charge higher prices to and from hub airports for a variety of reasons, including increased market power (Borenstein, 1989), frequent flier programs (Lederman, 2008), access to scarce airport facilities (Bilotkach and Pai, 2016) and mixture of leisure/business passengers (Lee and Luengo-Prado, 2005). Moreover, Brueckner and Lin (2016) analyze the trade-offs between flight frequency and on-time performance at hub airports. Finally, Brueckner and Spiller (1991) study the antitrust implications of this type of network structure.

Researchers have also investigated the impact of an airport de-hubbing on flight operations and airfares. Examining thirty-seven instances of de-hubbing events worldwide, Redondi et al. (2012) find that the typical de-hubbed airport does not recover their original traffic level after five years. Examining de-hubbing at U.S. airports, Tan and Samuel (2016) find lower fares following de-hubbing at airports with a low-cost carrier presence, while higher fares occur after de-hubbing at airports without a low-cost carrier presence. Our paper differs from these papers in two important ways. First, we are interested in the impact of de-hubbing on product quality as opposed to seats offered (Redondi et al., 2012) or airfares (Tan and Samuel, 2016). More importantly, we use de-hubbing cases to analyze the efficiency gains or losses from an airline merger.

There has been some recent research exploring the link between airline mergers and product quality. Prince and Simon (2017) find that airline mergers have minimal impact on quality (on-

[3] American Airlines. (2013, November 12). "AMR Corporation and US Airways Announce Settlement with U.S. Department of Justice and State Attorneys General" [Press release]. Retrieved from http://news.aa.com/press-releases/default.aspx.

time performance) immediately following the merger, while documenting some evidence of long-run improvements in service quality (between three and five years) after the merger. On the other hand, Steven et al. (2016) find that immediately following airline mergers, service quality (on-time performance, flight cancellations, mishandled bags, and involuntary boarding denials) typically declines, while longer term effects of increased flight delays and involuntary boarding denials persist up to three years later. Given these contradicting results, there is a need for further empirical study on the link between mergers and product quality. Our work differs from Prince and Simon (2017) and Steven et al. (2016) since they both examine all flight operations throughout the U.S. following a merger, while this paper focuses solely on product quality at the de-hubbed airport after a merger. Finally, Chen and Gayle (2018) investigate the directness of the itinerary routing as their quality measure following the Delta/Northwest and Continental/United mergers. They find a decrease (increase) in product quality post-merger if the merging firms were competitors (not competitors) in the market.

Beyond the airline industry, others have examined the impact on product quality following mergers and acquisitions. For example, using a structural model of convenience store expansion in Japan, Nishida and Yang (2015) report that mergers have a detrimental effect on the underlying unobserved performance dynamics of the merged entity, whereas others have found a neutral effect on quality following a merger. Examining data from Consumer Reports across a variety of brands (e.g., washing machines or vacuum cleaners), Sheen (2014) finds that when two manufacturers of a given product merge, the product quality of their products converges after a two to three year period.

There have also been numerous studies which document improvements in product quality and firm performance following a merger. Reviewing 10-K product descriptions following mergers, Hoberg and Phillips (2010) find that the merged entity has improved operational performance as evidenced by an increase in the creation of new products which offer greater product differentiation compared to its rivals. In the Japanese cotton spinning industry, Braguinsky et al. (2015) find that there is a noticeable improvement in the acquired plants' productivity and profitability once new management/ownership took control. Maksimovic and Phillips (2001) show that transfer of corporate assets (by mergers, acquisitions, or plant sales) typically improve the allocation of resources and hence, result in an increase in productive efficiency. McGuckin and Nguyen (1995) examine more than 28,000 plant ownership changes in the U.S. food manufacturing industry over an eleven year period (in 1970s-80s) and find that a plant ownership change is associated with an improvement in the acquired plants productivity. More recently, Gugler and Siebert (2007) find that mergers in the semi-conductor industry are associated with net efficiency gains. Although there is not a clear consensus on the impact of mergers on product quality, most empirical studies indicate an improvement in product quality.

In sum, this paper explores the link between mergers and product quality by examining recent airport de-hubbing events which have followed airline mergers. Since 1998, airports have been de-hubbed both following mergers (four cases) and unrelated to mergers (three cases). We compare findings across both scenarios in order to determine the product quality changes attributed to merger-related de-hubbing. We find that product quality improvements are isolated to de-hubbing events which follow airline mergers rather than non-merger induced de-hubbing. Although consumer welfare is harmed from the reduction in the number of airports served following airport de-hubbing, we do, however, find a silver lining for consumers since merger efficiencies lead to improved product quality as travelers at de-hubbed airports experience more reliable flight schedules and shorter travel times. Therefore, policymakers and state attorney generals should also consider the efficiency gains from more reliable flight schedules and shorter travel times when calculating the costs and benefits from a proposed airline merger.

2 Data

The paper utilizes three databases provided by the Bureau of Transportation Statistics: Airline On-Time Performance Data, Airline Origin and Destination Survey (DB1B), and the T-100 Domestic Market data.[4] The on-time data provide information pertaining to on-time service quality, including domestic flight schedules, origin and destination airports, operating carrier, flight delays, and cancellations. Second, the DB1B data is a 10 percent sample of all domestic airline tickets by the reporting airlines. These data provide flight itinerary details including the airline ticket price and passengers transported. Finally, the T-100 data provide information on the number of departures along with seating capacity. Since the DB1B data are quarterly observations, we aggregate all three data sets to the quarterly level. Hence, each observation represents a carrier at the route level for each quarter and year. Our data set spans from 1998:Q1 to 2016:Q4.

Our sample includes flights within the contiguous United States for the ten largest US carriers (based on passengers served) during our sample period (in alphabetical order): AirTran Airways, Alaska Airlines, American Airlines, Continental Airlines, Delta Air Lines, JetBlue Airways, Northwest Airlines, Southwest Airlines, United Airlines, and US Airways.[5]

We define a route as a unidirectional airport-pair. For example, Delta provides nonstop service between Baltimore/Washington International Airport (BWI) and Hartsfield-Jackson Atlanta International Airport (ATL) in 2016:Q4. Our data set contains two observations pertaining to this example. One observation is Delta flying from BWI to ATL in 2016:Q4 and another observation is Delta flying from ATL to BWI in 2016:Q4.

While the FAA only uses a single criterion − passenger enplanements − to classify airports as hub or non-hub, we believe that the hub airport determination should be based on both passenger enplanements and passenger connectivity. A connecting passenger is identified as someone whose flight itinerary includes at least one stop. Passenger connectivity for an airline at a particular airport is then defined as the proportion of the airline's passenger traffic who are connecting passengers. For example, passenger connectivity for US Airways at BWI was 20.5% in 1998:Q1. In other words, one in five passengers used BWI as a connection between their origin airport and their final destination.

[4] All three databases can be downloaded at: `http://www.transtats.bts.gov`.

[5] Rankings based on either the number of flights flown or total revenue yield the same set of airlines.

Hence, our first criterion for an airport to be considered an airline's "hub" is that at least 20 percent of the airline's passengers at the airport are making connections. Our second criterion to be considered a "hub" is the airport must be among the 50 largest airports in the United States based on the number of enplanements.[6] We define an airport as being "de-hubbed" if passenger connectivity drops by 33 percent or more in the four quarters following de-hubbing compared to the previous four quarters.[7]

We exclude the quarter in which the de-hubbing event occurred in our regression analysis since Jeff Smisek, the former CEO of United Airlines, noted that "we have made the difficult decision to substantially reduce our flying from Cleveland. We will make this reduction in stages..." in the same 2014 letter to United's Cleveland employees as quoted in the introduction of this paper. As such, we will compare the performance of the carrier in the before period (four quarters preceding the de-hubbing event) with the post period (four quarters following the de-hubbing event), while excluding the transitional quarter in which de-hubbing occurs.

Table 1 presents the four major mergers in the U.S. airline industry in chronological order of when the merger was publicly announced, as well as the airport that was de-hubbed as a result of the merger: Lambert-St. Louis International Airport (STL), McCarran International Airport (LAS), Memphis International Airport (MEM), and Cleveland Hopkins International Airport (CLE).[8]

Table 1: List of Mergers and Related De-Hubbed Airports

Merger					Airport Ranking	
Acquirer	Acquired	Merger Announced	Airport	De-Hub Date	Before	After
American	TWA	2001:Q2	STL	2004:Q1	22	32
America West	US Airways	2005:Q2	LAS	2009:Q1	7	9
Delta	Northwest	2008:Q2	MEM	2013:Q4	50	63
United	Continental	2010:Q2	CLE	2014:Q3	40	46

[6] The airport rankings can be found at: `https://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/`.

[7] As a robustness check, we also considered alternative reductions in passenger connectivity of 25 percent and 50 percent and find qualitatively similar results which are available upon request.

[8] American Airlines acquired Reno Air in 1999 and subsequently de-hubbed both San Jose and Reno airports. We excluded both of these events since Reno Air is not a major legacy carrier.

Figures 1 - 4 located at the end of the paper provide a visual representation of the connectivity of flights at each of the four merger related de-hubbing airports. In each of these graphs, we indicate the number of flight operations by the acquirer airline (red dotted line), the acquired airline (blue dashed line), and both airlines combined (black solid line) for the sample period of 1998:Q1 to 2016:Q4. We identify the quarter in which de-hubbing occurs based on our de-hubbing criteria using a vertical gray dashed line. The shaded regions demarcate the before and after de-hubbing periods used in the regression analysis.

Table 2: The Number of Spoke Airports Serviced by the De-Hubbed Airline

Airport (Airline)	STL (AA)	LAS (US)	MEM (DL)	CLE (UA)
Before De-Hubbing	56	33	13	19
After De-Hubbing	22	13	7	10
Percent Change	-60.7%	-60.6%	-46.2%	-47.4%

Note: This table reports the number of spoke airports that the de-hubbed airline serviced. The before de-hubbing time period is the year preceding de-hubbing, whereas the after de-hubbing time period is the year following de-hubbing.

One of the ramifications of our definition for de-hubbing is that the de-hubbed airport also experiences a significant reduction in the number of non-stop flight offerings by the de-hubbed airline, which is clearly detrimental to consumer welfare.[9] Table 2 shows that the magnitude of this reduction with the former hub airline typically cutting in half the number of non-stop airports served following de-hubbing, with the reduction ranging from 46.2% (MEM) to 60.7% (STL). Given the reduction in travel flexibility, the purpose of our paper is to measure the product quality and service reliability of the flights that remain at the de-hubbed airport.

3 Empirical Analysis

Our empirical approach to estimate the effect of the de-hubbing on product quality is to conduct a difference-in-differences (DID) estimation. The advantage of a DID specification is that

[9] We interchangeably use the terms “de-hubbed airline” and “former hub airline” throughout the paper.

it enables us to conduct a before and after comparison of how de-hubbing affects product quality in the treatment group (routes in which one of the endpoint airports is the de-hubbed airport) and the control group (routes in which neither endpoint airport is the de-hubbed airport). We also use a difference-in-difference-in-differences (DDD) estimation to determine how the former hub airline performs in comparison with rival airlines at the same de-hubbed airport. The regression results generally imply that de-hubbed airports following mergers typically experience an increase in product quality due to more reliable flight schedules and shorter travel times.

One caveat of our analysis is that mergers and de-hubbing events are endogenous since the airports selected for de-hubbing are not randomly chosen by the airline. Although previous research has investigated particular de-hubbing cases (Bilotkach et al., 2014; Wei and Grubesic, 2015), the reasons why an airport gets de-hubbed vary on a case-by-case basis so unfortunately there is no consensus on a universal motivation for de-hubbing. As such, we take as given that these de-hubbing events have occurred and then measure how these events have impacted the efficiency of flight operations at the de-hubbed airports in order to determine if service quality is improving or worsening at these facilities.

While our data span nineteen years, for each of the four de-hubbing cases, we restrict the sample to just eight quarters: the four quarters before and the four quarters after the de-hubbing event. Since Figures 1 - 4 suggest that de-hubbing does not occur abruptly and immediately, the transitional quarter in which the de-hubbing occurs is also omitted. The result is a data set of 269,025 quarterly observations involving 8,875 routes. Summary statistics appear in Table 3. Approximately one-fifth of flights in the sample arrived late (15+ minutes after the scheduled arrival time). The average travel time of 168 minutes represents the difference between the actual arrival time and scheduled departure time. Flight cancellations are somewhat rare events occurring in just 1.4% of the sample. These are similar to the summary statistics in related papers.

Table 3: Summary Statistics

Variable	Definition	Mean (Std. Dev.)
$pdelay_{ijt}$	Proportion of flights with delayed arrivals for carrier i on route j in time period t	0.192 (0.110)
$traveltime_{ijt}$	Average number of minutes (actual arrival time - scheduled departure time) for carrier i to fly route j in time period t	167.546 (84.205)
$pcancel_{ijt}$	Proportion of cancelled flights for carrier i on route j in time period t	0.014 (0.031)
$originflights_{jt}$	Number of flights at origin airport of route j in time period t Note: $lnoriginflights = ln(originflights)$	18,512.82 (23,334.48)
$destflights_{jt}$	Number of flights at destination airport of route j in time period t Note: $lndestflights = ln(destflights)$	18,501.44 (23,325.97)
$ncom_{jt}$	Number of carriers operating on route j in time period t	2.041 (1.206)
$marketshare_{ijt}$	Market share for carrier i on route j in time period t Note: *marketshare* for monopolist = 1.0	0.723 (0.308)
$yield_{ijt}$	Yield for carrier i on route j in time period t Note: $yield = \frac{price}{distance}$	0.316 (0.314)
$price_{ijt}$	Average one-way fare for carrier i on route j in time period t	193.69 (71.65)
$distance_j$	One-way distance (in miles) between the endpoints of route j	942.417 (600.535)
Routes	Number of routes in the sample	8,875
N	Number of observations	269,025

The following difference-in-differences (DID) specification is used in our analysis:

$$y_{ijt} = \beta_1 X_{ijt} + \beta_2 airport_j + \beta_3 dehub_t + \beta_4 (airport_j \times dehub_t) + \alpha_{ij} + \tau_t + \varepsilon_{ijt}, \quad (1)$$

with y_{ijt} being either the proportion of delayed arrivals ($pdelay_{ijt}$),[10] average minutes of travel time ($traveltime_{ijt}$),[11] or the proportion of flight cancellations ($pcancel_{ijt}$) for airline i along route j at time t.

[10] We focus our attention on delayed arrivals instead of delayed departures since pilots can make up time while airborne following a delayed departure. Airlines can also pad their scheduled departure and arrival times in order to reduce the likelihood of delays and avoid potential fines from the FAA associated with prolonged delays. In other words, flights can depart behind schedule, yet still arrive at the destination on time. See Rupp (2009) for an in-depth look at flight delays.

[11] Since *traveltime* is defined as the actual arrival time minus scheduled departure time, this measure cannot be manipulated by the carriers. In addition, the continuous variable *traveltime* does not rely on an arbitrary cut-off of 15 minutes as the delay threshold. See Bishop et al. (2011) for alternative measures of on-time performance.

The *airport* indicator variable equals one if the de-hubbed airport is either the origin or destination airport, and zero if neither endpoint airport is the de-hubbed airport and at least one of the endpoint airports is ranked as a top 50 airport in the year that de-hubbing occurred.[12] As such, the treatment group consists of routes originating or ending at the de-hubbed airport, whereas other routes with at least one endpoint airport that is similarly sized to the de-hubbed airport serve as the control group. A second indicator variable *dehub* takes the value of one during the post-de-hubbing period, and zero during the pre-de-hubbing period. Hence, the interaction term $airport \times dehub$ only has the value of one for routes to/from the de-hubbed airport during the post-de-hubbing period.

Additional explanatory variables (X_{ijt}) include three types of variables. First, we account for airport congestion using the natural log of the number of flights at the route's origin airport ($lnoriginflights$) and the route's destination airport ($lndestflights$). We also include two measures for competition: a count of the number of carriers serving the route (*ncom*) and route-level market share by carrier ($marketshare$).[13] Finally, we proxy for route profitability using route yield for the carrier ($yield$), which is constructed as the average one-way airfare divided by flight distance.

We include two fixed effects: α_{ij} represents the carrier-route fixed effects and τ_t represents year-quarter fixed effects. Since the *airport* variable is time-constant, it becomes absorbed by the carrier-route fixed effects in the estimation. In a similar fashion, the *dehub* variable is absorbed by year-quarter fixed effects. Standard errors are clustered at the carrier-route level due to the potential of correlation within carriers on a route over time.

The key variable of interest is the $airport \times dehub$ interaction term. Should we find a negative and statistically significant coefficient for the interaction term, this would suggest that product quality improves following the de-hubbing event (recall that a negative value represents a reduction in the flight delays, or shorter travel times, or a reduction in flight cancellations at departure). For

[12] Since Rupp and Holmes (2006) find flight cancellations are more prevalent during adverse conditions at the origin airport, the *airport* variable indicates whether the de-hubbed airport is the origin airport of the route only in the *pcancel* estimation. Regardless, removing this constraint produces qualitatively similar results.

[13] Given that low-cost carriers may impact product quality (Rupp and Liu, 2018), we replace *ncom* with two alternative specifications: 1) the number of low-cost carriers and the number of legacy carriers and 2) a dummy variable for the presence of a low-cost carrier. The results in either of these cases are qualitatively similar.

the sake of clarity, we note that we run separate regressions for each of the four de-hubbed airport events; hence, the *airport* and *dehub* dummies are unique to each individual de-hubbing event.[14]

Using the proportion of delayed arrivals (*pdelay*) as the dependent variable, Table 4 presents the DID regression results for each of the four de-hubbed airports following a merger. For every DID estimation in the paper, we will report two estimations for each de-hubbing event using the same format. On the left-side of each column (odd numbered columns), we include results for the standard difference-in-differences specification: the interaction term of interest, $airport \times dehub$, as well as both carrier-route fixed effects and year-quarter fixed effects (which are not reported). On the right-side of each column (even numbered columns), we report results for the $airport \times dehub$ interaction term along with additional control variables that account for possible factors of on-time performance at airports (flight operations, market competition, and route profitability) since these variables have been previously shown to influence on-time service quality (Rupp et al., 2006).

Given that airport congestion plays such a prominent role in on-time performance (Mayer and Sinai, 2003; Rupp, 2009), we will discuss the even numbered columns which include controls for airport congestion at both origination and destination airports. Should the merged entity experience operational efficiency gains and/or synergies following the merger and subsequent de-hubbing, then we should observe an improvement in product quality above and beyond an argument based on capacity or competition. This would be associated with a negative and statistically significant estimate for the $airport \times dehub$ interaction term. On the other hand, should the newly merged entity experience diseconomies of scale due to growing pains from the integration of the two companies, then we should find positive and significant coefficients for the $airport \times dehub$ interaction term. Finally, an insignificant estimate for the interaction term would suggest that the newly merged company did not experience operational gains or losses from the merger and subsequent airport de-hubbing.

[14]The after de-hubbing time period for MEM overlaps with the before de-hubbing time period for CLE. As a robustness check, we drop any observations pertaining to routes with CLE as an endpoint airport in the regression for MEM. Similarly, we omit any observations related to routes with MEM as an endpoint airport in the regression for CLE. The regression results are qualitatively similar to those reported throughout the paper for both MEM and CLE.

Table 4: DID Results for De-Hubbing Following a Merger
Proportion of Delayed Arrivals ($pdelay$)

	STL		LAS		MEM		CLE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$airport \times dehub$	-0.024^{***}	-0.025^{***}	-0.020^{***}	-0.021^{***}	-0.010	-0.014	-0.054^{***}	-0.048^{**}
	(0.005)	(0.006)	(0.004)	(0.004)	(0.010)	(0.010)	(0.020)	(0.019)
$lnoriginflights$		-0.001		0.003		-0.013^{**}		-0.017^{***}
		(0.008)		(0.005)		(0.006)		(0.006)
$lndestflights$		0.004		0.001		-0.010^{*}		-0.008
		(0.007)		(0.005)		(0.006)		(0.006)
$ncom$		0.001		-0.003^{*}		-0.001		0.002
		(0.001)		(0.001)		(0.001)		(0.001)
$marketshare$		-0.017^{*}		0.001		0.028^{**}		-0.009
		(0.010)		(0.011)		(0.011)		(0.010)
$yield$		0.049^{***}		-0.019		0.023^{**}		0.003
		(0.010)		(0.012)		(0.011)		(0.009)
N	27,570	24,929	28,600	25,934	28,566	25,624	29,184	26,091

Note: Each difference-in-differences (DID) regression follows the specification in Equation (1) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. * indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

Table 4 suggests that product quality improves following an airport de-hubbing event since the interaction term $airport \times dehub$ is negative and statistically significant in six of eight DID specifications. Specifically, we find that the DID specifications for STL (column (2)), LAS (column (4)), and CLE (column (8)) indicate that de-hubbing contributed to a 2.5, 2.1, and 4.8 percentage point reductions in the proportion of delayed arrivals, respectively, for all airlines servicing the de-hubbed airport, whereas the estimated coefficient for $airport \times dehub$ is negative yet insignificant for MEM (column (6)). Recall that the average proportion of flight delays in the sample is 19.2 percent; hence, the percentage reduction in proportion of flight delays is considerably larger and economically significant, ranging from 11% to 25% fewer flight delays following de-hubbing.

Although some of the competition variables are statistically significant, their exclusion in the regressions did not have a qualitative impact on the estimated coefficient for the $airport \times dehub$ interaction terms as we find similar results for the odd numbered specifications as the proportion of flight delays ranges from 10% to 28%. Note that once again the estimate for the $airport \times dehub$ interaction term associated with MEM (column (5)) remains negative and insignificant with the exclusion of the competition variables. In sum, the results generally suggests that a positive ramification from merger induced de-hubbing is an increase in product quality through fewer delays and hence creating more reliable flight schedules.

Table 5: DID Results for De-Hubbing Following a Merger
Average Minutes of Travel Time (*traveltime*)

	STL		LAS		MEM		CLE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
airport × *dehub*	−4.766***	−4.636***	−1.864***	−1.863***	−1.691**	−2.312***	−5.049***	−4.701**
	(0.523)	(0.592)	(0.361)	(0.364)	(0.807)	(0.841)	(1.958)	(1.969)
lnoriginflights		−0.051		0.064		−1.262		−2.500***
		(0.769)		(0.654)		(0.797)		(0.836)
lndestflights		−0.010		−0.555		−2.108***		−1.182*
		(0.680)		(0.430)		(0.684)		(0.632)
ncom		0.197		−0.166		−0.156		0.011
		(0.124)		(0.157)		(0.145)		(0.147)
marketshare		−0.566		0.278		2.580*		−0.429
		(0.920)		(1.393)		(1.334)		(1.268)
yield		2.252***		−0.518		2.804**		0.636
		(0.825)		(1.124)		(1.183)		(0.927)
N	27,553	24,927	28,583	25,927	28,561	25,622	29,176	26,089

Note: Each difference-in-differences (DID) regression follows the specification in Equation (1) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. * indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

Table 5 shows the DID regression results for our four cases of de-hubbing with minutes of *traveltime* serving as our quality measure. In a similar fashion as with Table 4, we estimate regressions for each de-hubbed airport with the odd numbered columns including just the fixed effects and *airport* × *dehub* interaction term, whereas the even numbered columns (our preferred specification) include additional controls for route competition, airport congestion, and route profitability. We are especially interested in the *airport* × *dehub* coefficient, which is found to be negative and statistically significant in all eight specifications. This result suggests that product quality as measured by minutes of *traveltime* falls after an airport has been de-hubbed. Perhaps due to less airport congestion from hub operations, travelers experience significantly shorter travel times for each of the merger related de-hubbing events. As discussed in Mayer and Sinai (2003), hub carriers create flight banks, grouping arrivals and then departures at the hub airport, in an effort to minimize passenger connection times. The DID results for the basic specifications suggest significantly shorter travel times for each of the four de-hubbed airports. Specifically, STL (Column (2)), LAS (Column

(4)), MEM (Column (6)), and CLE (Column (8)) experienced a reduction in *traveltime* by 4.6, 1.9, 2.3, and 4.7 minutes, respectively, for all airlines servicing the de-hubbed airport.

Once again we find minimal impact on the regression results for the $airport \times dehub$ interaction term with the exclusion of the competition variables in the estimation. Specifically, the results for the DID specifications that include competition variables for STL (Column (1)), LAS (Column (3)), MEM (Column (5)), and CLE (Column (7)) suggest similar magnitude effects as de-hubbing contributed to significant reductions of *traveltime* of 4.8, 1.9, 1.7, and 5.0 minutes, respectively. The combined regression results reported in both Tables 4 and 5 indicate that product quality improvements of less frequent delays and shorter travel times are associated with de-hubbing events which follow airline mergers.

Within the airline industry, a one or two minute change can make the difference between having an "on-time" flight and a "delayed" flight. Given the industry standard that an official delay occurs if the flight arrives at least 15 minutes behind schedule, we can interpret the economic significance by considering that a 1.863 minute *traveltime* reduction experienced at LAS (Column (4)) is a 1.863/15 = 12.4% reduction compared to the 15 minute threshold.

Although Table 3 reports that the average travel time is 168 minutes, the average arrival time difference (the difference between the actual arrival time and the scheduled arrival time) for all flights by the top 10 airlines during our sample time period (1998:Q1 - 2016:Q4) is 5.795 minutes. As such, we can alternatively assess the economic significance by considering that the reduction in *traveltime* by 1.863 minutes at LAS would amount to a 1.863/5.795 = 32.8% reduction in the arrival time difference.

Our third and final measure of product quality involves flight cancellations. The DID estimations for the proportion of flight cancellations appear in Table 6. We find that all four de-hubbed airports have significantly lower flight cancellation rates with STL (column (2)), LAS (column (4)), MEM (column (6)), and CLE (column (8)) experiencing 0.35 (STL), 0.23 (LAS), 0.40 (MEM), and 0.18 (CLE) percentage point reductions in flight cancellations. To put these numbers into perspective, recall that the average cancellation rate in our sample as reported in Table 3 is only 1.4%.

Hence the percentage change when compared to the typical airport cancellation rate is considerably larger and economically significant: 25% (STL), 16% (LAS), 29% (MEM), and 13% (CLE) reduction in cancellations after de-hubbing. Given a reduction in flight frequency after an airline de-hubs its operations, an airline may be reluctant to cancel flights to/from its former hub since doing so will create longer passenger wait times due to the infrequent service now being provided.

Table 6: DID Results for De-Hubbing Following a Merger
Proportion of Flight Cancellations (*pcancel*)

	STL		LAS		MEM		CLE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$airport \times dehub$	-0.0031^{***}	-0.0035^{***}	-0.0023^{***}	-0.0023^{***}	-0.0029	-0.0040^{**}	-0.0017^{**}	-0.0018^{*}
	(0.0011)	(0.0012)	(0.0006)	(0.0006)	(0.0018)	(0.0020)	(0.0008)	(0.0010)
$lnoriginflights$		-0.0008		-0.0034^{*}		-0.0015		-0.0007
		(0.0009)		(0.0018)		(0.0019)		(0.0014)
$lndestflights$		-0.0004		-0.0028		-0.0010		-0.0004
		(0.0008)		(0.0018)		(0.0017)		(0.0012)
$ncom$		-0.0009^{***}		-0.0007^{***}		-0.0005^{*}		-0.0007^{**}
		(0.0003)		(0.0003)		(0.0003)		(0.0003)
$marketshare$		0.0025		-0.0001		-0.0053		-0.0059^{*}
		(0.0017)		(0.0026)		(0.0046)		(0.0036)
$yield$		-0.0092^{***}		-0.0042		0.0061^{**}		0.0063^{***}
		(0.0023)		(0.0046)		(0.0029)		(0.0015)
N	27,570	24,929	28,600	25,934	28,566	25,624	29,184	26,091

Note: Each difference-in-differences (DID) regression follows the specification in Equation (1) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. * indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

After excluding controls for the number of airport operations, route competition, and route profitability, we find that three of four de-hubbed airports have significantly lower flight cancellation rates, ranging from 0.17 (CLE) to 0.31 (STL) percentage point reductions. While a fourth de-hubbed airport, MEM, also experiences a reduction in cancellation rates, its t-statistic (1.61) is just outside the 10% significance level. Nonetheless, we find considerable evidence to suggest that merger related de-hubbing events significantly improve product quality by reducing flight cancellation rates. More generally, while it is not surprising that de-hubbed airports significantly reduce both the proportion of passengers making connections and the number of non-stop offerings, we find a silver lining for these less congested de-hubbed airports as these facilities have improved schedule reliability with fewer flight delays, lower cancellation rates, and reduced travel times.

The DID approach provides a pooled effect of the impact of de-hubbing on product quality. We have not identified, however, which airlines are driving the improved performance at the de-hubbed airport. Is the former hub airline or rival airlines (or both) benefitting from the merger induced de-hubbing event? We answer this question using a difference-in-difference-in-differences (DDD) approach that differentiates whether the de-hubbing airline experiences a different effect on product quality compared to its rivals at the same airport being de-hubbed. The general specification for the DDD regressions is as follows:

$$\begin{aligned} y_{ijt} &= \beta_1 X_{ijt} + \beta_2 airport_j + \beta_3 dehub_t + \beta_4 (airport_j \times dehub_t) \\ &+ \beta_5 carrier_i + \beta_6 (carrier_i \times dehub_t) + \beta_7 (carrier_i \times airport_j) \\ &+ \beta_8 (carrier_i \times airport_j \times dehub_t) + \alpha_{ij} + \tau_t + \varepsilon_{ijt}. \end{aligned} \tag{2}$$

The DDD specification (Equation (2)) includes all of the variables in the DID specification (Equation (1)) with the addition of the *carrier* variable, which is an indicator variable equal to one if the carrier is the de-hubbed airline and zero if it is a rival airline. Once again, we include carrier-route fixed effects, which absorb the *airport*, *carrier*, and $carrier \times airport$ variables, as well as year-quarter fixed effects, which absorb the *dehub* variable. Standard errors continue to be clustered at the carrier-route level due to the potential of correlation within carriers on a route over time. We conduct separate regressions for each de-hubbing case so consequently the *airport*, *dehub*, and *carrier* variables are specific to each of the four cases of de-hubbing in our sample.

As with the DID approach, our variable of interest is the interaction term $airport \times dehub$, however, we are now additionally interested in the difference-in-difference-in-differences estimator $carrier \times airport \times dehub$. Given the inclusion of the *carrier* variable in our DDD analysis, the interpretation of our original variable of interest differs slightly. Now, a negative and statistically significant coefficient for the $airport \times dehub$ interaction term implies that rival airlines' product quality increases (due to either a reduction in the proportion of delayed arrivals, a shorter travel time, or a reduction in the proportion of flight cancellations), on average, after the airport has been de-hubbed, whereas this variable represented a pooled effect of the de-hubbing airline and its rival airlines in the DID analysis. Moreover, the $carrier \times airport \times dehub$ interaction term is interpreted as the difference between the difference-in-differences estimators for the de-hubbing airline and its rival airlines. As such, a negative and statistically significant coefficient for the $carrier \times airport \times dehub$ interaction term implies that product quality for the de-hubbing airline improves relatively more than product quality for rival airlines.

The change in product quality for the de-hubbed airline is found by summing the coefficients for the $airport \times dehub$ and the $carrier \times airport \times dehub$ interaction terms. We conduct an F test for each DDD regression to check whether the estimated coefficients of the two interaction terms sum to zero. The null hypothesis for the F test is that there is no change in the product quality measure for the de-hubbing airline ($H_0 : \beta_4 + \beta_8 = 0$).

Table 7: DDD Results for De-Hubbing Following a Merger
Proportion of Delayed Arrivals (*pdelay*)

	STL		LAS		MEM		CLE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$airport \times dehub$	−0.004	−0.003	−0.016***	−0.018***	0.005	0.006	−0.122***	−0.094***
	(0.006)	(0.006)	(0.004)	(0.004)	(0.008)	(0.008)	(0.042)	(0.035)
$carrier \times dehub$	−0.005*	−0.005	0.029***	0.028***	−0.018***	−0.019***	0.039***	0.043***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
$carrier \times airport \times dehub$	−0.040***	−0.051***	−0.033***	−0.029***	−0.005	−0.011	0.080*	0.047
	(0.010)	(0.011)	(0.008)	(0.009)	(0.014)	(0.015)	(0.045)	(0.039)
$lnoriginflights$		−0.003		0.003		−0.011*		−0.017***
		(0.008)		(0.005)		(0.006)		(0.006)
$lndestflights$		0.002		0.001		−0.008		−0.009
		(0.008)		(0.005)		(0.006)		(0.006)
$ncom$		0.001		−0.002		−0.001		0.002**
		(0.001)		(0.001)		(0.001)		(0.001)
$marketshare$		−0.020**		0.001		0.025**		0.005
		(0.010)		(0.011)		(0.011)		(0.011)
$yield$		0.049***		−0.018		0.031***		0.004
		(0.010)		(0.012)		(0.011)		(0.009)
N	27,570	24,929	28,600	25,934	28,566	25,624	29,184	26,091

Note: Each difference-in-difference-in-differences (DDD) regression follows the specification in Equation (2) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. ∗ indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

Table 7 reports the DDD estimation results using *pdelay* as the dependent variable. We have a similar approach to the DID estimations, where once again the odd numbered columns (1-7) represent specifications for just the fixed effects and interaction terms, while the even numbered columns (2-8) include controls for airport congestion, route competition, and route profitability measures. Again, there are two coefficients of interest: $airport \times dehub$ interaction term and the $carrier \times airport \times dehub$ interaction term.

Table 7 shows that the DDD estimations are generally robust to whether we include (or exclude) additional controls for airport congestion, route competition, and route profitability. Examining the performance of rival carriers at the de-hubbed airport, we find that rival carriers experience significant improvements in the proportion of flight delays in two of four de-hubbed cases (LAS and CLE) compared to the other U.S. airports where they operate which were not de-hubbed. Columns (3) and (7) show a statistically significant reduction in the proportion of flight delays by rival carriers of 1.6 and 12.2 percentage points at LAS and CLE, respectively. Given that the typical airport in our sample has 19.2 percent of flights delayed (Table 3), the corresponding percentage changes of 8% (LAS) and 64% (CLE) fewer flight delays by rival airlines are economically significant. One possible explanation for the improved performance by rival carriers following a de-hubbing event is that the de-hubbed airline is no longer overburdening the airport at peak travel periods. Similar results are recorded when we include the additional controls for airport congestion, route competition, and route profitability based on the estimates for the $airport \times dehub$ interaction terms reported in the even columns in Table 7. We find that rival airlines at both LAS (column (4)) and CLE (column (8)) have a significant reduction in the proportion of delayed flights of 1.8 and 9.4 percentage points, respectively. We find no significant changes in rival airline performance at either STL or MEM.

Determining the performance of the de-hubbed airline is slightly more involved since there are two coefficients of interest which must be summed to find the net change in service quality of the de-hubbed airline. Specifically, we add the estimated coefficients for the interaction terms $airport \times dehub$ and $carrier \times airport \times dehub$ to determine the net change in performance by the de-hubbed airline in comparison to non-de-hubbed airports. For example, for the de-hubbed LAS airport Column (4) of Table 7 shows the $airport \times dehub$ interaction term is -0.018 and the $carrier \times airport \times dehub$ term is -0.029. To determine the performance of the de-hubbed airline

(US Airways) at LAS, we sum the coefficients which equals -0.047. As such, US Airways experiences a 4.7 percentage point reduction in the *pdelay* at LAS following the de-hubbing event compared to non-de-hubbed airports. Moreover, this improvement in performance for US Airways is statistically significant since we reject the null hypothesis of the F test that the estimated coefficients sum to zero (F-stat = 39.64; p-value = 0.000). In other words, the product quality of the de-hubbed airline (US Airways) at LAS significantly improves to a greater extent (4.7 percentage point lower probability of delay) compared to rival carriers at LAS (1.8 percentage point reduction in *pdelay*) for a difference of 2.9 percentage points. Hence while de-hubbing reduces the frequency of flight delays by rival carriers, it has an even larger impact (twice the magnitude) on the frequency of flight delays by the de-hubbed airline (US Airways) at LAS.

While rival carriers experience no noticeable changes in flight delays at STL, we find significant improvements in the frequency of flight delays by the de-hubbed airline (American) at STL. Column (2) in Table 7 shows a 5.4 percentage point reduction (-0.003 + -0.051 = -0.054) in the proportion of flight delays at STL (F-stat = 36.20; p-value = 0.000). The corresponding percentage change is economically significant with a 28.1% reduction (-5.4/19.2 = -0.281) in flight delays at STL by American. Hence the findings at both LAS and STL indicate that hub carriers experience larger service quality improvements than their rivals following the airport de-hubbing. We should also note that we find no change in service quality by the de-hubbed airline or rival airlines at one de-hubbed airport (MEM). Interestingly, the $carrier \times airport \times dehub$ is insignificant at CLE, whereas the $airport \times dehub$ interaction terms is negative and statistically significant (-0.094). This suggests that both rival and de-hub airline (United) provide improved service quality due to fewer flight delays at CLE following the de-hubbing event. In every other specification in Table 7 we find similar quantitative and qualitative results for the odd numbered columns as once again hub airlines have fewer flight delays in three of four de-hubbing cases presented in Table 7. We now turn to the triple difference results for another measure of product quality: travel time.

Table 8: DDD Results for De-Hubbing Following a Merger
Average Minutes of Travel Time (*traveltime*)

	STL		LAS		MEM		CLE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
airport × *dehub*	−1.746***	−1.530***	−1.020***	−0.962**	0.239	0.655	−8.936**	−7.428**
	(0.473)	(0.476)	(0.377)	(0.384)	(0.907)	(0.823)	(3.943)	(3.663)
carrier × *dehub*	0.236	0.380	0.640*	0.825**	−2.717***	−2.739***	3.723***	3.855***
	(0.345)	(0.278)	(0.336)	(0.332)	(0.283)	(0.319)	(0.466)	(0.494)
carrier × *airport* × *dehub*	−7.018***	−7.743***	−4.903***	−5.215***	−0.343	−1.599	3.442	1.898
	(0.867)	(0.992)	(0.906)	(0.908)	(1.314)	(1.342)	(4.377)	(4.224)
lnoriginflights		−0.251		0.010		−1.062		−2.545***
		(0.782)		(0.655)		(0.813)		(0.836)
lndestflights		−0.200		−0.610		−1.906***		−1.223*
		(0.689)		(0.431)		(0.693)		(0.632)
ncom		0.217*		−0.140		−0.145		0.070
		(0.125)		(0.157)		(0.144)		(0.145)
marketshare		−1.164		0.136		2.225*		0.677
		(0.922)		(1.394)		(1.337)		(1.283)
yield		2.327***		−0.511		3.940***		0.745
		(0.823)		(1.125)		(1.242)		(0.926)
N	27,553	24,927	28,583	25,927	28,561	25,622	29,176	26,089

Note: Each difference-in-difference-in-differences (DDD) regression follows the specification in Equation (2) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. ∗ indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

Table 8 presents the difference-in-difference-in-differences estimation results for *traveltime*. The *airport* × *dehub* interaction term is negative and significant in three of four estimations, which suggests that rival carriers at STL, LAS, and CLE experience relatively shorter travel times following the de-hubbing event compared to the rival carriers' performance at non-de-hubbed U.S. airports. We find no significant change in *traveltime* by rival carriers at MEM. We follow the same convention as in the previous DDD table, where the odd numbered columns include fixed effects and interaction terms, while the even numbered columns include additional controls for airport congestion, route competition, and route profitability. Given the importance of controlling for airport congestion, we focus our attention on the even numbered column results. We do find, however, comparable results for both specifications. Columns (2), (4) and (8) indicate a *traveltime* reduction of 1.5, 1.0, and 7.4 minutes by rival carriers following de-hubbing at STL, LAS, and CLE, respectively. These results are consistent with the previous DDD specification for proportion of delayed arrivals since rival carriers at both LAS and CLE are significantly less likely to be delayed following de-hubbing. We note that while there is no significant change in the frequency of flight delays at STL following de-hubbing, we do, however, find a statistically significant (1.5 minute) reduction in *traveltime* for rival airlines at STL. Hence, in most situations the product quality of rival airlines improves as measured by less frequent delays (two of four cases) and reduced travel times (three of four cases) following a merger induced airport de-hubbing event.

Once again, similar results are obtained with the additional controls for airport congestion, route competition, and route profitability controls based on the estimates for the $carrier \times airport \times dehub$ interaction term reported in the even numbered columns in Table 8. The $carrier \times airport \times dehub$ estimates in Table 8 reveal that de-hubbed airlines at both STL and LAS experienced significant reductions in *traveltime* compared to rival airlines. Specifically, Column (2) of Table 8 shows the $airport \times dehub$ interaction term is -1.53 and the $carrier \times airport \times dehub$ term is -7.74. Hence, the de-hubbed airline (American Airlines) at STL has 9.27 minutes shorter *traveltime* (F-stat = 106.04; p-value = 0.000). In other words, the product quality of the de-hubbed airline at STL improves to a greater extent than the improvement experienced by rival airlines. To be more precise, the difference in the former hub airline performance is 7.74 minutes shorter *traveltime* compared to rival airlines. We also find that the de-hubbed airline (US Airways) at LAS experiences a significant improvement in *traveltime* compared to its rivals. The $airport \times dehub$ term shows that rivals airlines at LAS had 1.0 minute reduction in *traveltime*, while after summing the two interaction terms in column (4) we find that the de-hubbed airline (US Airways) at LAS had 6.2 minutes shorter *traveltime* following de-hubbing (F-stat = 57.73; p-value = 0.000). Once again the former hub airline has a larger improvement than its rival following a merger induced de-hubbing event. While United Airlines (former hub airline) at CLE experienced a reduction in *traveltime* of 7.4 minutes (see Column (8)), this shortened *traveltime* was also seen by rival airlines, hence there is no performance difference between the de-hubbed airline and its rivals at CLE. Finally, we did not detect any significant changes in *traveltime* for de-hubbed airlines or rival airlines at MEM.

Our final DDD specification tracks the proportion of flight cancellations at de-hubbed airports with the results appearing on Table 9. The $airport \times dehub$ interaction term is negative and significant at both STL (-0.70 percentage points in Column (1)) and LAS (-0.17 percentage points in

Column (3)). Since Table 3 reports that 1.4% of flights at the typical airport in our sample gets cancelled, our regression results are economically significant with rival airlines experiencing 50% and 12% fewer cancellations at de-hubbed STL and LAS, respectively, compared to other non-de-hubbed U.S. airports where the rival airlines operate. On the other hand, we find no significant changes in flight cancellations by rival airlines following de-hubbing at MEM (column (6)) or CLE (column (8)) when compared to cancellation rates at other comparable U.S. airports where the rival airlines operate. Similar results are recorded for both odd and even numbered columns.

Table 9: DDD Results for De-Hubbing Following a Merger
Proportion of Flight Cancellations (*pcancel*)

	STL		LAS		MEM		CLE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$airport \times dehub$	-0.0065^{***}	-0.0070^{***}	-0.0019^{***}	-0.0017^{***}	-0.0027	-0.0015	-0.0012	-0.0003
	(0.0014)	(0.0014)	(0.0006)	(0.0006)	(0.0081)	(0.0083)	(0.0014)	(0.0017)
$carrier \times dehub$	-0.0019^{***}	-0.0019^{***}	0.0049^{***}	0.0044^{***}	-0.0023^{***}	-0.0023^{***}	0.0005	-0.0007
	(0.0005)	(0.0006)	(0.0007)	(0.0007)	(0.0004)	(0.0004)	(0.0012)	(0.0010)
$carrier \times airport \times dehub$	0.0091^{***}	0.0098^{***}	-0.0045^{***}	-0.0052^{***}	0.0014	-0.0014	-0.0013	-0.0020
	(0.0021)	(0.0023)	(0.0014)	(0.0015)	(0.0081)	(0.0084)	(0.0020)	(0.0023)
$lnoriginflights$		-0.0007		-0.0035^{*}		-0.0014		-0.0007
		(0.0009)		(0.0019)		(0.0019)		(0.0014)
$lndestflights$		-0.0002		-0.0028		-0.0008		-0.0004
		(0.0008)		(0.0018)		(0.0017)		(0.0012)
$ncom$		-0.0009^{***}		-0.0007^{**}		-0.0005		-0.0007^{**}
		(0.0003)		(0.0003)		(0.0003)		(0.0003)
$marketshare$		0.0036^{**}		-0.0001		-0.0056		-0.0062^{*}
		(0.0017)		(0.0026)		(0.0046)		(0.0036)
$yield$		-0.0093^{***}		-0.0041		0.0071^{**}		0.0063^{***}
		(0.0023)		(0.0046)		(0.0030)		(0.0015)
N	27,570	24,929	28,600	25,934	28,566	25,624	29,184	26,091

Note: Each difference-in-difference-in-differences (DDD) regression follows the specification in Equation (2) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. $*$ indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

Turning our attention to the relative performance of the de-hubbed airline, the estimate for $carrier \times airport \times dehub$ combined with the $airport \times dehub$ interaction term are used to calculate the change in former hub airline cancellations post-de-hubbing. We find a slightly higher flight cancellation rates at STL by American Airlines (de-hubbed airline) of 0.28 percentage points (column (2)); however, this increase is statistically insignificant (F-stat = 2.52; p-value = 0.1126). The de-hubbed airline (US Airways) at LAS, however, experiences a 0.69 percentage point reduction in flight cancellations following de-hubbing (column (4)), which is statistically significant (F-stat = 24.53; p-value = 0.000) and economically significant (49% lower than the 1.4% average cancellation rate). One possible reason for a reduction in cancellation rates at LAS by the former hub airline is that a reduction in daily flight offerings between two airport pairs creates greater passenger inconvenience (longer wait times) should a flight be canceled (Rupp and Holmes, 2006). There are no noticeable changes in cancellation rates by the de-hubbed airline at either MEM (column (6)) or CLE (column (8)). In sum, we find that rival airlines appear to benefit (in two of four cases) from the reduction in congestion immediately following a merger induced de-hubbing event. On the other hand, we find no clear relationship between the de-hubbed airline and cancellation rates since the performance by the former hub airline resulted in no change in cancellation rates in three of the four de-hubbing cases.

One can argue that the before de-hubbing time period is capturing a post-merger effect. In order to tease out the effect of de-hubbing on product quality from the merger effect on product quality, we identify three de-hubbing cases that are unrelated to mergers. Analyzing these de-hubbing cases serves as a robustness check since it enables us to determine whether the previously documented de-hubbing effects also occur for non-merger situations. The three de-hubbed airports (in chronological order of the de-hub date) during our sample period include US Airways at Baltimore/Washington International Thurgood Marshall Airport (BWI), Delta Airlines at Dallas/Fort Worth International Airport (DFW), and US Airways at Pittsburgh International Airport (PIT). Table 10 lists these airports, their de-hub date, and airport ranking four quarters before and four quarters after de-hubbing.

Table 10: List of De-Hubbed Airports Unrelated to Mergers

			Airport Ranking	
De-Hub Airline	Airport	De-Hub Date	Before	After
US Airways	BWI	2002:Q1	22	23
Delta	DFW	2005:Q1	4	4
US Airways	PIT	2008:Q1	43	45

As with Figures 1 - 4 for the de-hubbing cases associated with mergers, Figures 5 - 7 appear at the end of the paper and provide a visual representation of the proportion of passengers making flight connections for the three airport de-hubbing events which occur unrelated to mergers. In each of these graphs, we indicate the average proportion of passengers making connections by the de-hubbing airline (black solid line) for our sample period of 1998:Q1 to 2016:Q4. We have denoted the quarter in which de-hubbing occurs by using a vertical gray dashed line. The shaded regions demarcate the before and after de-hubbing periods used in the regression analysis. Figures 5 - 7 show the substantial drop in the proportion of connecting passengers at BWI, DFW, and PIT, respectively, that defines a de-hubbing occurrence.

Due to space constraints, we restrict our comparison analysis of merger induced de-hubbing events vs. de-hubbing cases unrelated to mergers by using a single measure of product quality: *traveltime*.[15] Table 11 presents the DID regression results using the average minutes of *traveltime* as the dependent variable for the three de-hubbing cases unrelated to mergers. These results are compared with its counterpart: merger induced de-hubbing events appearing on Table 5. Once again the key variable of interest is the $airport \times dehub$ interaction term. We find that the results for the unrelated to merger de-hubbing events range from having significantly longer *traveltime* at BWI (3 minutes) to slightly shorter *traveltime* at DFW (about 1 minute) to having no change in *traveltime* at PIT. The exclusion of controls for congestion and competition variables reported in the odd numbered columns in Table 11 yields qualitatively similar results.

Why do the *traveltime* results vary so wildly for these de-hubbing events? The underlying cause for each of these three de-hubbing events is different. US Airways retreated from BWI due to the emerging dominant position of Southwest Airlines at BWI and a strong negative demand shock following the September 11 terrorist attacks. US Airways pulled back from PIT for a different reason. After failing to renegotiate substantial reductions in gate lease arrangements, US Airways pulled its Pittsburgh hub and reallocated flights to its hub in Philadelphia.[16] Finally, airports can be de-hubbed for financial reasons. Delta Airlines chose to pull out of DFW, which also served as a hub airport for American Airlines, as part of a restructuring/reorganization plan.[17]

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[15]Results for proportion of flight delays and cancelation rates for BWI, DFW, and PIT are qualitatively similar to travel times and are available upon request.

[16]Sharkey, Joe. (2004, September 14). "Pittsburgh, Once a Showplace Hub, Feels US Airways' Woes." *The New York Times*.

[17]Associated Press. (2005, January 31). "Delta ending three decades of hub operations at DFW Airport." *USA Today*.

Table 11: DID Results for De-Hubbing Unrelated to Mergers
Average Minutes of Travel Time (*traveltime*)

	BWI		DFW		PIT	
	(1)	(2)	(3)	(4)	(5)	(6)
$airport \times dehub$	3.023***	2.927***	−0.777**	−0.756**	−1.174	−1.077
	(0.447)	(0.443)	(0.307)	(0.299)	(0.769)	(0.765)
lnoriginflights		0.382		−1.170		−1.805***
		(0.255)		(1.749)		(0.546)
lndestflights		0.250		−0.545		−0.623*
		(0.208)		(0.582)		(0.371)
ncom		0.434***		−0.370**		−0.118
		(0.140)		(0.183)		(0.154)
marketshare		1.647**		−0.800		−0.964
		(0.822)		(1.218)		(1.657)
yield		0.358		−5.589***		−6.170***
		(0.819)		(1.034)		(1.191)
N	27,223	24,971	28,101	25,201	29,446	26,595

Note: Each difference-in-differences (DID) regression follows the specification in Equation (1) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. * indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

While Table 11 shows no clear relationship between *traveltime* and de-hubbing events unrelated to mergers, Table 5 reveals a robust result across all specifications as each of the four de-hubbed airports (STL, LAS, MEM, and CLE) following a merger experience significantly shorter *traveltime* ranging from 2 to 5 minute reductions. Thus, these findings lend support for the claim that merger related de-hubbing events reduce *traveltime* and hence improve product quality whereas de-hubbing events independent of mergers have an inconclusive impact on *traveltime* and product quality. Given that product quality improvements appear restricted to merger induced airport de-hubbing events, we next examine the performance of both rival airlines and de-hubbed airlines to determine whether there is improved performance.

The difference-in-difference-in-differences specification allows an examination of the performance of rival airlines and de-hubbed airlines following the de-hubbing event. Table 12 presents the DDD regression results for flight delays at the three de-hubbed airports that are unrelated to mergers. Given that two of the de-hubbed airports are highly competitive due to the presence of rival hub airlines: US Airways and Southwest at BWI and Delta and American at DFW, we focus on the even numbered specifications in Table 12 which include competition, congestion, and profitability measures. The rival firm interaction term for $airport \times dehub$ presents mixed results as rival airlines experienced significantly longer $traveltime$ (3.3 minutes) at BWI; slightly, yet significantly shorter $traveltime$ (0.9 minute) at DFW; and no change in travel times at PIT in comparison to rival airline performance at non-de-hubbed airports. In comparison to merger induced de-hubbing events, we previously found (see even numbered columns in Table 8) that rival carriers consistently provide better product quality as they have significantly shorter $traveltime$ after an airport is de-hubbed post-merger: LAS (1 minute reduction), STL (1.5 minutes less) and CLE (7.4 minutes shorter). Hence, these findings suggest that the improved product quality offered by rival carriers surrounding de-hubbing is isolated to merger induced de-hubbing events.

Table 12: DDD Results for De-Hubbing Unrelated to Mergers
Average Minutes of Travel Time ($traveltime$)

	BWI		DFW		PIT	
	(1)	(2)	(3)	(4)	(5)	(6)
$airport \times dehub$	3.480***	3.344***	−0.991***	−0.854***	−0.452	−0.140
	(0.456)	(0.455)	(0.320)	(0.305)	(0.820)	(0.810)
$carrier \times dehub$	−0.512*	−0.576**	−2.393***	−1.982***	−5.310***	−4.572***
	(0.262)	(0.254)	(0.318)	(0.333)	(0.556)	(0.685)
$carrier \times airport \times dehub$	−4.458***	−3.963***	−1.075	−2.540*	2.007	1.019
	(1.330)	(1.359)	(0.902)	(1.307)	(1.720)	(1.822)
$lnoriginflights$		0.295		−1.287		−1.239**
		(0.254)		(1.761)		(0.567)
$lndestflights$		0.164		−0.651		−0.059
		(0.210)		(0.580)		(0.372)
$ncom$		0.443***		−0.330*		−0.207
		(0.140)		(0.186)		(0.148)
$marketshare$		1.555*		−0.773		−1.316
		(0.821)		(1.219)		(1.655)
$yield$		0.350		−5.208***		−5.674***
		(0.821)		(1.008)		(1.113)
N	27,223	24,971	28,101	25,201	29,446	26,595

Note: Each difference-in-difference-in-differences (DDD) regression follows the specification in Equation (2) and include both carrier-route and year-quarter fixed effects which are not reported. Standard errors, in parentheses, are clustered by carrier-route. ∗ indicates significance at 10% level, ** indicates significance at 5% level, and *** indicates significance at 1% level.

Finally, we compare the relative performance of former hub airlines after de-hubbing following mergers and independent of mergers. Once again, we sum the two estimated interaction term coefficients $airport \times dehub$ and $carrier \times airport \times dehub$ to determine the product quality performance of the former hub airline. Focusing again on the even numbered column estimations that include controls for airport congestion and competition, Table 12 shows that the hub airline (US Airways) has a small (0.6 minutes), yet statistically insignificant (F-stat = 0.23; p-value = 0.629) reduction in *traveltime* at BWI. The de-hubbed airline (Delta) experiences a significant reduction (3.4 minutes less) in *traveltime* at DFW (F-stat = 7.36; p-value = 0.0067). We detect no significant change for the de-hubbed airline (US Airways) performance at PIT (F-stat = 0.31; p-value = 0.5795). In sum, we find a significant reduction in only one of three cases of de-hubbing events that occur independent of mergers. By contrast, the even columns from Table 8 reveal significant *traveltime* reductions by hub airlines in three of four cases of de-hubbing events following a merger. Specifically, the de-hubbed airline at STL, LAS, and CLE have between 6.2 to 9.3 minutes shorter *traveltime* following the merger induced de-hubbing event. Only at MEM do we find no significant change in *traveltime* for the hub airline (Delta).

To summarize our findings, regardless of the cause of the airport de-hubbing (due to merger or unrelated to mergers), we find shorter *traveltime* for de-hubbed airlines when de-hubbing occurs. The magnitude of the former hub airline *traveltime* savings appears larger for merger related de-hubbing events (ranging from 6.2 to 9.3 minutes shorter *traveltime*) compared to de-hubbing independent of mergers (0.6 to 3.4 minutes less *traveltime*). Hence, product quality measured by passenger *traveltime* improves from de-hubbing events. We find larger product quality improvements when de-hubbing is triggered by airline mergers.

4 Conclusion

The $2.6 billion merger between Virgin America and Alaska Airlines in 2016 continues a two decades long trend of consolidation in the airline industry. Until recently, each merger in the U.S. airline industry has resulted in a hub airport becoming de-hubbed. In fact, one of the conditions required before regulators would approve the 2015 US Airways and American Airlines merger was requiring that American maintain the level of flight operations at their hub airports for at least three years following the completion of the merger.

Although previous papers have studied the effect of competition on product quality (Rupp et al., 2006; Rupp and Liu, 2018) and the impact of mergers on on-time performance (Prince and Simon, 2017), this paper contributes to the literature by examining how product quality changes at de-hubbed airports following mergers and independent of mergers. It is not surprising that both flight frequency and number of non-stop destinations served by the former hub airline undergo significant reductions following the de-hubbing of an airport. Both of these changes clearly reduce consumer welfare. Yet we find that these less congested airports typically provide passengers with significantly better schedule reliability as flights are less likely to be delayed, fewer cancellations occur, and flights have reduced travel times.

In most de-hubbing situations, both the de-hubbed airline and rival airlines operating at the de-hubbed airport experience improved product quality. The de-hubbed airline, however, typically experiences larger product quality improvements from either less frequent delays and/or shorter travel times. Interestingly, most of these improvements are associated with older de-hubbing events following mergers (STL and LAS), while the newer ones (MEM and CLE) seem to have fairly mixed effects. In other words, the silver lining seems to be disappearing with the newer mergers and their subsequent de-hubbing events. Similarly, Vaze et al. (2017) find that although recent airline mergers have generally led to a net gain in consumer welfare, the welfare gains decline with each subsequent merger. Although they do not investigate the de-hubbing phenomenon, Vaze et al. (2017) conclude that future mergers may lead to minimal (or negative) welfare gains based on airfares, service frequency, and travel time. Future work can investigate whether the silver lining from de-hubbing indeed disappears in future mergers.

Finally, we compare the reason for the airport de-hubbing as either related to a recent merger or unrelated to a merger. We find that product quality improvements following de-hubbing events are isolated to merger induced de-hubbing and hence do not carry over to non-merger induced de-hubbing events. While policymakers and state attorney generals worry about a reduction in employment and flight offerings following an airport de-hubbing, we find a silver lining for airline passengers since airport de-hubbing improves product quality in the form of more reliable flight schedules and reduced travel times.

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Figures

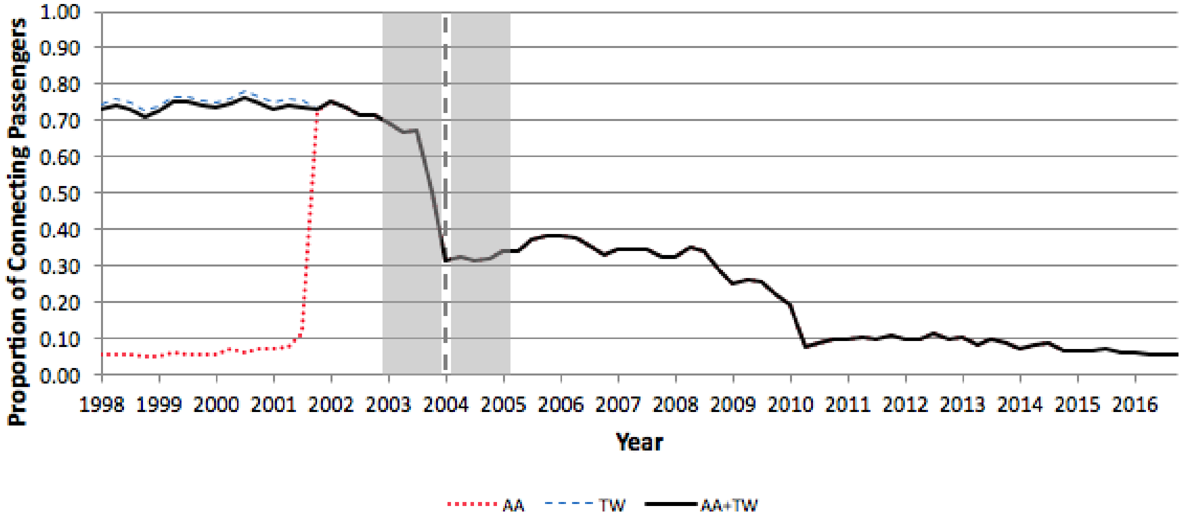

Figure 1: Connecting Travel for De-Hubbing Airline (STL - American Airlines)

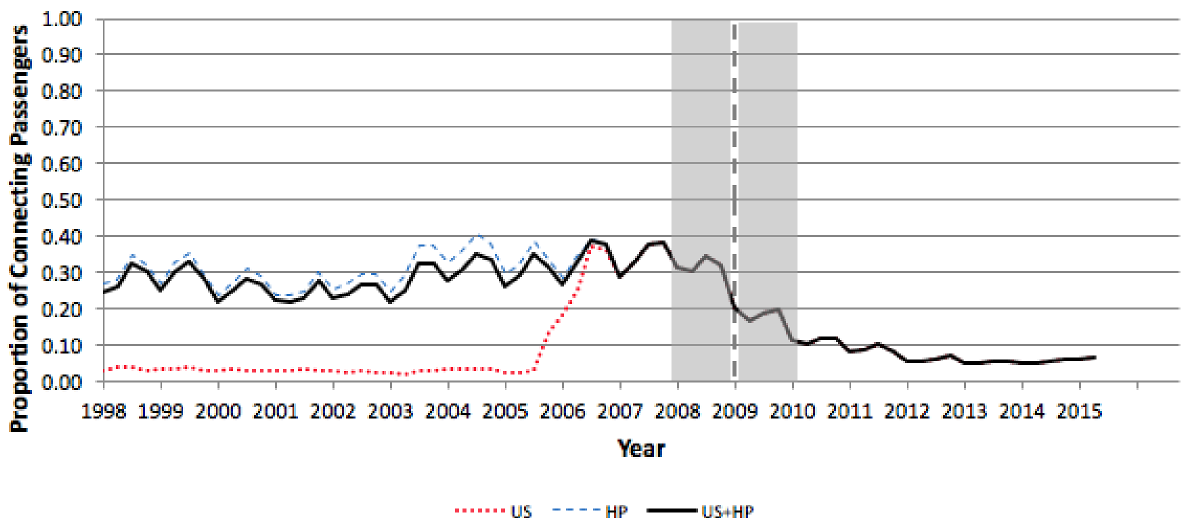

Figure 2: Connecting Travel for De-Hubbing Airline (LAS - US Airways)

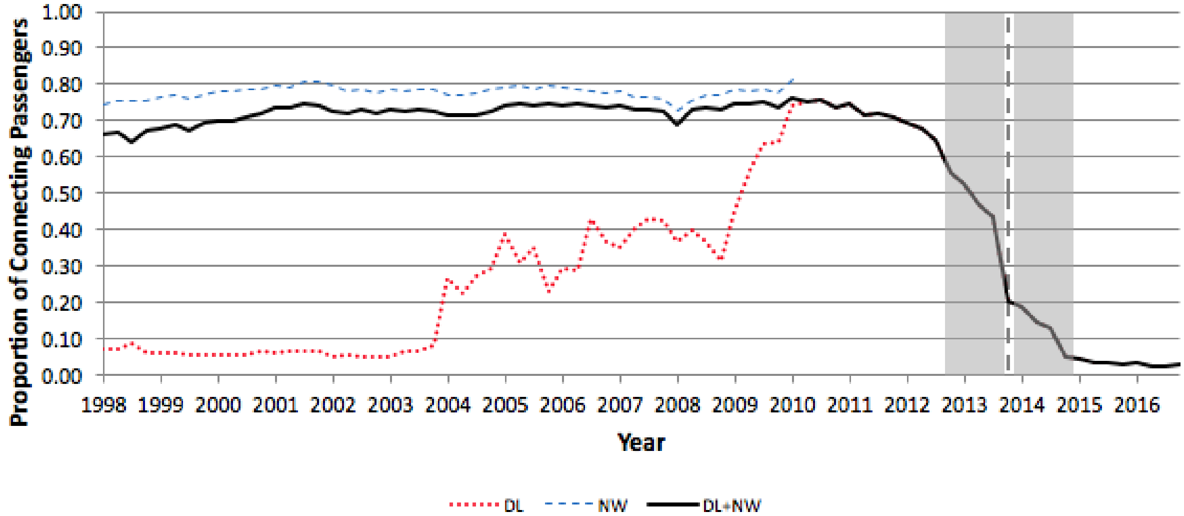

Figure 3: Connecting Travel for De-Hubbing Airline (MEM - Delta Air Lines)

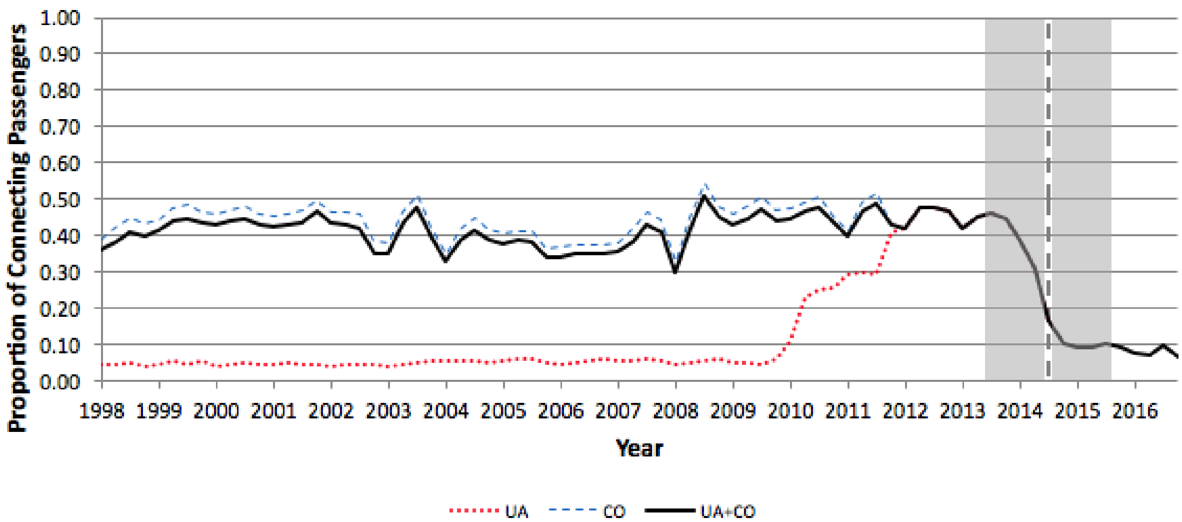

Figure 4: Connecting Travel for De-Hubbing Airline (CLE - United Air Lines)

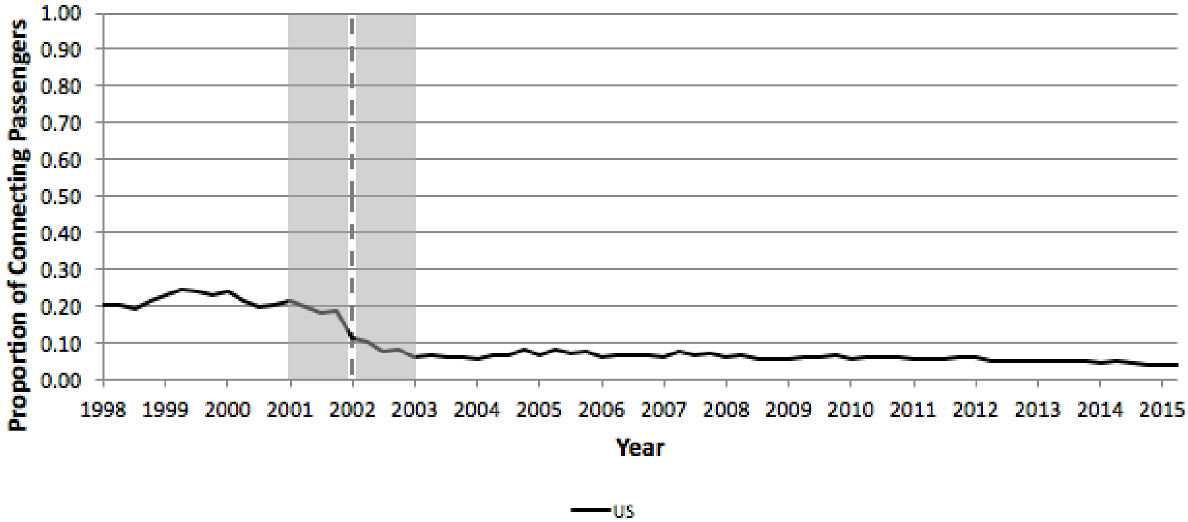

Figure 5: Connecting Travel for De-Hubbing Airline (BWI - US Airways)

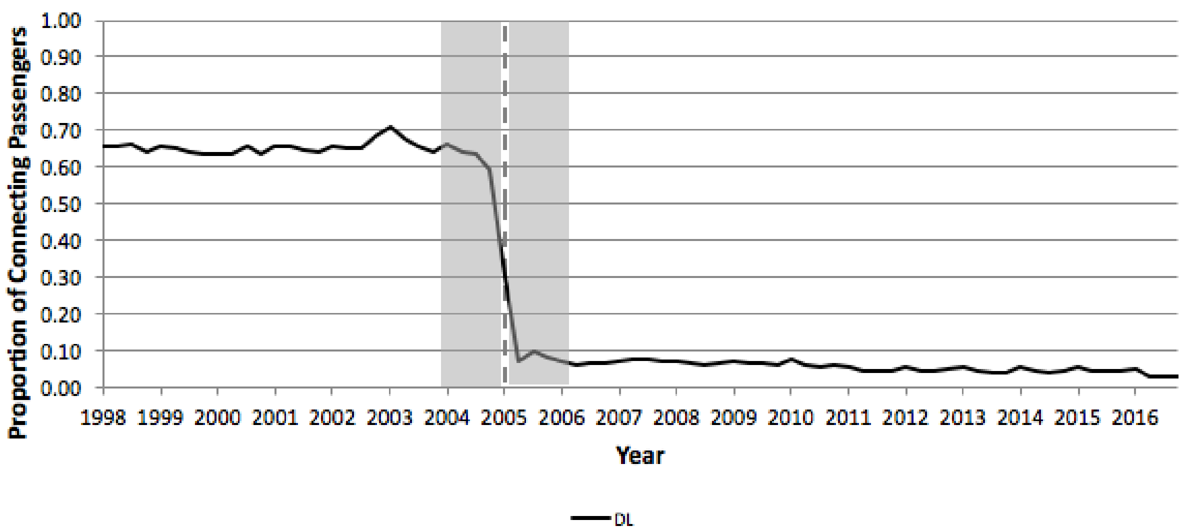

Figure 6: Connecting Travel for De-Hubbing Airline (DFW - Delta Air Lines)

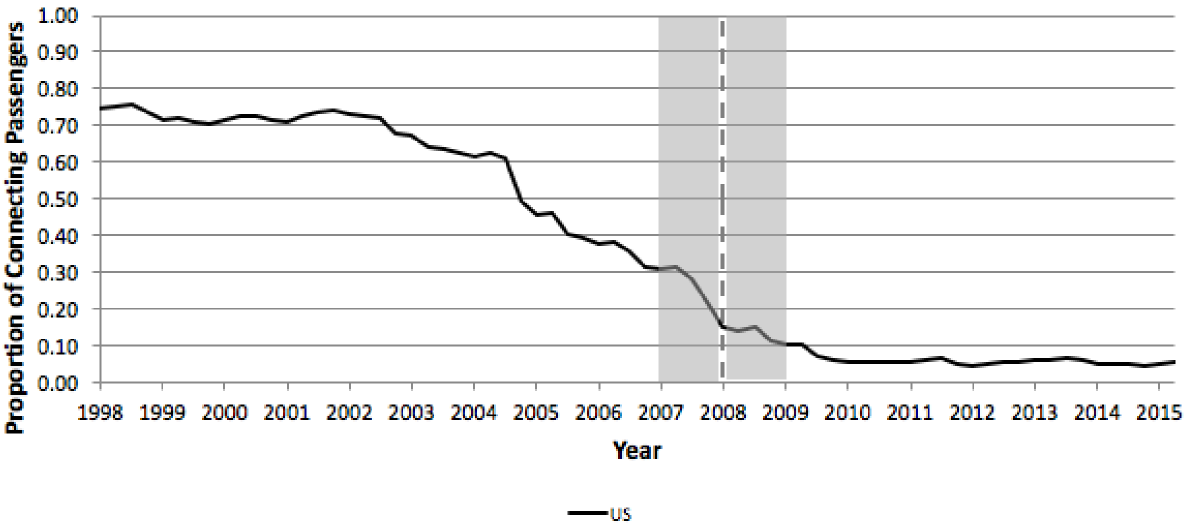

Figure 7: Connecting Travel for De-Hubbing Airline (PIT - US Airways)