The Effect of De-Hubbing on Airfares

Kerry M. Tan* Andrew Samuel†

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Abstract

This paper studies the price effect of de-hubbing, which occurs when an airline ceases hub operations at an airport. We develop a simple theoretical model to study the impact of de-hubbing on prices and quantities of direct flights at the hub airport. Using an event study of seven cases of de-hubbing between 1993 and 2009, we analyze how average airfares change following de-hubbing. Consistent with the theoretical implications, the empirical results suggest that airfares decrease when there is a low-cost carrier presence at the de-hubbed airport, whereas airfares increase when the de-hubbed airport is not serviced by a low-cost carrier.

Keywords: De-Hubbing, Legacy Carriers, Low-Cost Carriers, Hub-And-Spoke Network, Airfares, Airline Competition

*Corresponding author: Department of Economics, Loyola University Maryland, 4501 N Charles St., Baltimore, MD 21210, kmtan@loyola.edu, (410)617-2460

†Department of Economics, Loyola University Maryland, 4501 N Charles St., Baltimore, MD 21210, asamuel@loyola.edu, (410)617-5328

1 Introduction

Hub-and-spoke networks have become the predominant route network structure for legacy carriers since the U.S. airline industry deregulated in 1978. Under this system, a legacy carrier moves passenger traffic between spoke airports through one of its hub airports in order to exploit economies of scope and economies of traffic density. Each of these airlines has several hub airports strategically located in different regions of the United States.[1] However, some of the legacy carriers have recently de-hubbed an airport by ceasing hub operations at that airport, which significantly reduces capacity and the number of spoke airports serviced by the de-hubbed airline. For example, American Airlines de-hubbed both Nashville International Airport (BNA) and Raleigh-Durham International Airport (RDU) in 1995, as well as Lambert-St. Louis International Airport (STL) in 2004. Delta Air Lines de-hubbed Cincinnati/Northern Kentucky International Airport (CVG) in 2006 and Dallas/Fort Worth International Airport (DFW) in 2005. Finally, US Airways de-hubbed Newark Liberty International Airport (EWR) in 1995, whereas Continental Airlines de-hubbed Denver International Airport (DEN) in 1995. This paper analyzes the impact of de-hubbing on airfares at these seven de-hubbed airports.

There is a small, yet growing literature on the economic impact of de-hubbing in the airline industry. Redondi, Malighetti, and Paleari (2012) formally define the criteria for identifying cases of de-hubbing and identify 37 airports that have been de-hubbed between 1997 and 2009 worldwide. They find that de-hubbing, which can occur due to weak demand or a strategic decision to focus on other nearby hub airports, results in a significant and permanent decrease in the number of scheduled flights and seats offered. However, they do not take into consideration the ramifications of de-hubbing on airfares, which is one of the major contributions of our paper. Bilotkach, Mueller, and Nemeth (2014) estimate the consumer welfare effects of de-hubbing using the Budapest Liszt Ferenc International Airport as a case study. They find that there was a net decrease in overall capacity following the de-hubbing of that airport by Malev Hungarian Airlines despite

[1] For example, American Airlines currently utilizes Dallas/Fort Worth International Airport, John F. Kennedy International Airport, Los Angeles International Airport, Miami International Airport, and O'Hare International Airport as hub airports within the United States.

low-cost carriers increasing their service to the airport and weigh the reduction in flight service with potential lower airfares charged by low-cost carriers. To the best of our knowledge, our paper is the first to study the effect of de-hubbing on airfares in the U.S. airline industry.

In contrast to the lack of attention spent on de-hubbing, the existing literature has been focused on the hub premium, in which prices are higher, on average, when at least one of the route's endpoints is a hub airport for the servicing airline. Legacy carriers experience more market power at their hub airports because passengers are attracted to the higher frequency of flights and the increased variety of destinations that they offer from the hub airport. Moreover, Lederman (2008) finds that certain passengers are willing to pay higher prices in order to receive future awards from the airline's frequent-flyer program. Early works empirically estimated the value of the hub premium by regressing logged airfares on airport market shares, while controlling for other factors. Borenstein (1989) and Evans and Kessides (1993) both find that airport market shares has a positive and statistically significant effect on airfares. More recently, Lee and Luengo-Prado (2005) use hub dummy variables as a more explicit proxy for the hub premium and find that prices are between 12.2% and 13.0% higher, on average, when the flight travels to or from an airline's hub airport. Finally, Bilotkach and Pai (2014) use a clever difference-in-differences estimation strategy to distinguish a hub premium from a dominance premium at major U.S. airports that serve as a hub for two airlines. To be sure, this paper does not attempt to identify the existence of a hub premium; rather, we focus on price changes on routes where an airline has de-hubbed at least one of the endpoint airports. Indeed, in contrast to the prior literature on hub-premiums which focuses on studying the difference between hub and non-hub routes at a given point in time, we are interested in the impact of prices before and after de-hubbing. Thus, we are specifically interested in studying how de-hubbing changes the market structure because of changes in the de-hubbed airline as well as due to the strategic responses (to de-hubbing) of other airlines in that same market.

To study this issue, we develop a simple theoretical model that explains how the presence of low-cost carriers influences the price response to de-hubbing. The key results of the model are driven by the differences in the cost structure for legacy carriers and low-cost carriers. Although economies of density are possessed by both the de-hubbing airline and its rivals, the economies of density are assumed to be stronger for low-cost carrier rivals than legacy carrier rivals. Under this assumption, our model predicts that average airfares should decrease after de-hubbing when the de-hubbed airport is serviced by a low-cost carrier, whereas prices should increase where no low-cost carrier exists. The model's predictions regarding changes in airline capacity are also consistent with the data. Although we present only the duopoly case, our results hold for the general oligopoly case.

In order to analyze these theoretical predictions, we study seven instances of de-hubbing at domestic airports between 1993 and 2009. Using a difference-in-differences estimation approach, we find a positive and statistically significant price increase after de-hubbing at some airports, whereas airfares significantly decreased to and from other de-hubbed airports. The distinction between the contrasting results depends on whether low-cost carriers service the de-hubbed airport. Low-cost carriers respond to de-hubbing by increasing their capacity on routes to and from the de-hubbed airport, which puts more competitive pressure on airfares. On the other hand, airfares for routes to or from de-hubbed airports without any low-cost carrier presence increase due to the reduction in the availability of substitutes because of the net reduction in capacity. Thus, the empirical results are consistent with the testable hypotheses of our theoretical model.

2 A Model with De-Hubbing

In this section we present a simple stylized model of competition between two airlines: a hub airline that de-hubs at an airport and a rival airline, which may be either a legacy carrier or a low-cost carrier. The model is similar in spirit to Brueckner and Spiller (1991) with some key simplifications in order to focus on the empirical analysis of the price effects of de-hubbing. We use the model to derive comparative static results of the impact of de-hubbing on average prices and quantities of direct flights to and from the de-hubbed airport (and do not focus on connecting flights). It should be noted that these comparative statics are independent of the impact of de-hubbing on connecting traffic markets.

Consider an airline with a hub and spoke network at some hub city. There are n exogenously determined spokes, therefore, there are n hub-inclusive markets.[2] We assume that the hub airline competes with a separate competitor within each of the n hub-inclusive markets. Thus, there are n identical, segmented, duopoly markets in which the hub airline competes with a rival airline. Although in reality airline markets are not duopolies, the key comparative static results we derive extend to the case with more than two firms. Additionally, there are $n(n-1)$ non-hub markets that use the hub to travel between non-hub cities in the hub and spoke network (i.e. connecting flight travel). The hub traffic market of the hub airline is identified with the letter H and the rival airline with the letter L (to denote legacy or low-cost carrier), and the non-hub traffic (of the hub airline) is identified by NH.

Within each of the n markets, the hub and rival airline's products are assumed to be perfect substitutes.[3] Thus, the inverse demand curve for the hub and rival airline is given by,

$$p = a - b(q_H + q_L),$$

where q_H is the hub traffic quantity of the hub airline and q_L the hub traffic of the rival airline. Inverse demand (price) for the hub airline (in the non-hub market) is given by,[4]

$$P = a - \beta(q_{NH}).$$

With regard to costs we follow Brueckner and Spiller (1991) and assume that both airlines possess economies of density,[5] but that the hub airline's economies of density are increasing in the number

[2] Hub-inclusive markets refers to travel to and from the hub as opposed to *through* it. This follows the terminology used in Brueckner and Spiller (1991) and Brueckner, Dyer, and Spiller (1992).

[3] We follow the standard Cournot framework as presented in Martin (2002). Although we assume that the airlines' products are perfect substitutes, none of our results depend on this assumption.

[4] Although we assume identical intercepts for the hub and non-hub demand, the results of our model are not sensitive to this assumption.

[5] Most economists believe the airline industry has economies of density, but there is no agreement that the industry has economies of scale (holding density constant). As such, we focus on economies of density instead of economies of scale. See Caves, Christensen, and Tretheway (1984) for a detailed discussion on this issue.

of spokes n. To reflect this, the hub airline's total cost in each of the n markets is,

$$c_H(q_H + (n-1)q_{NH}) - \gamma \frac{(q_H + (n-1)q_{NH})^2}{2},$$

and the rival airline total cost is given by,

$$c_L q_L - \delta \frac{q_L^2}{2},$$

where c_H, c_L, δ, γ are all positive constants, and δ and γ capture the intensity of the economies of density.[6]

Given the above demand and costs, the profit of the hub airline is,

$$\frac{n(n-1)}{2}(a - \beta q_{NH})\, q_{NH} + n[a - b(q_H + q_L)]q_H - n\left(c_H(q_H + (n-1)q_{NH}) - \gamma \frac{(q_H + (n-1)q_{NH})^2}{2}\right).$$

Similarly, the rival airline's profit is,

$$q_L(a - b(q_H + q_L)) - c_L q_L - \delta \frac{q_L^2}{2}.$$

We now study the equilibrium in these markets, focusing on the "Cournot-Nash" outcomes in the hub airline market. The first order conditions for the hub airline's profit maximization imply that,

$$q_{NH} = \frac{a - 2c_H + 2\gamma q_H}{(2(b - \gamma(n-1))}, \tag{1}$$

and

$$q_H = \frac{a - c_H + (n-1)\gamma q_{NH}}{2b - \gamma} - \frac{b}{2b - \gamma} q_L. \tag{2}$$

[6]Note that our model is analytically almost equivalent to a model where de-hubbing affects the intercept of the demand (instead of through the cost function).

Similarly, the rival airline's first order condition yields,

$$q_L = \frac{a - c_L}{2b - \delta} - \frac{b}{2b - \delta} q_H. \tag{3}$$

Note that Equations (2) and (3) are the best responses of the hub and rival airline in the hub market, given q_{NH}. This system of equations can be solved for an equilibrium in the hub and rival markets respectively.

We assume that the second order conditions are satisfied which implies that $2b - \delta > 0$, $2b - \gamma > 0$, and $\beta > \gamma(n-1)$. Further, to ensure that the above equilibrium is a stable, positive, interior solution we shall also assume that, $a - 2c_H > 0$, $a - 2c_L > 0$, $2b(\beta - (\gamma(n-1))) - \gamma\beta > 0$, $2b\beta(c_H - c_L) - b\gamma(n-1)(a - 2c_L) - \gamma\beta(a - c_L) > 0$, and $\beta - \gamma(n-1)(ab - a\delta + bc_L) + \beta(2b - \delta)(a - 2c_H) > 0$.[7]

With dehubbing, the number of spokes (n) declines, which affects prices indirectly through the quantities chosen in equilibrium. It should be noted that modeling the de-hubbing process as a continuous (rather than binary) decision is reasonable in light of the fact that de-hubbing does not occur overnight, but rather gradually over a period of several months (see Figure 1). Straightforward calculations produce the following comparative static results with respect to n.

Result 1 *The equilibrium prices and quantity have the following comparative static properties with respect to n.*

1. *The per-market quantity of the hub-airline, q_H, is increasing in n.*

2. *Rival airline (either legacy or low-cost) quantity, q_L, is decreasing in n.*

3. *Average price is increasing in n if and only if $\delta > b$.*

Proof Solving Equations (1), (2) and (3) yields the equilibrium quantities, q^*_{NH}, q^*_H, and q^*_L.

[7] Note that a must be greater than c_H and c_L so that the costs are less than the "choke price." These assumptions are sufficient to guarantee the existence of an interior stable equilibrium, which further allows us to conduct comparative static exercises. See Novshek (1985) and Martin (2002) for more details. Satisfying these assumptions essentially requires that a be sufficiently large, which is very likely true in our data (see footnote 11).

1. Substituting Equation (1) into Equation (2) and solving for q_H yields,

$$q_H^*(q_L) = \frac{\beta(a-2c_H)+a(\beta-\gamma(n-1))}{2b(\beta-\gamma(n-1))-\beta\gamma} - \frac{b(\beta-\gamma(n-1))}{2b(\beta-\gamma(n-1))-\beta\gamma} q_L,$$

   which is the hub-airlines best response to q_L in any single hub market. A straightforward calculation shows that the both the "x" and "y" intercepts are increasing in n. Thus, given the linearity of q_H^* in q_L, and our stability and existence conditions on these best responses, an increase in n will increase the equilibrium q_H and decrease q_L.

2. See the analysis for [1.]

3. At the equilibrium quantities, the derivative of hub traffic prices with respect to n is,

$$-\frac{b\beta\gamma(b-\delta)\left(a\left(3b^2-2b\delta-\gamma\delta\right)+\left(4b\delta-6b^2\right)c_H+2b\gamma c_L\right)}{2\left(3b^2(\beta+\gamma-\gamma n)+\beta\gamma\delta-2b(\beta(\gamma+\delta)-\gamma\delta(n-1))\right)^2}$$

   After some steps, it can be shown that $\left(a\left(3b^2-2b\delta-\gamma\delta\right)+\left(4b\delta-6b^2\right)c_H+2b\gamma c_L\right)$ is positive given our assumptions. Thus, prices are increasing in n if and only if $b<\delta$.

■

We expect that $\delta > b$ when competing with a rival airline that is a low-cost carrier (and $\delta < b$ when competing with a rival airline that is legacy) for the following reason. Empirical evidence suggests that low cost carriers compete predominantly in price-sensitive markets that often consist of mostly leisure-oriented travelers (see Smyth and Pearce (2006) and Dresner (2006)). Thus, if demand is sufficiently elastic (i.e. b is sufficiently low so that it is $< \delta$), then our model predicts that average price will be increasing in n.[8] Hence, we expect that in markets with low-cost carriers, de-hubbing will cause average prices to fall.[9]

[8] Recall that b is the (absolute value of the) slope of the inverse demand curve, with smaller values of b implying more elastic demand. We are grateful to an anonymous referee for providing us with this insight.

[9] It may also be possible to support our assertion that $\delta > b$ when competing with a low-cost carrier by focusing on the cost structure. Specifically, there is some indication that low-carriers have stronger economies of density (Smyth and Pearce 2006), which would also imply that $\delta > b$. However, even if only marginal costs are lower (i.e. $c_H > c_L$), as assumed in Fageda and Flores-Fillol (2012), our model's predictions would not be affected as long as demand is sufficiently elastic for leisure travelers. Since it is empirically difficult to isolate the marginal costs from the economies

In light of the above discussion, our model generates the following testable hypothesis with respect to de hubbing. First, as a result of de-hubbing, the hub airline will reduce the number of seats and flights. Second, the competing airline will increase the number of seats. Finally, when competing against legacy carriers average prices will increase, however, average prices will decrease when competing with a low-cost carrier. [10]

3 Data

We construct a dataset from three sources in order to test the effect of de-hubbing on airfares. The main dataset used in this paper is the Airline Origin and Destination Survey (DB1B), which is a 10% survey of domestic travel that is published quarterly by the Bureau of Transportation Statistics. An observation in the raw data provides information on the number of passengers who paid a certain price to fly with a particular airline on a given route, as well as the distance between the two endpoints of the route. Using this data, we are able to calculate both the mean average airfare and the number of passengers for a particular airline on a given route in each year-quarter. We also obtain data on the number of scheduled flights and available seats for travel within the United States by domestic airlines from the T-100 database, which is also published by the Bureau of Transportation Statistics. The monthly traffic and capacity data is then aggregated at the route-carrier level for each year-quarter. Finally, we augment this dataset with annual estimates on population and per capita income for metropolitan statistical areas (MSA), which can be found in the Local Area Personal Income tables that are created and distributed by the Bureau of Economic Analysis. Data from 1993 to 2009 are collected from each of the three data sources.

We focus on coach class fares on nonstop flights between the top 100 airports within the con-

of density, we only rely on the "demand side" to support our assertion.

[10] We do not analyze the impact of de-hubbing on total quantity at a hub airport, since it is not clear what happens on the routes that used to be served by the hub airline prior to de-hubbing. However, it would be consistent with this analysis to assume that the rival airline acts as a monopolist on these routes. In this case, we should expect overall quantity on these routes to decrease. However, the total market quantity, $Q = n(q_H + q_L)$ on the routes that are still served by the hub airline (after de-hubbing) may still rise or fall. Thus, the effect on total quantity as a result of de-hubbing is ambiguous. Since our focus is on the price effects of de-hubbing we do not explore this issue in depth.

tinental United States.[11] These correspond to traffic at hub markets as discussed in Section 2. Following Ito and Lee (2005), we eliminate any observations with a reported price that is less than \$25 or more than \$1500 as these observations are believed to be either frequent-flyers or incorrectly coded. We also drop any observations where the airline has a market share of less than 1% as is done in Borenstein (1989). The resulting dataset consists of 1,687,696 observations on 8,158 routes. Summary statistics are summarized in Table 1.

De-hubbing is defined using two criteria and is loosely based on Redondi, Malighetti, and Paleari (2012), who identified 37 airports world-wide that were de-hubbed between 1997 and 2009. First, de-hubbing is said to occur in a particular year-quarter whenever an airline decreases its total number of flights to and from that airport by at least 50% in the time period before de-hubbing, defined to be the three to six quarters prior to that year-quarter, versus the time period after de-hubbing, defined to be the three to six quarters following that year-quarter.[12] This allows for a one-year excluded period surrounding the de-hub date that accounts for the transitional time period in which de-hubbing takes effect. This also prevents spurious temporary capacity changes from being identified as instances of de-hubbing.[13] Moreover, there are some cases in which an airline will dramatically decrease capacity at smaller airports that are not used for typical hub operations. Therefore, the second criterion for de-hubbing is that the de-hubbed airport must be one of the top 50 airports in terms of passenger traffic.[14] This effectively focuses de-hubbing cases on major airports located in the United States. Using this criteria, various legacy carriers de-hubbed a total of seven airports in the United States: Nashville International Airport (BNA), Baltimore/Washington

[11] Rankings are based on the number of boardings in 2009 and are obtained from the Federal Aviation Administration. The airport with the most amount of boardings is Hartsfield-Jackson Atlanta International Airport, while the 100th-ranked airport is Myrtle Beach International Airport.

[12] Redondi, Malighetti, and Paleari (2012) uses the number of connections instead of the number of flights. Their results not only ignore certain clear instances of de-hubbing in the United States but also include false positive instances of de-hubbing.

[13] There was a sharp decrease in the number of flights by US Airways to and from Ronald Reagan Washington National Airport (DCA) in 2001:Q4. It is believed that this was a short-run response to a negative shock to demand following the September 11 attacks and not a concerted de-hubbing effort as evidenced by a spike in capacity beginning in 2004:Q4.

[14] The 50th largest airport is Dallas Love Field and the 51st largest airport is Southwest Florida International Airport. The smallest de-hubbed airports are Raleigh-Durham International Airport and Nashville International Airport, which were the 38th and 39th ranked airport, respectively.

International Thurgood Marshall Airport (BWI), Cincinnati/Northern Kentucky International Airport (CVG), Denver International Airport (DEN), Dallas/Forth Worth International Airport (DFW), Newark Liberty International Airport (EWR), and Lambert-St. Louis International Airport (STL). The accuracy and timing of these de-hubbing instances were then verified using public sources. Figure 1 graphs the total number of flights scheduled to and from each of these seven airports for the de-hubbing airline between 1993 and 2009. The gray dashed line indicates the time period when the airport is considered to become de-hubbed. Given the criteria for de-hubbing, Figure 1 unsurprisingly shows a sharp decline in the number of flights following de-hubbing at each of the seven airports.

Table 2 presents two ways to study the effect of de-hubbing on capacity: the total number of flights, which is the sum of the scheduled departure and arrival flights at the airport, and the total number of seats, which is the sum of the seats offered on all of those flights. In order to analyze the de-hubbing effect, we compare the time period before de-hubbing, defined to be the three to six quarters prior to the airport becoming de-hubbed, with the time period after de-hubbing, defined to be the three to six quarters following de-hubbing. The percent change from these two time periods is also reported in Table 2. These two measures of quantity are summarized for all airlines servicing the airport, which is composed of the de-hubbing airline, legacy carrier competitors,[15] and low-cost carrier competitors.[16] By definition, de-hubbing leads to a decrease in the total number of flights and the total number of seats by the de-hubbing airline. However, the composition of airlines at these de-hubbed airport is mixed. At BNA, DEN,[17] DFW, and STL, low-cost carriers serviced the de-hubbed airport before and after de-hubbing. At these airports, the competitors responded to de-hubbing by increasing capacity. For example, the total number of flights and seats offered by all airlines servicing BNA increased by 10.2% and 9.9%, respectively, while American Airlines,

[15]The six legacy carriers are American Airlines, Continental Airlines, Delta Air Lines, Northwest Airlines, United Airlines, and US Airways.

[16]The five low-cost carriers are AirTran Airways, Frontier Airlines, JetBlue Airways, Southwest Airlines, and Spirit Airlines.

[17]Frontier Airlines, the only low-cost carrier at DEN, started servicing the airport in the final quarter of the "before de-hubbing" time period, which leads to the drastic increase in capacity in the "after de-hubbing" time period. Frontier Airlines scheduled 4,922 flights in the final quarter of the "after de-hubbing" time period, which is still a large increase in capacity.

the airline that de-hubbed BNA, reduced the number of flights by 74.9% and the total number of seats offered by 75.4%. However, both legacy carrier and low-cost carrier competitors responded to de-hubbing by substantially increasing their own capacity; however, not by enough to offset the reduction in capacity by the de-hubbing airline. On the other hand, CVG, EWR, and RDU never experienced low-cost carrier presence. As a result, there was generally a relatively large net decrease in capacity following de-hubbing. For example, the total number of scheduled flights and seats offered by all airlines decreased by 60.6% and 56.9% following de-hubbing by Delta Air Lines at CVG.

The theoretical model assumes that the de-hubbing airline decreases the number of spoke airports servicing the de-hubbed airport. Table 3 shows the number of spoke airports serviced from the de-hubbing airline in the year before de-hubbing and in the year after de-hubbing. The number of spoke airports serviced by the de-hubbing airline declines for each and every de-hubbing case. Thus, not only does the de-hubbing airline dramatically decrease its flight capacity but it also stops servicing some of the spoke airports once it de-hubs an airport.

4 Empirical Analysis

In order to test the effect of de-hubbing on airfares, we conduct an event study on seven airports that were de-hubbed between 1993 and 2009. By using a difference-in-differences approach, we are able to infer an overall before and after effect of de-hubbing on airfares for hub markets. The regression results suggest that average airfares decrease following de-hubbing at airports with low-cost carriers, whereas average airfares increase following de-hubbing at airports with no low-cost carrier presence. The following section formalizes the estimation strategy and discusses the regression results.

We use a two-way fixed effects model in order to yield a differences-in-differences (DID) estimate on the effect of de-hubbing on airfares.[18] The dependent variable is logged average airfares

[18] Studies on hub premiums typically rely on cross-sectional variation to identify a hub premium; however, this paper utilizes variation over time in the hub status of particular airports to estimate the de-hubbing effect on airfares.

(*lnprice*). We control for the geometric mean of the population (*pop*) and per capita income (*income*) of the two endpoint airports' MSAs, as well the number of legacy carriers (*nLEG*) and low-cost carriers (*nLCC*) that service the route.[19] We also include a dummy variable (*airport*) that indicates whether the de-hubbed airport is one of the route's endpoint airports, another dummy variable (*dehub*) that indicates whether the time period is pre- or post-de-hubbing, and the interaction term of the two dummy variables ($airport \times dehub$). The *airport* variable is constructed to limit the data sample to a before and after period, where the before period starts six quarters prior to the de-hubbing time period and ends three quarters before de-hubbing, whereas the after period starts three quarters following the de-hubbing time period and ends six quarters after de-hubbing. This allows for a one-year excluded period surrounding the de-hub date in order to account for the transitional time period in which de-hubbing takes effect. The specification for the difference-in-differences regression model is as follows:

$$lnprice_{ijt} = \gamma_{ij} + \nu_t + \alpha X_{ijt} + \beta_1 airport_j + \beta_2 dehub_t + \beta_3 (airport_j \times dehub_t) + \varepsilon_{ijt}, \qquad (4)$$

where $lnprice_{ijt}$ is the average one-way airfare for airline i on route j in time t, γ_{ij} is the carrier-route fixed effects, ν_t is the year-quarter fixed effects, $airport_j$ is the airport dummy variable, $dehub_t$ is the de-hub time dummy variable, and X_{ijt} are the other control variables explained above. By construction, the *airport* dummy variable becomes absorbed by the route-carrier fixed effects, while the year-quarter fixed effects absorb the *dehub* dummy variable. We cluster the standard errors by route-carrier in order to account for intragroup correlation over time. Since the *airport* and *dehub* variables serve as the treatment variable and time variable in the standard DID approach, respectively, our variable of interest is the interaction term ($airport \times dehub$). A positive and statistically significant coefficient for the interaction term implies that airfares increase, on average, after the airport has been de-hubbed. The regression analysis is carried on all routes between the

[19] There is a potential causality issue if the development of low cost carriers led to both lower airfares and the decision for a legacy carrier to de-hub. However, no public sources attributed any of the seven de-hubbing cases to the growth of low-cost carriers. In fact, some airports that are de-hubbed have no low-cost carrier presence, which mitigates the concern that low-cost carriers are causing the de-hubbing decision.

top 100 airports with different regressions for each de-hubbing case within these markets but at different time periods, such that the *airport* and *dehub* dummies are specific to each of the seven instances of de-hubbing.

Table 4 reports the results of the DID regression for each of the seven de-hubbed airports. The coefficient for $airport \times dehub$, the control variable of interest, is positive and statistically significant for four of the seven de-hubbed airports, meaning that the DID method implies that average airfares at de-hubbed airports increases after it has been de-hubbed by a legacy carrier. The results suggest that de-hubbing contributed to a 36.8%,[20] 14.8%, and 10.3% increase in average airfares at CVG, EWR, and RDU, respectively. These are the same airports that never experienced low-cost carrier presence. On the other hand, the coefficient for $airport \times dehub$ is negative and statistically significant for four of the seven de-hubbed airports. The results suggest that average airfares decreased by 12.5%, 2.6%, 3.8%, and 4.1% at BNA, DEN, DFW, and STL, respectively. All four of these airports are serviced by a low-cost carrier. These results are consistent with the predictions from our theoretical model.

5 Conclusion

Legacy carriers have de-hubbed certain airports due to changes in demand and the competitive environment. This paper presents a stylized, theoretical, model to understand the price and quantity effects of de-hubbing on hub market traffic. We test the implications of the model, using an event study estimation approach. The paper serves as the first attempt to analyze the effect of de-hubbing on airfares in the U.S. airline industry.

We find that de-hubbing always leads to a decrease in capacity by the de-hubbing airline and an increase in capacity by rival airlines, which is consistent with our theoretical model. Furthermore, the price response to de-hubbing is nontrivial. Specifically, our theoretical framework implies that average airfares increase when no low-cost carrier services the de-hubbed airport, whereas average

[20]The percent change is found by exp(0.313) - 1 = 0.368.

airfares decrease when a low-cost carrier is present at the de-hubbed airport. Recall that these key theoretical implications regarding airfares are driven by the cost structure and its relationship to demand elasticity. To understand the intuition consider the (extreme) case where the rival does not possess any density economies ($b > \delta = 0$). In this case, average prices are always decreasing in n so that de-hubbing always raises average prices because even though the rival expands capacity (in response to de-hubbing) it cannot capitalize on economies of density. Thus, the smaller supply combined with possibly inelastic demand, will lead to higher average prices. When the rival is a low cost carrier, then we expect that demand will be elastic while density economies of the rival will be large ($b < \delta$). In this case when an airline de-hubs, its rival expands and in doing so it can exploit its density economies and lower its marginal costs even further. These lower marginal costs will translate into lower prices for consumers through the usual "cost pass through" process. Thus, as reflected in our model, average price should be increasing in n.

Our regression results are consistent with these theoretical predictions. Namely, average airfares increase following de-hubbing at airports where no low-cost carrier is present, whereas average airfares decrease when a low-cost carrier services the de-hubbed airport. As a result, the effect of de-hubbing on consumer welfare depends on the competitive environment, specifically low-cost carrier presence. A recent IATA briefing on airline costs (Smyth and Pearce (2006)) remarks that legacy carriers can learn from the cost saving strategies implemented by the low-cost carriers. Our results suggest that the mere presence of low-cost carriers helps to reduce the average airfares at that airport, thus increasing consumer surplus of those passengers. Thus, this paper contributes to the literature on the effect of de-hubbing and also provides novel insight into the growing literature on the competition between legacy carriers and low-cost carriers.

The paper suggests two areas of future research. First, we only focus on direct flights at the hub markets, not connecting flights through the hub (i.e non-hub markets). We leave it to future work to understand and identify what occurs in these non-hub markets as a result of de-hubbing. Second, an important remaining research question is to understand the motivations for de-hubbing since there appears to be no overarching reason why airlines de-hub certain airports. For example, Delta Air Lines de-hubbed CVG in 2006:Q1 prior to their merger with Northwest Airlines, which was announced in April 2008. Although Denver had once served as the location for Continental Airlines's headquarters, it de-hubbed DEN in 1995:Q2 in response to higher costs and landing fees. Upon acquiring Trans World Airlines (TWA) in 2001, American Airlines set up hub operations at STL, where TWA had been headquartered. STL was supposed to alleviate the traffic congestion at Chicago O'Hare International Airport and Dallas/Fort Worth International Airport, two of American's other hub airports. However, the merger resulted in a financial drain and American Airlines subsequently de-hubbed STL in 2004:Q1. This lack of a clear, consistent pattern behind the reasons for de-hubbing make a theoretical model somewhat premature at this stage. Nonetheless, the findings in this paper may offer some guidance for future work on this topic.

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Table 1: Summary Statistics

Variable	Definition	Mean (Std. Dev.)
$price_{ijt}$	Average one-way market fare for carrier i on route j in time period t	201.15
		(66.56)
$distance_j$	One-way distance (in miles) between the endpoints of route j	1,268.58
		(656.24)
$passengers_{ijt}$	Number of passengers for carrier i on route j in time period t	2,375.66
		(6917.25)
$nLEG_{jt}$	Number of legacy carriers operating route j in time period t	3.75
		(1.51)
$nLCC_{jt}$	Number of low-cost carriers operating route j in time period t	0.57
		(0.69)
pop_{jt}	Geometric mean of population (in hundreds of thousands) of origin	25.42
	and destination airports' MSA on route j in time period t	(20.51)
$income_{jt}$	Geometric mean of per capita income (in tens of thousands) of origin	3.34
	and destination airports' MSA on route j in time period t	(0.72)
Routes	Number of routes in the sample	8,158
N	Number of observations	1,687,696

Table 2: Capacity Before and After De-Hubbing

		Total Number of Flights			Total Number of Seats		
		Before De-Hubbing	After De-Hubbing	Percent Change	Before De-Hubbing	After De-Hubbing	Percent Change
BNA	All Airlines	97,718	87,795	-10.2%	12,042,051	10,847,173	-9.9%
	American	59,653	14,981	-74.9%	7,458,624	1,832,697	-75.4%
	Competitors (Legacy)	25,536	41,464	62.4%	2,985,963	4,928,786	65.1%
	Competitors (Low-Cost)	12,529	31,350	150.2%	1,597,464	4,085,690	155.8%
CVG	All Airlines	108,694	42,845	-60.6%	15,398,308	6,634,380	-56.9%
	Delta	106,544	42,213	-61.3%	15,168,678	6,446,077	-57.5%
	Competitors (Legacy)	2,150	1,632	-24.1%	229,630	188,303	-18.0%
	Competitors (Low-Cost)	n/a	n/a	n/a	n/a	n/a	n/a
DEN	All Airlines	305,246	269,078	-11.8%	42,549,206	39,181,974	-8.0%
	Continental	80,288	8,785	-89.1%	11,207,542	1,777,968	-89.5%
	Competitors (Legacy)	223,971	243,787	8.8%	31,276,180	36,164,652	15.6%
	Competitors (Low-Cost)	987	110,484	11,093.9%	16,506	1,839,354	11,043.5%
DFW	All Airlines	405,082	384,801	-5.0%	54,560,294	53,988,248	-1.0%
	Delta	41,301	9,886	-76.1%	6,129,535	1,478,199	-75.9%
	Competitors (Legacy)	354,547	360,412	1.7%	47,309,647	50,734,767	7.2%
	Competitors (Low-Cost)	9,234	14,503	57.1%	1,121,112	1,775,282	58.4%
EWR	All Airlines	239,275	228,763	-4.4%	33,367,249	30,538,635	-8.5%
	US Airways	40,423	10,114	-75.0%	4,239,833	1,314,820	-69.0%
	Competitors (Legacy)	198,852	218,649	10.0%	29,127,416	29,223,815	0.3%
	Competitors (Low-Cost)	n/a	n/a	n/a	n/a	n/a	n/a
RDU	All Airlines	95,967	50,162	-47.7%	12,494,187	6,062,706	-51.5%
	American	63,136	10,965	-82.6%	8,822,068	1,506,793	-82.9%
	Competitors (Legacy)	32,831	39,197	19.4%	3,672,119	4,555,913	24.1%
	Competitors (Low-Cost)	n/a	n/a	n/a	n/a	n/a	n/a
STL	All Airlines	231,089	101,861	-55.9%	31,145,731	13,615,542	-56.3%
	American	162,454	39,947	-75.4%	22,196,619	5,629,108	-74.6%
	Competitors (Legacy)	20,100	18,627	-7.3%	2,381,949	2,113,964	-11.3%
	Competitors (Low-Cost)	48,535	43,287	-10.8%	6,567,163	5,872,470	-10.6%

Note: This table reports changes in capacity by all airlines, the de-hubbing airline, and other airlines present at the de-hubbed airport. The total number of flights is the sum of the scheduled departure and arrival flights at the particular airport, whereas the total number of seats is the sum of the offered seats on all of those flights. The before and after periods includes the the three to six quarters prior to and following de-hubbing, respectively. This allows for a one-year excluded period around the de-hub date that accounts for the transitional time period in which de-hubbing takes effect.

Table 3: The Number of Spoke Airports Serviced by the De-Hubbed Airline

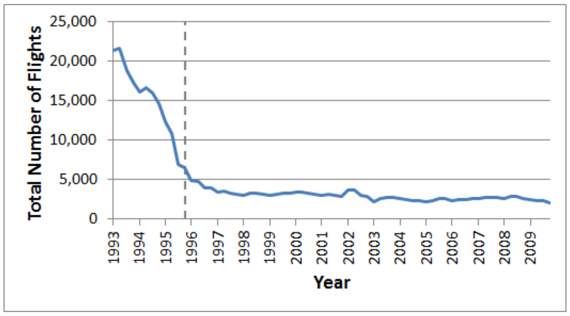
	BNA	CVG	DEN	DFW	EWR	RDU	STL
Before De-Hubbing	77	87	68	82	52	82	81
After De-Hubbing	51	82	27	54	41	48	76

Note: This table reports the number of spoke airports that the de-hubbd 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.

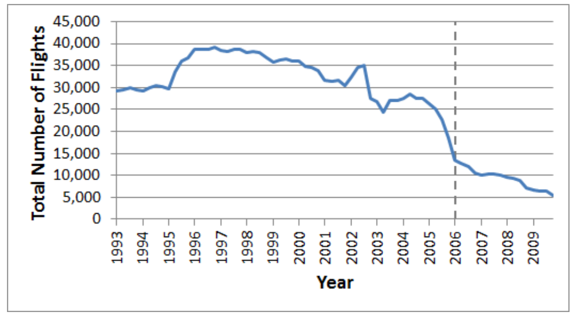
Table 4: Difference-in-Differences Estimation Results
(Dependent Variable: *lnprice*)

Variable	BNA	CVG	DEN	DFW	EWR	RDU	STL
$airport \times dehub$	-0.125**	0.313**	-0.026**	-0.039**	0.138**	0.098**	-0.042**
	(0.011)	(0.008)	(0.008)	(0.007)	(0.011)	(0.012)	(0.006)
pop	-0.039**	-0.014**	-0.039**	-0.008**	-0.046**	-0.041**	-0.015**
	(0.002)	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)	(0.002)
$income$	0.175**	-0.016	-0.030	-0.066**	-0.063**	-0.059	-0.030*
	(0.027)	(0.009)	(0.032)	(0.009)	(0.033)	(0.032)	(0.014)
$nLEG$	-0.036**	-0.005**	-0.031**	-0.003**	-0.031**	-0.039**	-0.008**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$nLCC$	-0.198**	-0.044**	-0.210**	-0.072**	-0.207**	-0.203**	-0.064**
	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)	(0.005)	(0.002)
N	167,048	225,060	166,711	219,681	166,711	166,835	216,658

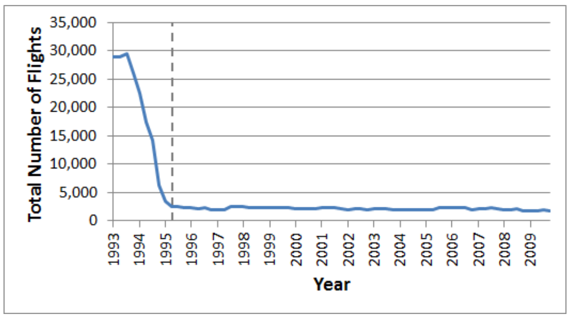
Note: This table reports the results of the two-way fixed effects price regressions outlined in Equation 4. Observations are at the route-carrier-year-quarter level. By construction, the *airport* dummy variable becomes absorbed by the route-carrier fixed effects, while the *dehub* dummy variable gets absorbed by the year-quarter fixed effects. Route and year-quarter fixed effects suppressed. Standard errors, which are presented in parentheses, are clustered by route-carrier to account for correlation between a route-carrier combination over time.
* indicates significance at 5% level.
** indicates significance at 1% level.



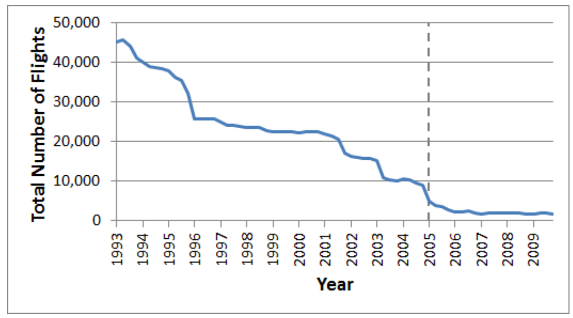
(a) BNA (American Airlines)



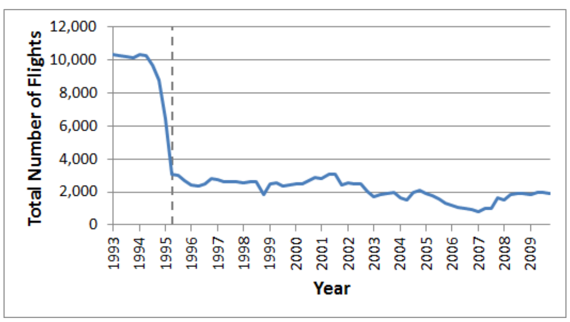
(b) CVG (Delta Air Lines)



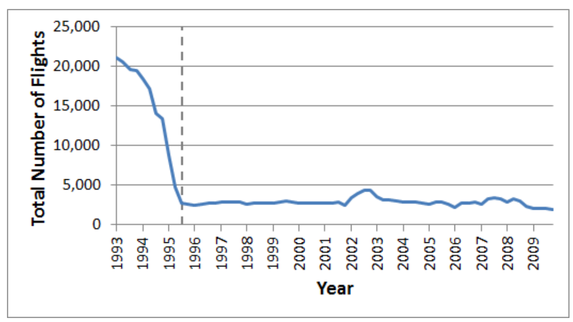
(c) DEN (Continental Airlines)



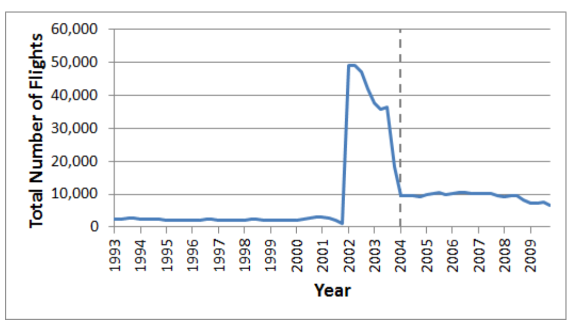
(d) DFW (Delta Air Lines)



(e) EWR (US Airways)



(f) RDU (American Airlines)



(g) STL (American Airlines)

Figure 1: Number of Flights by De-Hubbing Airline

The number of flights is the sum of the scheduled departure and arrival flights at the particular airport. The gray dashed line indicates the year-quarter that the airport became de-hubbed by the airline identified in parentheses.