Airline Hub Airports and Local Economic Outcomes

Marquise J. McGraw*†

February 26, 2018

Abstract

This paper considers the effects of airline hub airports on a city's economy over the 1978-2012 period. Using a panel dataset of yearly outcomes for cities with airports, combined with data for when an airport was labeled by an air carrier as a hub, I consider the effects of hub openings and hub closings. To accomplish this in the presence of possible endogeneity, I turn to a synthetic control event study design which allows for the estimation of causal outcomes. I find that hub airports increase per-worker wages by 1.1 to 1.8 percent, and economic output measures such as personal income and total payroll by 1.7 to 4.3 percent. These findings mostly arise from a hub's opening, rather than its closing. These findings support the hypothesis of airline hubs functioning as a productive amenity, providing high-quality infrastructure that supports business activity.

*Economist, Office of Research, Consumer Financial Protection Bureau. marquise.mcgraw@cfpb.gov

†I thank Enrico Moretti, David Card, Victor Couture, Mark Hansen, and John Bitzan for helpful comments and advice. I also thank seminar participants at Duke University, participants at the Transportation and Public Utilities Group session at the 2016 American Economic Association meetings, the 2015 meetings of the North American Regional Science Council and the Furman Center of New York University, specifically Anca Cristea and Ingrid Gould Ellen, for helpful comments on an earlier draft of this paper. I am grateful to Severin Borenstein for graciously proving me access to historical air traffic data. I thank Alice Wang, Chau Nguyen and Zitian Deng for excellent research assistance. This article is the result of the author's independent research while at Middlebury College and the University of California, Berkeley, and does not necessarily represent the views of the Consumer Financial Protection Bureau or the United States. All errors are my own.

1 Introduction

In an era of high fuel prices, high operating costs and increased competition, airlines have found themselves culling their networks to maximize efficiency and reduce costs. Over the past decade, a number of large mergers in the domestic airline industry, such as United Continental, Delta Northwest, American and U.S. Airways, and Southwest and AirTran. According to the U.S. Department of Transportation, these mergers have led these four combined carriers to have just under 70 percent of market share as of December 2017.[1]

Post-deregulation, airlines moved quickly to establish hubs, seeking to establish a market share advantage at various airports, hoping that this would drive profitability. While this drove operational efficiency, competitive pressures kept pricing advantages in check for the most part (Button, 2002). For travelers, hubs became popular as they allow access to most domestic destinations with no more than one connection. They also generally offer higher frequencies of flights to popular destinations. Time-sensitive business travelers in particular appreciate the flexibility and, in many cases, ability to easily travel non-stop to a variety of destinations. Thus, they are likely to value hubs. Various studies suggest cities may benefit from these hub airports. For example, Giroud (2013) has shown that new non-stop air routes have the potential to increase plant level investment by 8 percent and productivity by 1.3 percent to headquarter companies because of the availability of direct flights. Similarly, Bowen (2010) notes that airline hubs have facilitated the consolidation of corporate headquarters and, additionally, job growth. Button et al. (1999) argue that high-technology companies also have a clear preference for locating in cities with hub airports.

Despite these advantages that hubs offer, it is costly for airlines to establish and maintain hub airports. Thus, air carriers have a strong incentive to minimize the number of hubs they operate. In recent years, cities such as St. Louis, Memphis, Cleveland, and to a lesser extent, Cincinnati, all have experienced hub closures as a result of merger reorganizations. To date, little empirical research has been conducted to understand the effects these actions have had on cities. The goal of this study is to shed light on this topic. I compile an extensive yearly dataset consisting of air

[1] U.S. Department of Transportation, Bureau of Transportation Statistics: http://www.transtats.bts.gov/

traffic, employment, establishment, payroll and wage data for 85 cities that had airports prior to deregulation, 30 of which were labeled as airline hubs for at least some portion of the study period, and others of which, based on air traffic in 1977, appeared to have the potential to become hubs but never did. Combining this with data collected on hub openings and closings yields a rich dataset of airport outcomes, in some cases from as early as 1965 to 2012.

Focusing on metropolitan-area (CBSA) level effects, in particular on wages but also employment and output, I first use difference-in-differences to exploit the temporal variation in hub openings and closings to shed light on overall effects in a panel setting. Then, I separately consider hub openings and closings. Because of the potential for endogeneity to bias standard difference-in-differences specifications in this setting, I ultimately combine event-study and synthetic control techniques to determine the causal effect of hub openings and closings on city outcomes. I find that hub airports increase per-worker wages by 1.1 to 1.8 percent, and economic output measures such as personal income and total payroll by 1.7 to 4.3 percent. These findings mostly arise from a hub's opening, rather than its closing. These findings support the hypothesis of airline hubs functioning as a productive amenity, providing high-quality infrastructure that supports business activity. I also show that positive employment outcomes are observed in related industries, such as air travel, hotels and lodging, wholesale trade, and amusements and recreation.

The rest of this paper proceeds as follows: Section 2 reviews the literature on air hubs and provides some background on how and why airport hubs might impact local economic outcomes. Section 3 provides information about the data and methodology, section 4 presents the results and discussion, and section 5 concludes.

2 Background

Airports in general have been shown to be important contributors to the health of their local economies. For example, Sheard (2014) uses the Civil Aeronautics Administration's 1944 National Airport Plan as an instrument for the current distribution of airports (by size, as measured by air traffic) in the U.S. His dependent variable of interest is employment shares. He finds that while airport size has some effect on employment in tradable sectors, it has no effect on employment in manufacturing or other non-tradable services. He also finds that airport size has practically zero effect on overall local employment. If this is true, than one might expect the loss (or gain) of a hub airport to matter little to a city's economy. Sheard (2015), using a different identification approach similar to the Bartik instrument, finds that the elasticity between airport size and employment is 0.02, and that between airport size and GDP to be 0.035.

Cohen et al. (2003) apply spatial econometrics techniques to a cost function approach. They find that increasing investment in own-state airport infrastructure tends to generate cost-savings benefits for the manufacturing industry, primarily due to non-production-related labor and materials savings. Based on this, we may expect hub airports to have some effect on employment and establishment outcomes in the tradable sector. They also find that such expansion is accompanied by spillover benefits to other airports, especially when investment is concentrated in a connected hub. If this is the case, these benefits will be captured in the estimates presented later in this paper. Percoco (2010) considers the impact of airports on Italian provinces. He finds that the elasticity of service-sector employment to airport passengers is 0.045, and that of spillover effects is almost 0.017.

Small airports were the focus of Button et al. (2010). They use a sample of 66 small airports in Virginia to estimate their effects on economic development, and find that a doubling of passenger numbers produces up to a 4 percent increase in per capita income in the areas studied. Blonigen and Cristea (2015) exploit the market changes induced by the 1978 Airline Deregulation Act to examine the relationship between air traffic and local economic growth. Using time-series variation in local growth rates over a 20-year period centered around deregulation (1969-1991), they find that air service has a positive and significant effect on regional growth, with the size of these effects differing by the size of the MSA and its industrial mix. LeFors (2014) constructs a measure of air accessibility, and uses it to examine how it contributes to growth. He finds increasing air accessibility increases the growth rate of employment in tradable services; however he finds weak effects on productivity and total employment growth.

Another strand of literature finds that hub airports, specifically, have characteristics that may prove to be unique to cities with hub airports. Button et al. (1999) examine employment data between hub and non-hub cities by year. They find an overall increase in high-tech, high paying jobs in hub cities. They also find a possible link between rapid growth in high-tech employment in cities that are hubs compared to those that are not, further suggesting that having a hub airport might be beneficial to a city's economy, at least when it comes to the technology sector. Neal (2011) finds that urban growth is driven by a city's "centrality" in business networks. This finding relies on estimation of a lagged dependent variable model, which does not necessarily prove causality. Giroud (2013) shows that new non-stop air routes have the potential to increase plant level investment by 8 percent and productivity by 1.3 percent. This implies that companies are much more likely to establish headquarter and other operations in cities partly based on the availability of direct flights to a city. Bowen (2010) notes that airline hubs have facilitated the consolidation of corporate headquarters and, correspondingly, job growth in cities, the majority of which have an airline hub. Neal (2012) and Neal (2014b) examine the potential effects hubs may have on urban creative economies. He categorizes hubs into various types: closeness hubs that offer non-stop services, betweenness hubs that offer intermediate connections, and degree hubs, or terminal destination hubs. He finds that only destination hubs substantially impact economic development and attract creative workers to a city.

In terms of hub location, O'Kelly (1998) finds that an optimal hub has few direct links between hubs, suggesting a motive for airlines to keep their number of hubs as small as possible. Others propose that location might be the most important factor in an airline's choice of hub. Jaillet et al. (1996) argues that candidacy for hubs depends more on geographic position than local demand level, leading to the conjecture that at least some hubs were created independent of city characteristics. As noted by Button and Lall (1999), business travelers are time-sensitive rather than price-sensitive, caring more about the frequency of flights, ease of rescheduling, and the services offered at airports than the price of a flight. Redding et al. (2011) provide a model and empirical analysis of the shift in Germany's main hub from Berlin to Frankfurt following the reunification of East and West Germany in 1990. They conclude that the location of an air hub is not uniquely determined by fundamentals; that is, multiple steady states exist. The chosen location likely has more to do with airlines' sunk costs than city fundamentals.

It is important to note that there is no single definition of a hub airport. For example, the U.S. General Accounting Office classifies an airport as a hub if more than 60 or 85 percent of its traffic is controlled by one or two dominant carriers, respectively. (In some studies, the respective numbers used change, such as 50 to 75 percent). The Federal Aviation Administration, by contrast, divides airports into large hub and medium hub subcategories based on the share of passenger traffic (enplanements) at an airport.[2] Academic research often defines a hub as an airport such that carriers feed three or more banks of traffic daily through it from 40 or more cities (Button, 2002).

Given these considerations, particularly the differing definitions of a hub, and the goal of this study, to understand the role of a hub in a local economy as a policy maker might perceive it, I will define a hub simply by the label given to it by air carriers. If, in its annual report or other public-facing documentation, an airline considers a particular airport to be a hub in a particular year, it will be considered a hub for the purposes of this study. This paper will utilize the salient features of a hub - the large amount of traffic generated, the choice of location being primarily based on airline sunk costs and operational needs, and operation for the sake of maximizing airline profit, not local city outcomes - to provide credible causal evidence on the relationship between an airport hub and local economic development.

This review suggests a primary mechanism via which airport hubs may affect local economies are reductions in input costs for firms relying on the type of access that airports can provide. The standard Roback (1982) model suggests that such a mechanism would increase firm productivity, increasing profits. This may show up in the data in a number of ways: higher per-worker wages, per-capita income, higher overall payroll, or higher overall employment levels. One may also expect to see an increase in the number of establishments. (Higher rents are another poten-

[2] A large hub has one percent or more of domestic passenger enplanements. A medium hub has 0.25 - 1.00 percent. A small hub has 0.05 - 0.249 percent, and a non-hub airport has less than 0.05 percent enplanements.

tial mechanism through which such effects may appear, but data limitations do not allow for an exploration of that topic in this article.)

3 Data and Methods

I construct a panel data set consisting of a city's airport hub status, passenger enplanements and operations, market access, employment and payroll data. To select the airports included in this study, I began with the sample of 157 airports provided in the 1964 *FAA Statistical Handbook*, as this provides a set of airports that could feasibly become hubs at some future time.[3] I keep those that in 1977 carried at least 0.1 percent of air traffic, which included those that would ever become airport hubs. This cutoff was chosen after examining the traffic levels of hub airports in the study, and noting that the smallest airport at the time to become a hub, San Jose (SJC), had a 1977 traffic level of 0.2 percent. 1977 data was used for this exercise as this represented airport usage just prior to deregulation in 1978. Multiple airport cities were eliminated because the econometric methods employed consider only a single binary "treatment effect" of the airport on its city. It is unclear how one should properly apportion the effect of a hub opening or closing event in a city with multiple airports; thus, this is left for further research.

The final sample consists of 85 airports, 30 that functioned as hubs for some part of their history, and 55 that were never designated as hub airports. Of the 30 airports, 21 were hubs for a "major" airline or predecessor to a "major" U.S. airline, e.g. Delta, United or American. Details of each hub airport are given in Table A.1, while those for hub potential airports are given in Tables A.2 and A.3 in the Appendix.

For each airport, I obtain air traffic data - enplanements (passenger counts) and operations (flights) from 1964, 1970, and 1976 - 2012 from the Federal Aviation Administration.[4] Given the importance of non-stop flights to business travelers, I use U.S. Department of Transportation DB1B

[3] To the best of my knowledge, this is the earliest comprehensive classification of hub cities in the United States by a governmental entity.

[4] FAA Terminal Area Forecast, https://aspm.faa.gov/main/taf.asp

market data to generate two simple measures of market access: counts of the number of cities that can be reached from any originating airport with no stops, and with no more than one connection. I also use this to generate a measure of one-way fares by originating airport.[5] Unfortunately, I was unable to locate similar information on flight frequency going back this far, as this may be another attractive feature of a hub.

Primary data on city employment outcomes are derived from the County Business Patterns (CBP).[6] Data were obtained for each year from 1964 to 2012 for total employment and industry employment in a variety of sectors. In this study, I focus on overall outcomes, as well as air transportation, wholesale trade, hotels and lodging, and amusement and recreation. I also obtain the data for establishments by sector, and total payroll. I use Standard Industrial Classification (SIC) categories throughout the entire study period to classify employment.[7] Where necessary, data were converted from NAICS groups to SIC groups.[8][9] Finally, all county-level data was aggregated to the Census-Based Statistical Area (CBSA) level.

Data on population and personal income are obtained from the U.S. Bureau of Economic Analysis.[10] for each of the industries listed above, at the metropolitan area level.[11] I also obtain these data for earnings, earnings per worker, wages and salaries earned, wages and salaries per worker, personal income, and per-capita personal income.[12]

---

[5]I am grateful to Severin Borenstein for providing this data. These fares exclude first-class or other special coupons, an important limitation to bear in mind. For more details: https://sites.google.com/site/borenstein/airdata

[6]U.S. Census Bureau, Obtained from the National Historical Geographic Information System (NHGIS), www.nhgis.org..

[7]These industries correspond to the following SIC codes: 45 (Air Travel), 50-51 (Wholesale Trade), 71 (Hotels and Lodging), and 79 (Amusement & Recreation Services).

[8]SIC to NAICS conversions were accomplished using the fixed point equations provided by the U.S. Department of Housing and Urban Development: http://socds.huduser.org/CBPSE/note.htm

[9]Missing data was imputed using establishment counts and the midpoint for the number of employees at each establishment. Missing data affected substantially fewer than one percent of the data points in the analysis.

[10]Tables CA5 and CA5N, Regional Economic Accounts, Bureau of Economic Analysis, U.S. Department of Commerce: http://www.bea.gov/regional/

[11]Service industries were excluded, as numerous changes were made to the taxonomy of component industries in 2000.

[12]Census Based Statistical Areas, based on 2010 definitions, are the primary unit of observation in this analysis.

3.1 Methodology

As noted in Section 2, there are a variety of definitions of hub airports. In this study, I consider the consequences of an airline labeling an airport as their hub. To create the database of airline hubs, I culled airline web sites, annual reports, newspaper articles, aviation trade publications and other historical sources. As the baseline for the events affecting hub status, e.g. mergers, bankruptcies, and acquisitions, I use the list compiled by Airlines for America, the aviation industry trade group.[13] Relevant events were compiled into a timeline shown in Figure 1. The timing of resulting hub openings and closings is summarized in Table A.1.

3.1.1 Initial estimates: Panel FE/Difference-in-Differences

In the case of the panel difference-in-difference estimator, identification is based on the assumption that hub openings and closures were due to (plausibly exogenous) changes in the network structure resulting from industry activity - mergers, acquisitions, airline closures, airline openings, or an airline's desire to build market share. Hub downsizings that include reductions in traffic, but not a complete closure, are not included. I use both fixed effects regression as well as event-study methods to identify the effects of these airports on their cities. I run the following specifications:

$$Y_{it} = \alpha + \beta(H = 1) + Z_{it} + \gamma_i + \tau_t + \varepsilon_{it} \tag{1}$$

where β identifies the (log) change in the employment, payroll, population or aviation-related outcome of interest Y_{it}; γ_i is a city fixed effect and τ_t is a year fixed effect. The primary unit of observation is the CBSA. The preferred specification also incorporates linear city-specific time trends. The preferred specification is thus as follows:

$$Y_{it} = \alpha + \beta(H = 1) + Z_{it} + \gamma_i + \tau_t + \eta_i \cdot (time) + \varepsilon_{it} \tag{2}$$

where in this case $\eta_i \cdot (time)$ is the city-specific trend. Z_{it} is a vector of control variables that

[13] http://airlines.org/data/u-s-airline-mergers-and-acquisitions/

include controls for employment shares, whether the airport is a Southwest Airlines focus city, and whether the airport is a cargo hub for FedEx or UPS. Standard errors are clustered at the CBSA level. Note that in this case, identification comes only from the opening and closing effects experienced by airports that became hub airports at some time over the study period. However, the inclusion of non-hub airports in the specifications help improve precision of the estimates.

3.1.2 Short-Run Effects of Hub Openings and Closings: Synthetic Control Event-Time Difference-in-Differences

While the panel estimates in section 3.1.1 provide useful information on the value of hub airports to their respective cities, concerns related to endogeneity remain. For example, there could be simultaneous causality issues that even the inclusion of city-specific time trends may under-or-overcorrect for. For example, hubs are more likely to close in cities with less economic activity to begin with. Although one may argue that airlines choose where to open and close hubs based on competitive reasons or business realities, undoubtedly one of the inputs in those decisions is the current and expected future health of the local economy. As a result, conventional event-study analysis on hub opening and closing activity could still potentially be biased. Additionally, panel studies of this type incorporating fixed effects are notoriously susceptible to attenuation bias, leading to downward bias in the estimates. Both sets of concerns are problematic here, as in most cases the effects of hubs, at best, may be on the order of only a few percentage points.

To mitigate this concern, I turn to synthetic controls, which will allow for causal inference independent of these concerns. The use of synthetic controls was first proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010). This method allows for the extension of the traditional differences-in-differences framework by allowing treatment effects to vary over time. In my case, the synthetic control is constructed as the weighted average of CBSAs in the "donor pool" - that is, the set of control airports that never became hubs but nevertheless are included in the analysis. Under the identifying assumption that conditional on controls, a treated unit would have otherwise evolved as an estimated control unit does, the difference between the actual "treated" outcome and the synthetically constructed "control" outcome gives us the causal treatment effect of hub airport status on the desired outcome.

Suppose there is a sample of $C+1$ CBSAs, indexed by c, among which unit $c=1$ is the treated CBSA and $c=2$ to $c=C+1$ are potential controls. We also assume a balanced panel with a positive number of pre-intervention periods, T_0, as well as a positive number of post-intervention periods, T_1, with $T_0+T_1=T$. Let Y_{ct} represent the outcome of unit c at time t. For a given t (with $t \geq T_0$), the synthetic control estimator of airport's effect is given by the difference between the treatment and synthetic control at that period:

$$Y_{1t} - \sum_{c=2}^{C+1} w_c^* Y_{ct}$$

where: $\mathbf{W} = (w_2, ..., w_{C+1})^T$ is a $(C \times 1)$ vector of positive weights that sum to 1; $\mathbf{X}_1$ is a $(k \times 1)$ vector containing a set of pre-intervention characteristic values; and $\mathbf{X}$ is a $(k \times C)$ matrix collecting the values of the same variables for the CBSAs in the set of airport potential CBSAs.

The synthetic control algorithm chooses optimal weights $\mathbf{W}^*$ that minimizes the mean square prediction error (MSPE) given by

$$\text{MSPE} = \|X_1 - X_0 W\|_V = \sqrt{(X_1 - X_0 W)^T V (X_1 - X_0 W)},$$

where an optimal choice of variable weights $\mathbf{V}$ assigns weights to linear combinations of the variables in X_0 and X_1. In practice, I implement this estimation strategy using Abadie et al. (2011)'s `R` package `Synth`. Control vector X includes past outcomes of the predictor of interest, employment shares, a cubic in latitude and longitude as well as indicator variables for Census region to ensure that hub airports are matched with airports most similar to them. Historical information that played a role in airport location are also included, namely, whether a city was on an air mail route in 1938, and whether a city had a commercial or municipal airport in operation in 1926. This information helps the synthetic control estimator better identify candidates for the matching process, as well as identifying the optimal weights $\mathbf{W}^*$ for those matched airports.

This estimation method, which has quickly gained prominence in empirical microeconomics and political science, allows the estimation of causal effects in a wide variety of settings. The method, however, is not without some important drawbacks and caveats. For example, as noted by Doudchenko and Imbens (2016), difference-in-differences allows for a non-zero intercept corresponding to permanent differences; the synthetic control method applied here does not. Also, the constraint that the set of weights W must sum to one is also not trivial; a more flexible estimation method could yield somewhat different results. Athey and Imbens (2016) note that in cases where a unit may be on the extreme end of a distribution of units, allowing for a different set of weights could be more ideal. In practice, then, the synthetic control method may fail to perfectly estimate control units for hub airports on the upper end of the size distribution. However, the synthetic control estimator does an admirable job at producing counterfactual units that have a parallel trend in the vast majority of cases.

This is all that is required, then, to create a set of synthetic control units that can be used in place of control variables in an event-time difference-in-differences framework. After pooling the units, final estimation is given by the following:

$$Y_{it} = \alpha + \gamma_i + \tau_t + \sum_{k=j}^{5} \beta_k (H = 1) + \varepsilon_{it} \tag{3}$$

where $j = -5$ for hub opening events and $j = -3$ for hub closing events. As in all other analyses, standard errors are clustered at the CBSA level. An additional advantage of this estimator is that the synthetic units incorporate specific time trends, so additional controls for these are not necessary in the final estimation.

4 Results and Discussion

4.1 Baseline Model: Panel Diff-in-Diff Evidence

The panel regression analysis consists of two groups of airport hubs. The primary group consists of the entire set of 30 airports identified by the methodology in Section 3.1. The second is a subset of 21 airports designated "major hubs". These are simply hubs that were labeled as hubs by predecessor airlines which would eventually merge into one of the current legacy airlines (American, Delta, or United). Detailed airline genealogies used for this purpose are found in Figures A.1 through A.5 in the Appendix.

Table 1 summarizes the key findings at the airport level. For enplanements, specification (1) indicates that controlling only for CBSA and year fixed effects, hubs led to a 32 percent increase in passenger traffic. Controlling for the presence of a Southwest Airlines focus city or a UPS/FedEx cargo hub reduces this to 25 percent. Adding CBSA-specific trends leads to an ultimate traffic increase attributable to the hub of 12 percent. Data limitations do not allow for this passenger traffic to be separated into connecting and origin/destination passengers, but it is assumed some portion of that traffic will spend time in the respective hub airport city. Turning to other outcomes of interest, flights (operations) increase similarly to passenger traffic. Employment in the air travel sector rises proportionately with passenger traffic with an estimated 17 percent increase after all controls, and hotels and lodging employment increases in the city as well, with an increase of approximately 5 percent. In the "major hubs" group, there is also some evidence of an increase in wholesale employment attributable to the hub.

[TABLE 1 ABOUT HERE]

Table 2 summarizes key effects that hubs have on cities. Note that in general, after accounting for all controls, the effect of hubs on all aggregate output measures such as personal income, total payroll, employment levels and establishment counts are estimated to be approximately zero. However, in most cases the coefficients estimated are not zero across all specifications. It appears that the city-specific trends may be overfitting the model. This induces a downward bias in these results. To check whether these results are valid or are biased due to endogeneity, I turn to the synthetic control event study estimation procedure detailed in Section 3.1.2.

[TABLE 2 ABOUT HERE]

Table 3 summarizes key outcomes for wages and related outcomes at the individual worker level. Again, estimated effects tend to zero after all controls are included. Additionally, as before, this is not consistent across all specifications. There is some evidence that the measures considered, per-capita personal income, payroll per worker, earnings per worker, and wages and salary per worker, may increase as a result of the hub airports. Again, I turn to the synthetic control event study to substantiate this result.

[TABLE 3 ABOUT HERE]

4.2 Synthetic Control Event Study

To better understand the findings presented in Section 4.1, I combine synthetic control estimation with an event-study design to separately estimate the effects of hub openings and hub closings on the local economy. In each specification, I control for five years prior to and after hub opening for hub openings, and three years prior and five years after for hub closings.[14] Each specification includes city and year fixed effects. Additionally, by nature, the synthetic control estimator accounts for case-specific time trends. This replaces the need to separately add city-specific linear time trends. After estimating a synthetic control unit for each case, I normalize the dates of the hub opening or closing events such that all estimates are relative to $t = -1$; that is, one year prior to the hub opening or closing. This set was restricted to the set of hubs that opened and remained open for at least six years.

[14]Adding more than three years of data to estimate hub closings induced confounding factors that led to bias and poorly estimated pre-treatment outcomes.

Results are presented in both tabular and graphical form. Table 4 presents outcomes for passenger traffic, flight traffic, air travel employment, hotel employment, wholesale trade and amusements and recreation. The table also presents outcomes for two types of synthetic control estimations - one using only the past values of the outcomes of interest, and the other using geographic and historical airport location factors to fine-tune the matches. Overall, estimates indicate that the opening of a hub increases enplanements, operations, and air travel employment by similar amounts, roughly 30 to 35 percent. Hotel employment appears to increase as well (though this estimate is not precise when all factors are used to make the matches). Hub closings seem to have a negative effect on hotel employment, particularly when all hubs are considered, implying that those losses are likely incurred when smaller, more marginal, hubs close. However, none of the results are statistically significant. Hub openings appear to have little effect on wholesale trade employment or amusements and recreation employment. However, hub closings reduce wholesale trade employment by 4 percent in major hubs. Additionally, they reduce employment in the amusements and recreation sector by 5 to 9 percent. Figure 2 shows enplanement, operations, air travel and hotel outcomes graphically for hub openings. Appendix figure A.6 show the same for hub closings. Figure A.9 shows outcomes for wholesale trade and amusements and recreation.

[TABLE 4 / FIGURE 2 ABOUT HERE]

Table 5 and Figure 3 show outcomes for city economic output measures. These accrue mostly due to hub openings. Across all specifications, it seems the opening of a hub increases personal income, total payroll, total earnings, and total wage and salary income. Estimates of the size of this effect range from 1.7 percent to 4.3 percent. Generally, these estimates are between those estimated for the least restrictive panel model and the most restrictive. This is reassuring, and suggests the synthetic control estimator is successfully reducing endogeneity in these estimates. Effects appear to be slightly more pronounced for major airline hubs. It is unclear from the hub closing estimates whether closing hubs leads to a reduction in these values. As far as employment and establishment counts, the evidence is mixed. One is unable to conclude from this exercise that hubs lead to employment and/or establishment growth; however, these results certainly do not prove that employment growth is zero, either. Appendix Figure A.7 provides graphical outcomes for hub closures.

[TABLE 5 / FIGURE 3 ABOUT HERE]

Finally, I consider wage outcomes presented in Table 6 and Figure 4. Across virtually all measures, it appears that the presence of airport hubs increase per-capita personal income, payroll per worker, earnings per worker, and wages and salaries per worker, by 1.1 to 1.8 percent. These effects accrue from hub openings, but do not seem to decrease with hub closings. This is consistent with the Roback (1982) model indicating that the hub airport may enhance firm productivity, and can potentially be considered (in the absence of data on rents, of course) to be a productive amenity. Appendix Figure A.8 provides graphical output for hub closings and wages.

[TABLE 6 / FIGURE 4 ABOUT HERE]

Taken together, these results indicate hub airports do have an effect on their respective cities. These airports help support industries such as wholesale trade and amusements and recreation, lead to increases in output measures such as personal income and earnings, and lead to higher wages for employees as well. What might be the mechanism for such effects? I consider the number of destinations reachable non-stop and with up to one connection from these airports. If it is simply market access driving these outcomes, then one might expect these to increase. However, a glance at Figure 5 shows no conclusive evidence for this hypothesis. Most likely, the mechanism has to do with the quality of service as measured by the number of frequencies on popular routes, as business travelers value the convenience of multiple flights per day greatly. This quality infrastructure essentially facilitates business travel, and thus, the growth of and productivity of firms in general in cities with well-performing hubs.

5 Conclusion

This paper considers the effects of airline hub airports on a city's economy. Using a panel dataset of yearly outcomes for cities with airports, combined with data for when an airport was labeled by an air carrier as a hub, I considered the effects of hub openings and hub closings. To accomplish this in the presence of possible endogeneity, I turned to a synthetic control event study design which allowed for the estimation of causal outcomes. I find that hub airports increase per-worker wages by 1.1 to 1.8 percent, and economic output measures such as personal income and total payroll by 1.7 to 4.3 percent. These findings mostly arise from a hub's opening, rather than its closing. These findings support the hypothesis of airline hubs functioning as a productive amenity, providing high-quality infrastructure that supports business activity.

References

Abadie, Alberto, Alexis Diamond, and Jens Hainmueller, "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of Californias Tobacco Control Program," *Journal of the American Statistical Association*, June 2010, *105* (490), 493–505.

_ , _ , and _ , "Synth: An R Package for Synthetic Control Methods in Comparative Case Studies," *Journal of Statistical Software*, June 2011, *42* (13), 1–17.

_ , _ , and _ , "Comparative Politics and the Synthetic Control Method," *American Journal of Political Science*, 2015, *59* (2), 495–510.

_ and Guido W. Imbens, "Large Sample Properties of Matching Estimators for Average Treatment Effects," *Econometrica*, 2006, *74* (1), 235–267.

_ and Javier Gardeazabal, "The Economic Costs of Conflict: A Case Study of the Basque Country," *American Economic Review*, March 2003, *93* (1), 113–132.

Aguirregabiria, Victor and Chun-Yu Ho, "A Dynamic Oligopoly Game of the US Airline Industry: Estimation and Policy Experiments," *Journal of Econometrics*, September 2011, *168*, 156–173.

Athey, Susan and Guido Imbens, "The State of Applied Econometrics - Causality and Policy Evaluation," July 2016.

Baker, Douglas, Rico Merkert, and Md. Kamruzzaman, "Regional aviation and economic growth: cointegration and causality analysis in Australia," *Journal of Transport Geography*, February 2015, *43*, 140–150.

Blonigen, Bruce A. and Anca D. Cristea, "Air service and urban growth: Evidence from a quasi-natural policy experiment," *Journal of Urban Economics*, March 2015, *86*, 128–146.

Borenstein, Severin, "Airline Mergers, Airport Dominance, and Market Power," *American Economic Review*, May 1990, *80* (2), 400–404.

— , "The Evolution of US Airline Competition - Borenstein," *Journal of Economic Perspectives*, 1992, *6* (2), 45–73.

Bowen, John, *The economic geography of air transportation: space, time, and the freedom of the sky* number 81. In 'Routledge studies in the modern world economy.', London ; New York: Routledge, 2010.

Breyer, Stephen, *Airline Deregulation, Revisited* January 2011.

Burghouwt, Guillaume, *Airline Network Development in Europe and Its Implications for Airport Planning* Ashgate Studies in Aviation Economics and Management, Ashgate Pub Co, March 2007.

Button, Kenneth, "Debunking some common myths about airport hubs," *Journal of Air Transport Management*, May 2002, *8* (3), 177–188.

— and Somik Lall, "The Economics of Being an Airport Hub City," *Research in Transportation Economics*, 1999, *5*, 75–105.

— , — , Roger Stough, and Mark Trice, "High-technology employment and hub airports," *Journal of Air Transport Management*, January 1999, *5* (1), 53–59.

— , Soogwan Doh, and Junyang Yuan, "The role of small airports in economic development," *Journal of Airport Management*, January 2010, *4* (2), 125–136.

Campante, Filipe R. and David Yanagizawa-Drott, "Long-Range Growth: Economic Development in the Global Network of Air Links," SSRN Scholarly Paper ID 2877690, Social Science Research Network, Rochester, NY November 2016.

Chatterji, Aaron, Edward L. Glaeser, and William R. Kerr, "Clusters of Entrepreneurship and Innovation," Working Paper 19013, National Bureau of Economic Research May 2013.

Cohen, Jeffrey P., Morrison Paul, and Catherine J, "Airport Infrastructure Spillovers in a Network System," SSRN Scholarly Paper ID 2819582, Social Science Research Network, Rochester, NY 2003.

Conventz, "Hub Cities in the Knowledge Economy."

Cooper, Ronald, "Airports and Economic Development: An Overview," in "Transportation Research Record" 1990.

Costa, Tiago F. G., Gui Lohmann, and Alessandro V. M. Oliveira, "A model to identify airport hubs and their importance to tourism in Brazil," *Research in Transportation Economics*, 2010, *26* (1), 3–11.

Costa, Tiago F.G., Gui Lohmann, and Alessandro V.M. Oliveira, "A Model to Identify Airport Hubs and Their Importance to Tourism in Brazil," *Research in Transportation Economics*, 2010, *26*, 3–10.

Debbage, Keith G. and Dawn Delk, "The geography of air passenger volume and local employment patterns by US metropolitan core area: 1973-1996," *Journal of Air Transport Management*, May 2001, *7* (3), 159–167.

Doudchenko, Nikolay and Guido W. Imbens, "Balancing, Regression, Difference-In-Differences and Synthetic Control Methods: A Synthesis," Working Paper 22791, National Bureau of Economic Research October 2016. DOI: 10.3386/w22791.

Eller, Richard E., *Piedmont Airlines: A Complete History, 1948 - 1989*, Jefferson, North Carolina: McFarland & Company, Inc., Publishers, 2008.

Gillen, David, "The Evolution of Networks with Changes in Industry Structure and Strategy: Connectivity, Hub-and-Spoke and Alliances," *Research in Transportation Economics*, 2005, *13*, 49–73.

Giroud, Xavier, "Proximity and Investment: Evidence from Plant-Level Data," *The Quarterly Journal of Economics*, May 2013, *128* (2), 861–915.

Gordon, Douglas E., *Green Schools as High Performance Learning Facilities*, National Clearinghouse for Educational Facilities, September 2010.

Grant, Elaine X., "TWA - Death Of A Legend," *St. Louis Magazine*, July 2006.

Harty, Jack, *Weekend Rewind: A Look Back Into The Archive of Airchives Vault Of Aviation History* February 2014.

Hendricks, Ken, Michele Piccione, and Guogu Tan, "Entry and Exit in Hub-Spoke Networks," *The RAND Journal of Economics*, 1997, *28* (2), 291 – 303.

Irwin, Michael D. and John D. Kasarda, "Air Passenger Linkages and Employment Growth in U.S. Metropolitan Areas," *American Sociological Review*, August 1991, *56* (4), 524–537.

Jacobs Engineering Group, *CVG 2035 Master Plan*, Cincinnati/Northern Kentucky International Airport, June 2013.

Jaillet, Patrick, Gao Song, and Gang Yu, *Airline Network Design and Hub Location Problems* 1996.

Jr., Fred L. Smith and Braden Cox, *Airline Deregulation* 2008.

Kanafani, Adib and Atef A. Ghobrial, "Airline Hubbing - Some Implications For Airport Economics," *Transportation Research*, April 1984, *19A* (1), 15–27.

Kasarda, John D, *Aerotropolis: The Way We'll Live Next*, 1st ed ed., New York: Farrar, Straus and Giroux, 2011.

Lee, Darin and Maria Jose Luengo-Prado, "The Impact of Passenger Mix on Reported Hub Premiums in the U.S. Airline Industry," *Southern Economic Journal*, 2005, *72* (2).

LeFors, Michael, "The Role of Air Accessibility in Urban Development," 2014.

Lehman, William, *US Airways: A Heritage Story*.

Logan, Gabi, *The Effects of 9/11 on the Airline Industry*.

McCarthy, Patrick, "US Airport Costs and Production Technology A Translog Cost Function Analysis," *Journal of Transport Economics and Policy (JTEP)*, September 2014, *48* (3), 427–447.

McGraw-Hill Construction, "New and Retrofit Green Schools: The influence of a Green School on Its Occupants," Technical Report 2012.

McGraw, Marquise, "Perhaps the Sky's the Limit: Airports and Employment in Local Economies," 2016.

McLaughlin, David and Andrew Zajac, *American Airlines - US Airways Merger Settlement Approved* April 2014.

Mecham, Michael, "Natural Selection," *Aviation Week & Space Technology*, November 2004, *161* (19), 48–50.

Mosbah, Simon and Megan S. Ryerson, "Can US Metropolitan Areas Use Large Commercial Airports as Tools to Bolster Regional Economic Growth?," *CPL bibliography*, June 2016, *31* (3), 317–333.

Neal, Zachary, "Creative Employment and Jet Set Cities: Disentangling Causal Effects," *Urban Studies*, January 2012, p. 0042098011431282.

_ , "The devil is in the details: Differences in air traffic networks by scale, species, and season," *Social Networks*, July 2014, *38*, 63–73.

Neal, Zachary P, "The Causal Relationship Between Employment and Business Networks in U.s. Cities," *Journal of Urban Affairs*, May 2011, *33* (2), 167–184.

_ , "Types of Hub Cities and their Effects on Urban Creative Economies," 2014.

Office, U.S. Government Accountability, "Airline Competition: Fare and Service Changes at St. Louis Since the TWA-Ozark Merger," Briefing Report GAO/RCED-88-217BR, U.S. General Accounting Office, Washington DC September 1988.

_ , "Fares and Concentration at Small-CIty Airports," Report to Congressional Requesters GAO/RCED-91-51, US General Accounting Office January 1991.

_ , "Trends in Airfares at Airports in Small and Medium Sized Communities," Report to Congressional Requesters GAO9113 1991.

_ , "Higher Fares and Less Competition Continue at Concentrated Aiports," Report to the Chairman and Ranking Minority Member, Committee on Commerce, Science, and Transportation, US Senate GAO/RCED-93-171, US General Accounting Office July 1993.

O'Kelly, M. E., "A Geographer's Analysis of Hub-and-Spoke Networks," *Journal of Transport Geography*, 1998, *6* (3), 171–186.

_ **and D. L. Bryan**, "Hub Location with Flow Economies of Scale," *TRanspn Res. -B*, 1996, *32* (8), 605–616.

Percoco, Marco, "Airport Activity and Local Development: Evidence from Italy," *Urban Studies*, October 2010, *47* (11), 2427–2443.

Pilcher, James, *Why CVG Lost Half of All Flights* May 2010.

Redding, Stephen, Daniel M. Sturm, and Nikolaus Wolf, "Web-Based Technical Appendix for History and Industry Location: Evidence from German Airports," 2010.

Redding, Stephen J., Daniel M. Sturm, and Nikolaus Wolf, "History and Industry Location: Evidence from German Airports," *The Review of Economics and Statistics*, 2011, *93* (3), 814–831.

Roback, Jennifer, "Wages, Rents, and the Quality of Life," *Journal of Political Economy*, December 1982, *90* (6), 1257–1278. ArticleType: research-article / Full publication date: Dec., 1982 / Copyright Â© 1982 The University of Chicago Press.

Salpukas, Agis, "USAir Discovers There Is Life After a Messy Merger," *New York Times*, January 1992.

Shalett, Sidney M., "War Skills Ample in Cincinnati Area: Wright Sets Record in Cyclone Engines Such as Reported in Planes Over Tokyo," *New York Times*, May 1942.

Shaw, Shih-Lung, "Hub structures of major US passenger airlines," *Journal of Transport Geography*, March 1993, *1* (1), 47–58.

_ **and Russell L Ivy**, "Airline mergers and their effect on network structure," *Journal of Transport Geography*, December 1994, *2* (4), 234–246.

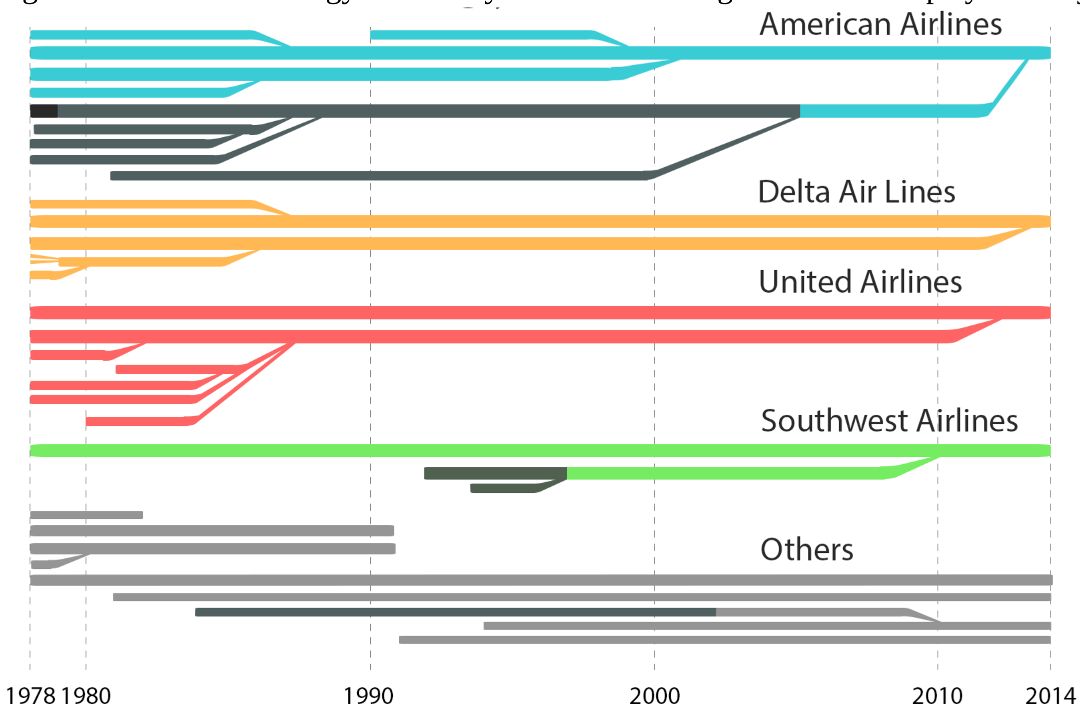
Sheard, Nicholas, "The Effect of Air Transport on the Production of Goods and Services.," 2012.

_ , "Airports and urban sectoral employment," *Journal of Urban Economics*, March 2014, *80*, 133–152.

_ , "Airport Improvements and Urban Growth," *AIX-Marseille Working Paper*, February 2015.

Sumner, Ryan L., "Survey and Research Report on the W.P.A. Douglas Airport Hangar," Survey, Levine Museum of the New South, Charlotte, NC May 2002.

Figure 1: Airline Genealogy: Summary Timeline of Mergers and Bankruptcy Activity



Individual genealogies for each airline group are provided in figures given in the Appendix. Shading corresponds to the eventual airline individual predecessor airlines would merge into.

Table 1: Results - Panel Regression - Airport Outcomes by Sample Group

	All Hubs ($n = 30$)				"Major" Hubs ($n = 21$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Enplanements	0.317***	0.252***	0.139**	0.122**	0.339***	0.281**	0.153*	0.149*
	(0.078)	(0.093)	(0.061)	(0.058)	(0.092)	(0.110)	(0.079)	(0.076)
n	2670	2590	2670	2590	2720	2639	2720	2639
Operations	0.292***	0.238***	0.140***	0.131***	0.367***	0.317***	0.188***	0.181***
	(0.067)	(0.077)	(0.051)	(0.047)	(0.065)	(0.078)	(0.057)	(0.052)
n	2670	2590	2670	2590	2720	2639	2720	2639
Air Travel Employment	0.238***	0.174**	0.228***	0.174***	0.235**	0.157	0.198**	0.157**
	(0.085)	(0.083)	(0.066)	(0.056)	(0.100)	(0.106)	(0.077)	(0.067)
n	2750	2670	2750	2670	2800	2719	2800	2719
Hotel Employment	0.096***	0.090**	0.070**	0.055**	0.109**	0.100**	0.079**	0.058*
	(0.036)	(0.037)	(0.027)	(0.025)	(0.044)	(0.045)	(0.034)	(0.032)
n	2750	2670	2750	2670	2800	2719	2800	2719
Wholesale Trade Employment	0.043	0.015	0.029	-0.006	0.062*	0.031	0.049***	0.010
	(0.032)	(0.024)	(0.018)	(0.010)	(0.036)	(0.026)	(0.018)	(0.008)
n	2750	2670	2750	2670	2800	2719	2800	2719
Amusements and Recreation Employment	-0.013	0.003	-0.025	-0.018	-0.045	-0.030	-0.025	-0.006
	(0.031)	(0.028)	(0.024)	(0.024)	(0.042)	(0.038)	(0.022)	(0.021)
n	2750	2670	2750	2670	2800	2719	2800	2719
CBSA/Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Share/SWA/Cargo Controls	N	Y	N	Y	N	Y	N	Y
CBSA-Specific Trend	N	N	Y	Y	N	N	Y	Y

Note on all columns: Dependent variable is a dummy variable for whether an airline has labeled an airport as a hub in a particular year. Each coefficient is from a fixed-effects regression on a binary variable indicating presence of a hub at a particular airport in a particular year, which includes airport (CBSA) fixed effects, year fixed effects, and flexible linear city-specific trends. Column (1) includes CBSA and year FE. Column (2) adds employment share controls and panel variables for the presence of Southwest airlines focus city and/or a major cargo hub. Columns (3) and (4) add city-specific linear trends to (1) and (2), respectively. Columns (5) through (8), respectively, provide estimates based on "Major" hubs, which are those hubs with an airline that would eventually be absorbed into a major legacy airline family. All models include "airport potential" airports which do not affect estimation of the coefficient on the dependent variable, but may improve efficiency. Standard errors in parentheses. All standard errors clustered at the CBSA level. $*p < 0.1, **p < 0.05, ***p < 0.01$

Table 2: Results - Panel Regression - Economic Output Outcomes by Sample Group

	All Hubs ($n = 30$)				"Major" Hubs ($n = 21$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Personal Income	0.039	0.025	0.012	-0.004	0.049	0.044*	0.021	0.008
	(0.027)	(0.024)	(0.013)	(0.009)	(0.033)	(0.025)	(0.014)	(0.008)
n	2715	2636	2715	2636	2765	2685	2765	2685
Total Payroll	0.054*	0.030	0.012	-0.011	0.052	0.037	0.024	0.007
	(0.028)	(0.024)	(0.016)	(0.011)	(0.035)	(0.027)	(0.017)	(0.010)
n	2747	2667	2747	2667	2797	2716	2797	2716
Total Earnings	0.050*	0.029	0.012	-0.010	0.061*	0.048*	0.021	0.004
	(0.028)	(0.024)	(0.015)	(0.010)	(0.035)	(0.026)	(0.016)	(0.010)
n	2715	2636	2715	2636	2765	2685	2765	2685
Total Wage and Salary Income	0.049*	0.026	0.009	-0.011	0.058*	0.045*	0.019	0.005
	(0.027)	(0.024)	(0.014)	(0.011)	(0.034)	(0.025)	(0.015)	(0.010)
	2715	2636	2715	2636	2765	2685	2765	2685
Total Employment	0.023	0.009	0.010	-0.005	0.027	0.020	0.021	0.010
	(0.028)	(0.022)	(0.012)	(0.009)	(0.033)	(0.024)	(0.013)	(0.008)
n	2750	2670	2750	2670	2800	2719	2800	2719
Total Establishments	0.020	0.012	0.005	-0.003	0.029	0.022	0.013*	0.005
	(0.023)	(0.021)	(0.008)	(0.008)	(0.026)	(0.020)	(0.007)	(0.005)
n	2750	2670	2750	2670	2800	2719	2800	2719
CBSA/Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Share/SWA/Cargo Controls	N	Y	N	Y	N	Y	N	Y
CBSA-Specific Trend	N	N	Y	Y	N	N	Y	Y

Note on all columns: Dependent variable is a dummy variable for whether an airline has labeled an airport as a hub in a particular year. Each coefficient is from a fixed-effects regression on a binary variable indicating presence of a hub at a particular airport in a particular year, which includes airport (CBSA) fixed effects, year fixed effects, and flexible linear city-specific trends. Column (1) includes CBSA and year FE. Column (2) adds employment share controls and panel variables for the presence of Southwest airlines focus city and/or a major cargo hub. Columns (3) and (4) add city-specific linear trends to (1) and (2), respectively. Columns (5) through (8), respectively, provide estimates based on “Major” hubs, which are those hubs with an airline that would eventually be absorbed into a major legacy airline family. All models include “airport potential” airports which do not affect estimation of the coefficient on the dependent variable, but may improve efficiency. Standard errors in parentheses. All standard errors clustered at the CBSA level. $*p < 0.1, **p < 0.05, ***p < 0.01$

Table 3: Results - Panel Regression - Wage Outcomes by Sample Group

	All Hubs ($n = 30$)				"Major" Hubs ($n = 21$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Per-Capita Personal Income	0.019*	0.011	0.013	0.001	0.019*	0.011	0.017	0.004
	(0.010)	(0.009)	(0.011)	(0.008)	(0.010)	(0.010)	(0.011)	(0.008)
n	2715	2636	2715	2636	2765	2685	2765	2685
Payroll Per Worker	0.033***	0.023*	0.002	-0.006	0.025**	0.017	0.004	-0.003
	(0.011)	(0.011)	(0.007)	(0.006)	(0.012)	(0.013)	(0.007)	(0.006)
n	2747	2667	2747	2667	2797	2716	2797	2716
Earnings Per Worker	0.024**	0.014	0.004	-0.006	0.020*	0.011	0.007	-0.001
	(0.009)	(0.009)	(0.008)	(0.006)	(0.011)	(0.012)	(0.008)	(0.007)
n	2715	2636	2715	2636	2765	2685	2765	2685
Wages and Salary Per Worker	0.023***	0.012	0.001	-0.007	0.017	0.008	0.005	-0.001
	(0.008)	(0.009)	(0.008)	(0.006)	(0.010)	(0.012)	(0.008)	(0.007)
n	2715	2636	2715	2636	2765	2685	2765	2685
CBSA/Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Share/SWA/Cargo Controls	N	Y	N	Y	N	Y	N	Y
CBSA-Specific Trend	N	N	Y	Y	N	N	Y	Y

Note on all columns: Dependent variable is a dummy variable for whether an airline has labeled an airport as a hub in a particular year. Each coefficient is from a fixed-effects regression on a binary variable indicating presence of a hub at a particular airport in a particular year, which includes airport (CBSA) fixed effects, year fixed effects, and flexible linear city-specific trends. Column (1) includes CBSA and year FE. Column (2) adds employment share controls and panel variables for the presence of Southwest airlines focus city and/or a major cargo hub. Columns (3) and (4) add city-specific linear trends to (1) and (2), respectively. Columns (5) through (8), respectively, provide estimates based on “Major” hubs, which are those hubs with an airline that would eventually be absorbed into a major legacy airline family. All models include “airport potential” airports which do not affect estimation of the coefficient on the dependent variable, but may improve efficiency. Standard errors in parentheses. All standard errors clustered at the CBSA level. $*p < 0.1, **p < 0.05, ***p < 0.01$

Table 4: Results - Synthetic Control Event Study - Airport Outcomes by Sample Group

	Hub Opening				Hub Closing			
	All Hubs		Major Hubs		All Hubs		Major Hubs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Enplanements	0.266***	0.299***	0.300***	0.336***	-0.332***	-0.256**	-0.395**	-0.260*
	(0.057)	(0.062)	(0.063)	(0.075)	(0.099)	(0.096)	(0.115)	(0.128)
n	21	19	17	15	12	12	8	8
Operations	0.299***	0.263***	0.397***	0.357***	-0.210**	-0.291**	-0.220*	-0.257*
	(0.074)	(0.063)	(0.061)	(0.054)	(0.084)	(0.092)	(0.101)	(0.120)
n	21	20	17	16	12	9	8	6
Air Travel Employment	0.310***	0.243***	0.372***	0.315***	-0.092	-0.129	-0.028	0.004
	(0.085)	(0.072)	(0.102)	(0.082)	(0.125)	(0.118)	(0.112)	(0.077)
n	27	26	21	20	14	11	10	7
Hotel Employment	0.093***	0.053	0.100**	0.065	-0.049	-0.056	-0.079	-0.051
	(0.030)	(0.034)	(0.036)	(0.041)	(0.064)	(0.061)	(0.072)	(0.071)
n	26	23	21	19	13	13	10	10
Wholesale Trade Employment	0.012	0.014	0.010	0.019	-0.009	0.002	-0.046**	-0.040**
	(0.015)	(0.016)	(0.017)	(0.021)	(0.045)	(0.048)	(0.015)	(0.016)
n	27	26	21	20	14	13	10	9
Amusements and Recreation Employment	-0.034	-0.048	-0.013	-0.017	-0.109**	-0.087**	-0.091**	-0.051*
	(0.040)	(0.035)	(0.047)	(0.037)	(0.036)	(0.032)	(0.033)	(0.024)
n	27	25	21	20	14	14	10	10
Full Set of Emp. Share/Location Controls	N	Y	N	Y	N	Y	N	Y

Note on all columns: Dependent variable is a dummy variable for whether an airline has labeled an airport as a hub in a particular year. Each coefficient is from an event-time difference-in-difference regression specification run on treated and synthetically constructed control units. Event study estimates presented here include controls for pre-treatment trends. In some cases, the synthetic control units were constructed solely based on the past history of the outcome variable of interest - these are the odd-numbered specifications presented above. In other cases, these were constructed using a full set of employment shares, latitude/longitude, Census region binary variables, and variables that predict early historical airport location - these are the even-numbered specifications above. Columns (1) - (4) present outcomes for hub openings, while Columns (5) - (8) present outcomes for hub closings. Columns (3), (4), (7) and (8) provide estimates based on “Major” hubs, which are those hubs with an airline that would eventually be absorbed into a major legacy airline family. All models include “airport potential” airports which do not affect estimation of the coefficient on the dependent variable, but may improve efficiency. Standard errors in parentheses. All standard errors clustered at the CBSA level. $*p < 0.1, **p < 0.05, ***p < 0.01$

Table 5: Results - Synthetic Control Event Study - Economic Output Outcomes by Sample Group

	Hub Opening				Hub Closing			
	All Hubs		Major Hubs		All Hubs		Major Hubs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Personal Income	0.025**	0.017*	0.027**	0.021*	-0.001	0.013	-0.027	0.004
	(0.010)	(0.009)	(0.012)	(0.011)	(0.016)	(0.012)	(0.016)	(0.015)
n	26	26	20	20	14	14	10	10
Total Payroll	0.043***	0.036***	0.049***	0.043***	0.020	0.003	-0.002	-0.009
	(0.014)	(0.009)	(0.016)	(0.012)	(0.019)	(0.015)	(0.022)	(0.017)
n	25	25	19	19	14	14	10	10
Total Earnings	0.034***	0.019*	0.037***	0.022*	0.007	0.003	-0.015	-0.014
	(0.011)	(0.010)	(0.013)	(0.011)	(0.016)	(0.015)	(0.017)	(0.018)
n	26	26	20	20	14	11	10	7
Total Wage and Salary Income	0.033***	0.018	0.038**	0.023*	0.006	-0.002	-0.019	-0.011
	(0.011)	(0.010)	(0.013)	(0.013)	(0.016)	(0.014)	(0.015)	(0.018)
n	26	24	20	18	14	13	10	9
Total Employment	0.034***	0.009	0.038**	0.013	0.011	0.007	-0.016	-0.003
	(0.012)	(0.011)	(0.014)	(0.013)	(0.017)	(0.010)	(0.015)	(0.011)
n	27	27	21	21	14	14	10	10
Total Establishments	0.019*	0.007	0.022*	0.008	0.023	0.014	0.004	0.000
	(0.009)	(0.008)	(0.011)	(0.010)	(0.014)	(0.011)	(0.016)	(0.014)
n	27	26	21	20	14	13	10	9
Full Set of Emp. Share/Location Controls	N	Y	N	Y	N	Y	N	Y

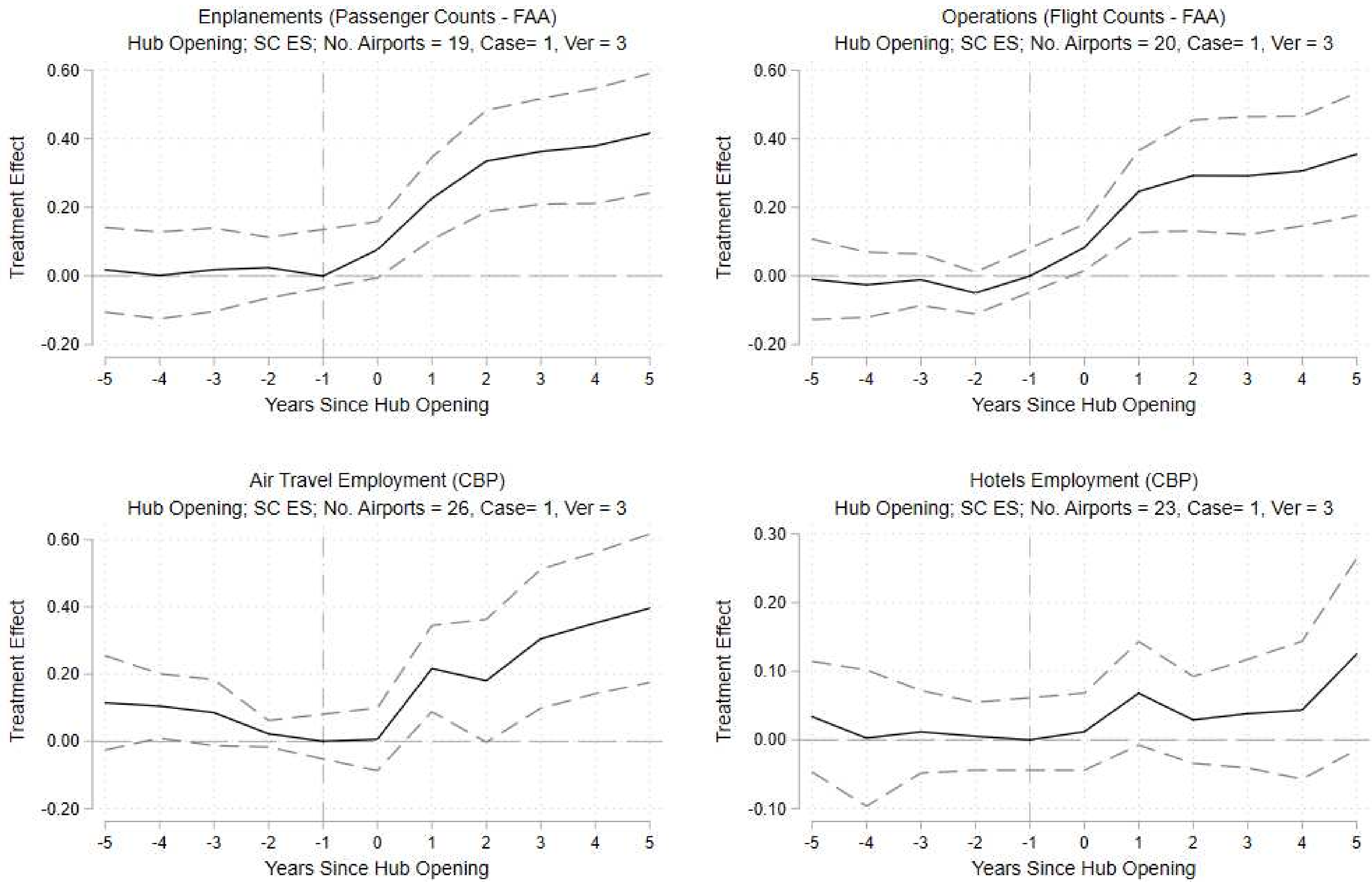
Note on all columns: Dependent variable is a dummy variable for whether an airline has labeled an airport as a hub in a particular year. Each coefficient is from an event-time difference-in-difference regression specification run on treated and synthetically constructed control units. Event study estimates presented here include controls for pre-treatment trends. In some cases, the synthetic control units were constructed solely based on the past history of the outcome variable of interest - these are the odd-numbered specifications presented above. In other cases, these were constructed using a full set of employment shares, latitude/longitude, Census region binary variables, and variables that predict early historical airport location - these are the even-numbered specifications above. Columns (1) - (4) present outcomes for hub openings, while Columns (5) - (8) present outcomes for hub closings. Columns (3), (4), (7) and (8) provide estimates based on “Major” hubs, which are those hubs with an airline that would eventually be absorbed into a major legacy airline family. All models include “airport potential” airports which do not affect estimation of the coefficient on the dependent variable, but may improve efficiency. Standard errors in parentheses. All standard errors clustered at the CBSA level. $*p < 0.1, **p < 0.05, ***p < 0.01$

Table 6: Results - Synthetic Control Event Study - Wage Outcomes by Sample Group

	Hub Opening				Hub Closing			
	All Hubs		Major Hubs		All Hubs		Major Hubs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Per-Capita Personal Income	0.023***	0.012***	0.031***	0.015***	-0.019	-0.012	-0.024	-0.015
	(0.007)	(0.004)	(0.009)	(0.004)	(0.014)	(0.010)	(0.018)	(0.013)
n	26	26	20	20	14	14	10	10
Payroll Per Worker	0.020***	0.016***	0.027***	0.018***	-0.004	-0.001	-0.010	-0.004
	(0.006)	(0.004)	(0.006)	(0.004)	(0.008)	(0.007)	(0.008)	(0.008)
n	25	25	19	19	14	14	10	10
Earnings Per Worker	0.030***	0.015***	0.035***	0.014***	-0.004	0.001	-0.007	0.000
	(0.006)	(0.004)	(0.008)	(0.004)	(0.009)	(0.008)	(0.010)	(0.010)
n	26	26	20	20	14	14	10	10
Wages and Salaries Per Worker	0.029***	0.011**	0.036***	0.011	-0.004	-0.003	-0.008	-0.006
	(0.006)	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
n	26	24	20	18	14	14	10	10
Full Set of Emp. Share/Location Controls	N	Y	N	Y	N	Y	N	Y

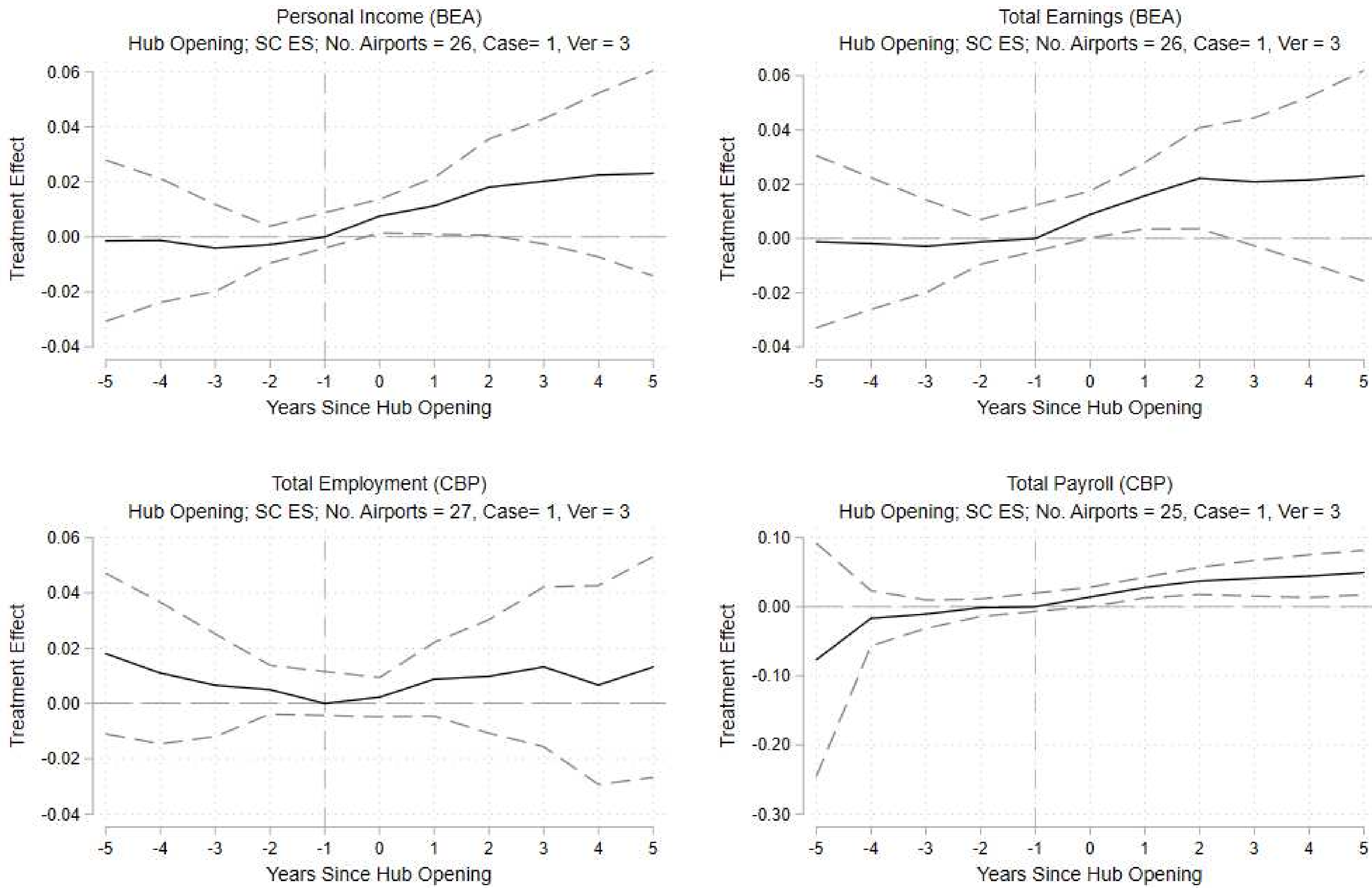
Note on all columns: Dependent variable is a dummy variable for whether an airline has labeled an airport as a hub in a particular year. Each coefficient is from an event-time difference-in-difference regression specification run on treated and synthetically constructed control units. Event study estimates presented here include controls for pre-treatment trends. In some cases, the synthetic control units were constructed solely based on the past history of the outcome variable of interest - these are the odd-numbered specifications presented above. In other cases, these were constructed using a full set of employment shares, latitude/longitude, Census region binary variables, and variables that predict early historical airport location - these are the even-numbered specifications above. Columns (1) - (4) present outcomes for hub openings, while Columns (5) - (8) present outcomes for hub closings. Columns (3), (4), (7) and (8) provide estimates based on “Major” hubs, which are those hubs with an airline that would eventually be absorbed into a major legacy airline family. All models include “airport potential” airports which do not affect estimation of the coefficient on the dependent variable, but may improve efficiency. Standard errors in parentheses. All standard errors clustered at the CBSA level. $*p < 0.1, **p < 0.05, ***p < 0.01$

Figure 2: Synthetic Control Event Study - Hub Openings - Air Travel Sector Outcomes



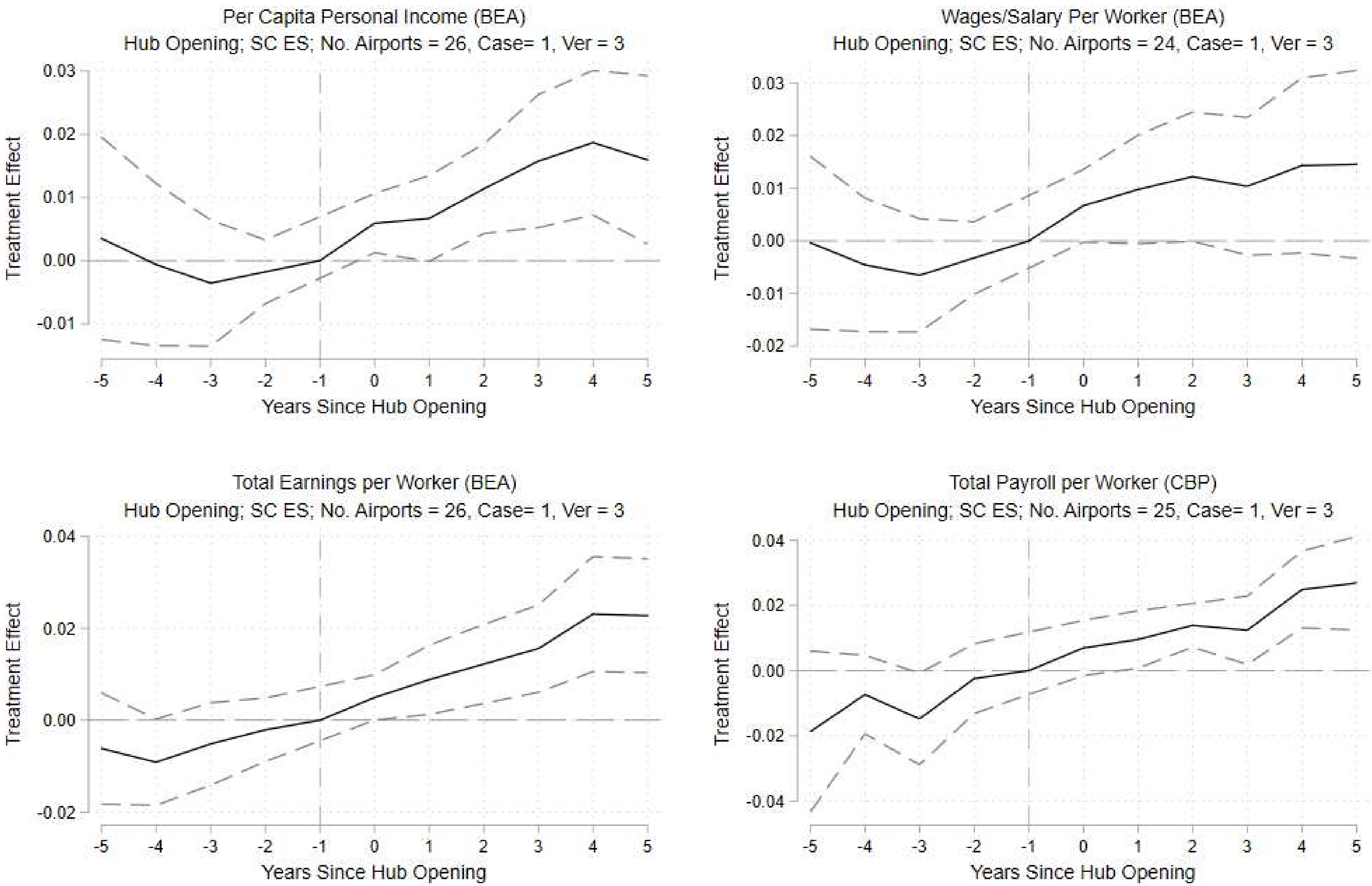
Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure 3: Synthetic Control Event Study - Hub Openings - City Economy Output Measures



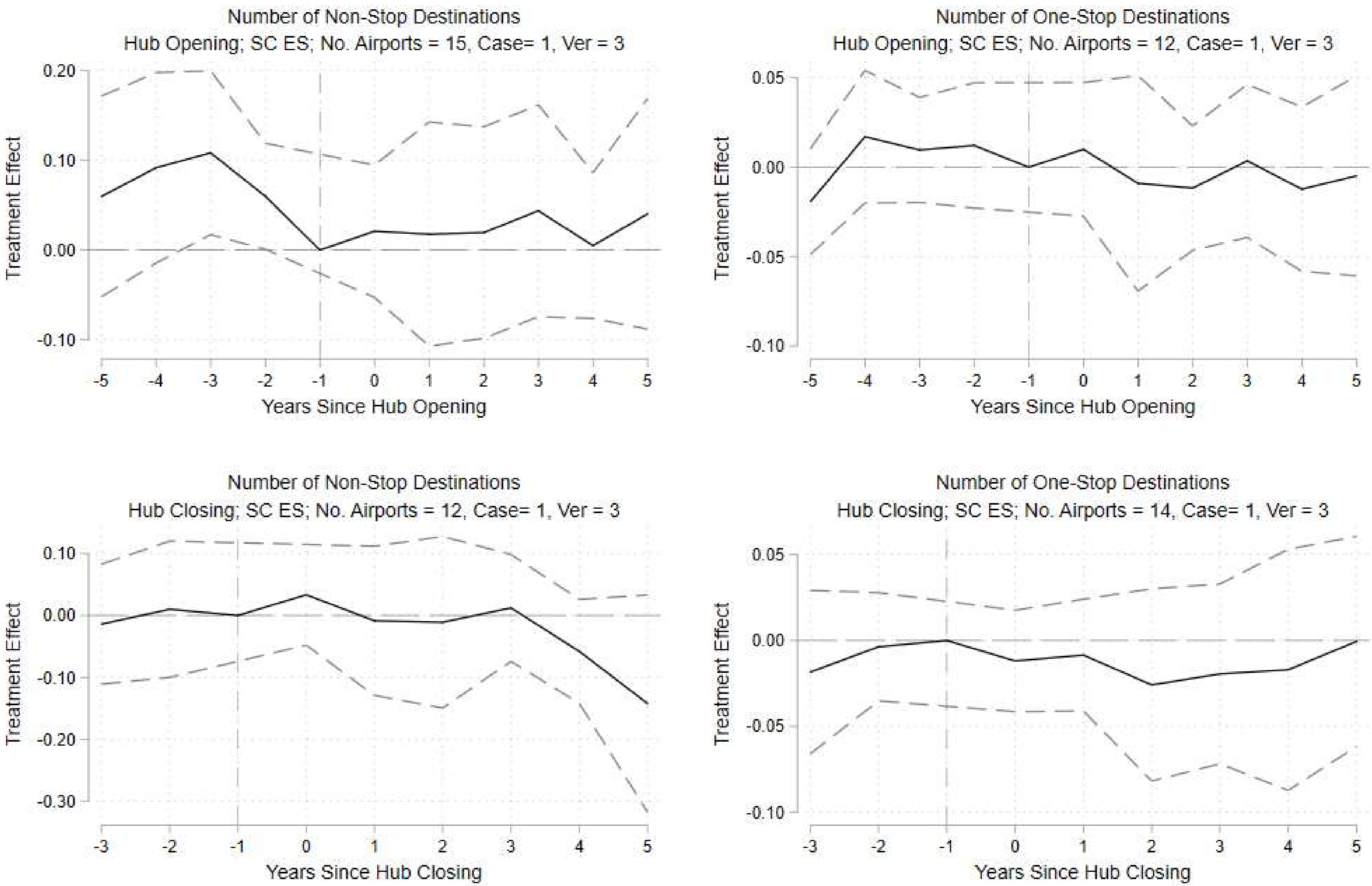
Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure 4: Synthetic Control Event Study - Hub Openings - Wage Measures



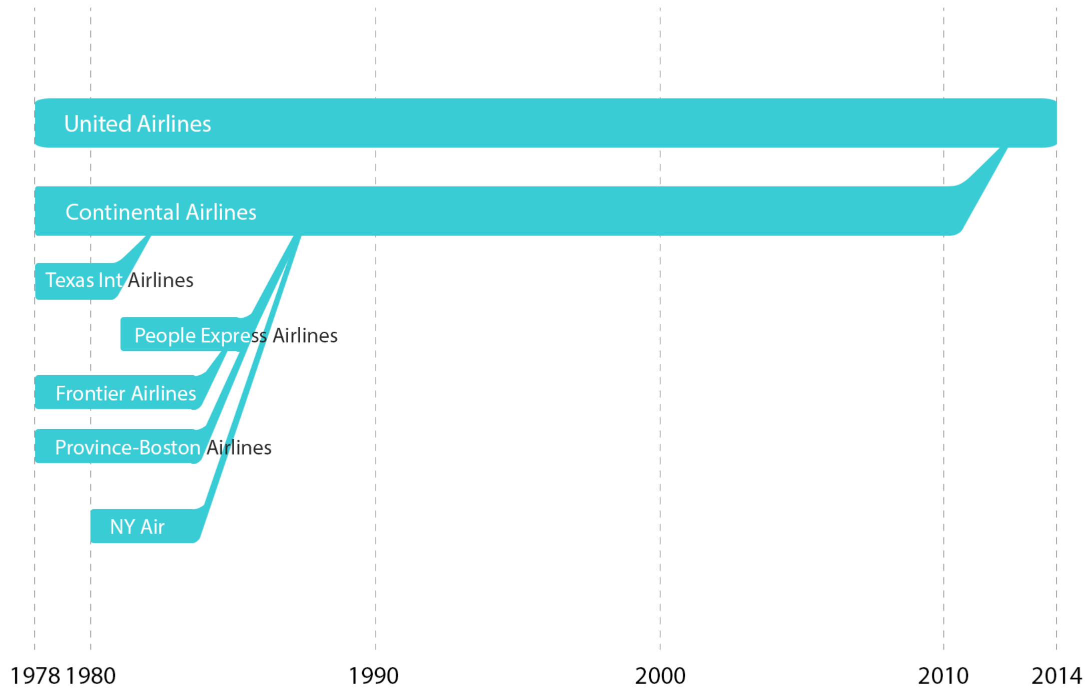
Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure 5: Synthetic Control Event Study - Number of Destinations



Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure A.1: Airline Genealogy: United



Shading corresponds to the eventual airline predecessor airlines would merge into.

A Appendix

Table A.1: Study Hub Airport Characteristics

AirportCode	AirportName	City	State	YearHubOpened	YearHubClosed	Passengers	Flights	NonStopDests	OneStopDests	AverageFare
ATL	Hartsfield - Jackson Atlanta Intl	Atlanta	GA	1978		23.82	600	190	401	163
BNA	Nashville Intl	Nashville	TN	1987	1995	2.72	91	129	300	153
BOI	Boise Air Terminal/Gowen Fld	Boise	ID	1983	2003	0.62	28	78	224	148
BOS	General Edward Lawrence Logan Intl	Boston	MA	2005		8.64	214	146	356	165
BWI	Baltimore/Washington Intl Thurgood Marshal	Baltimore	MD	1983	2003	5.34	147	127	315	148
CLE	Cleveland-Hopkins Intl	Cleveland	OH	1978		3.33	118	123	300	163
CLT	Charlotte/Douglas Intl	Charlotte	NC	1979		6.67	203	116	275	189
CMH	Port Columbus Intl	Columbus	OH	1991	2003	1.88	59	105	273	148
COS	City Of Colorado Springs Muni	Colorado Springs	CO	1995	1997	0.63	22	71	217	168
CVG	Cincinnati/Northern Kentucky Intl	Covington	KY	1986		3.52	132	112	268	201
DAY	James M Cox Dayton Intl	Dayton	OH	1982	1992	1	55	82	232	171
DTW	Detroit Metropolitan Wayne County	Detroit	MI	1984		9.18	249	130	302	155
JFK	John F Kennedy Intl	New York	NY	1992		8.19	242	65	172	187
LAS	Mc Carran Intl	Las Vegas	NV	1986	2008	10.75	230	77	183	106
LAX	Los Angeles Intl	Los Angeles	CA	1999		17.07	415	89	213	136
MCI	Kansas City Intl	Kansas City	MO	1985	2009	3.81	120	66	154	128
MCO	Orlando Intl	Orlando	FL	2008		8.49	182	65	156	136
MEM	Memphis Intl	Memphis	TN	1985		3.06	174	64	132	198
MKE	General Mitchell Intl	Milwaukee	WI	1985		1.91	72	52	127	163
MSP	Minneapolis-St Paul Intl/Wold-Chamberlain	Minneapolis	MN	1978		9.14	240	60	142	189
OMA	Eppley Airfield	Omaha	NE	1994	2002	1.17	42	36	93	151
ORD	Chicago O'Hare Intl	Chicago	IL	1979		25.53	604	60	134	178
PDX	Portland Intl	Portland	OR	1980		3.49	106	38	104	131
PHL	Philadelphia Intl	Philadelphia	PA	1985		6.93	205	46	105	182
PHX	Phoenix Sky Harbor Intl	Phoenix	AZ	1983		10.62	271	39	106	116
PIT	Pittsburgh Intl	Pittsburgh	PA	1979	2004	5.88	187	39	89	182
RDU	Raleigh-Durham Intl	Raleigh/Durham	NC	1987	2003	2.56	79	27	60	185
RNO	Reno/Tahoe Intl	Reno	NV	1992	1999	1.74	50	18	56	99
SAN	San Diego Intl	San Diego	CA	1978	1988	5.34	119	22	66	103
SEA	Seattle-Tacoma Intl	Seattle	WA	1980		7.86	194	22	64	140
SFO	San Francisco Intl	San Francisco	CA	1978		11.66	272	17	60	147
SJC	Norman Y. Mineta San Jose Intl	San Jose	CA	1988	2012	3.24	92	11	39	112
SLC	Salt Lake City Intl	Salt Lake City	UT	1982		5.34	136	13	41	155
STL	Lambert-St Louis Intl	St Louis	MO	1980	2003	7.85	230	12	36	143
SYR	Syracuse Hancock Intl	Syracuse	NY	1983	1991	0.8	37	6	16	163

Notes: AirportCode = FAA Airport location ID. NonStopDests = Number of destinations that can be reached with a non-stop flight from the airport. OneStopDests = Number of destinations that can be reached with no more than one connection from the airport. Passenger boardings in millions. Flights in thousands. Average Fare = (inflation-unadjusted) average one-way fare. Dates of closures during or after year 2012 are not included.

Table A.2: Study Hub Potential (Control) Airport Characteristics (Part 1 of 2)

AirportCode	AirportName	City	State	Passengers	Flights	NonStopDests	OneStopDests	AverageFare
ABE	Lehigh Valley Intl	Allentown	PA	0.24	13	61	210	
ALB	Albany Intl	Albany	NY	0.75	26	97	239	173
AMA	Rick Husband Amarillo Intl	Amarillo	TX	0.33	12	52	165	
AUS	Austin-Bergstrom Intl	Austin	TX	2.18	66	113	304	139
BDL	Bradley Intl	Windsor Locks	CT	2.09	61	114	295	173
BHM	Birmingham-Shuttlesworth Intl	Birmingham	AL	0.92	35	99	245	160
BIL	Billings Logan Intl	Billings	MT	0.24	13	60	183	
BUF	Buffalo Niagara Intl	Buffalo	NY	1.6	57	95	235	137
CHA	Lovell Field	Chattanooga	TN	0.15	9	40	159	
CHS	Charleston Afb/Intl	Charleston	SC	0.51	21	67	190	
CID	The Eastern Iowa	Cedar Rapids	IA	0.21	12	47	187	
CRW	Yeager	Charleston	WV	0.13	8	34	156	
DAB	Daytona Beach Intl	Daytona Beach	FL	0.28	9	41	119	
DSM	Des Moines Intl	Des Moines	IA	0.52	27	69	204	177
ELP	El Paso Intl	El Paso	TX	1.29	45	70	184	138
EVV	Evansville Rgnl	Evansville	IN	0.08	4	25	144	
FAT	Fresno Yosemite Intl	Fresno	CA	0.25	13	39	132	
FSD	Joe Foss Field	Sioux Falls	SD	0.21	13	40	134	
GEG	Spokane Intl	Spokane	WA	0.84	34	60	166	134
GRB	Austin Straubel Intl	Green Bay	WI	0.2	12	35	114	
GRR	Gerald R. Ford Intl	Grand Rapids	MI	0.51	22	59	155	
GSO	Piedmont Triad Intl	Greensboro	NC	0.75	36	60	163	171
GSP	Greenville Spartanburg Intl	Greer	SC	0.34	13	45	139	
HSV	Huntsville Intl-Carl T Jones Field	Huntsville	AL	0.27	14	38	125	
ICT	Wichita Mid-Continent	Wichita	KS	0.45	27	50	150	179

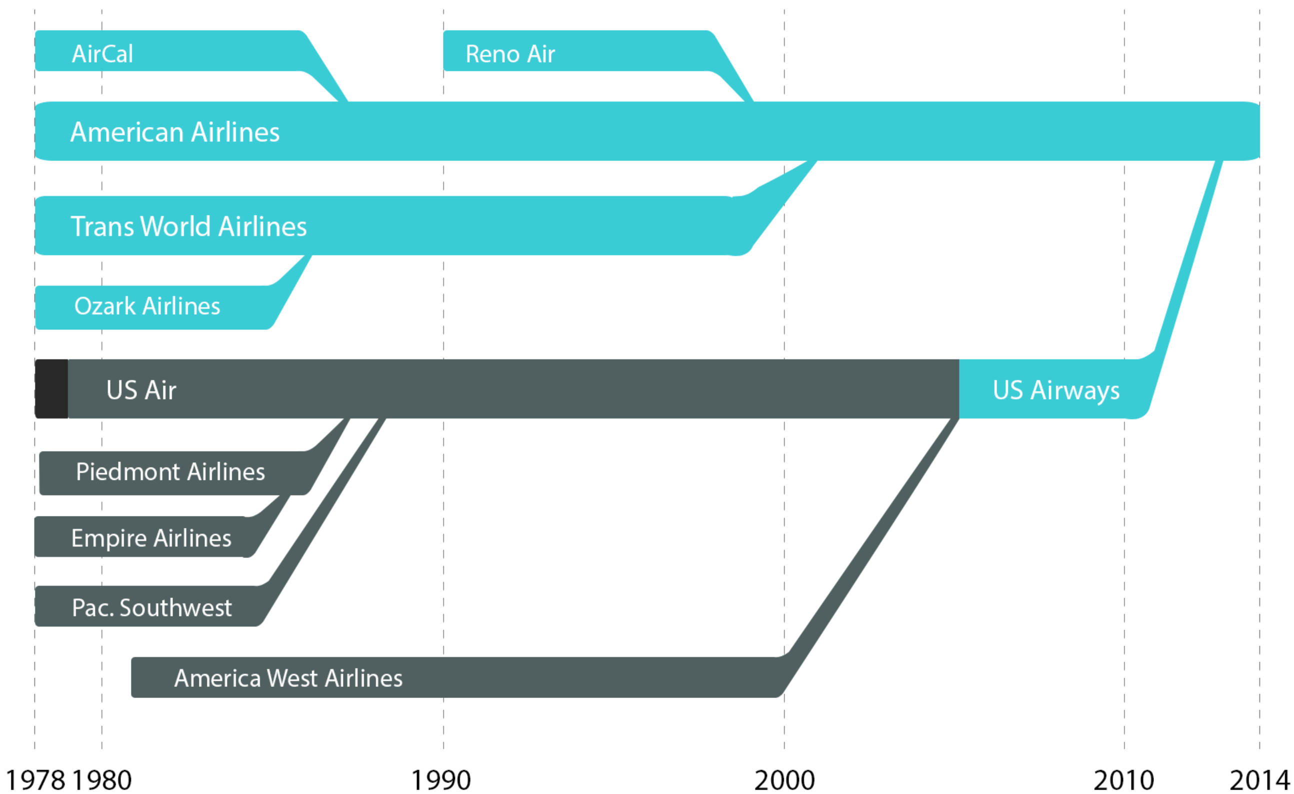
Notes: AirportCode = FAA Airport location ID. NonStopDests = Number of destinations that can be reached with a non-stop flight from the airport. OneStopDests = Number of destinations that can be reached with no more than one connection from the airport. Passenger boardings in millions. Flights in thousands. Average Fare = (inflation-unadjusted) average one-way fare.

Table A.3: Study Hub Potential (Control) Airport Characteristics (Part 2 of 2)

AirportCode	AirportName	City	State	Passengers	Flights	NonStopDests	OneStopDests	AverageFare
IND	Indianapolis Intl	Indianapolis	IN	2.32	91	75	190	146
JAN	Jackson-Evers Intl	Jackson	MS	0.35	17	42	107	
JAX	Jacksonville Intl	Jacksonville	FL	1.53	48	60	140	156
LBB	Lubbock Preston Smith Intl	Lubbock	TX	0.42	17	25	76	
LEX	Blue Grass	Lexington	KY	0.24	12	33	111	
LIT	Bill And Hillary Clinton National/Adams Fi	Little Rock	AR	0.74	27	46	118	156
MAF	Midland Intl	Midland	TX	0.42	15	22	69	
MDT	Harrisburg Intl	Harrisburg	PA	0.32	14	30	92	
MLI	Quad City Intl	Moline	IL	0.19	13	19	80	
MOB	Mobile Rgnl	Mobile	AL	0.24	12	22	67	
MSN	Dane County Rgnl-Truax Field	Madison	WI	0.35	17	29	79	
OKC	Will Rogers World	Oklahoma City	OK	1.25	44	37	94	160
PIA	General Downing - Peoria Intl	Peoria	IL	0.1	10	7	51	
PVD	Theodore Francis Green State	Providence	RI	1.21	35	23	50	174
ROC	Greater Rochester Intl	Rochester	NY	0.88	38	18	43	193
SAT	San Antonio Intl	San Antonio	TX	2.47	74	19	54	165
SDF	Louisville Intl-Standiford Field	Louisville	KY	1.07	79	16	40	154
SHV	Shreveport Rgnl	Shreveport	LA	0.21	14	6	26	
SMF	Sacramento Intl	Sacramento	CA	2.58	67	9	36	125
SRQ	Sarasota/Bradenton Intl	Sarasota/Bradenton	FL	0.6	17	5	18	
TLH	Tallahassee Rgnl	Tallahassee	FL	0.23	11	3	9	
TOL	Toledo Express	Toledo	OH	0.16	16	3	11	
TUL	Tulsa Intl	Tulsa	OK	1.13	43	3	16	189
TUS	Tucson Intl	Tucson	AZ	1.24	39	2	16	248
TYS	Mc Ghee Tyson	Knoxville	TN	0.39	19	1	5	

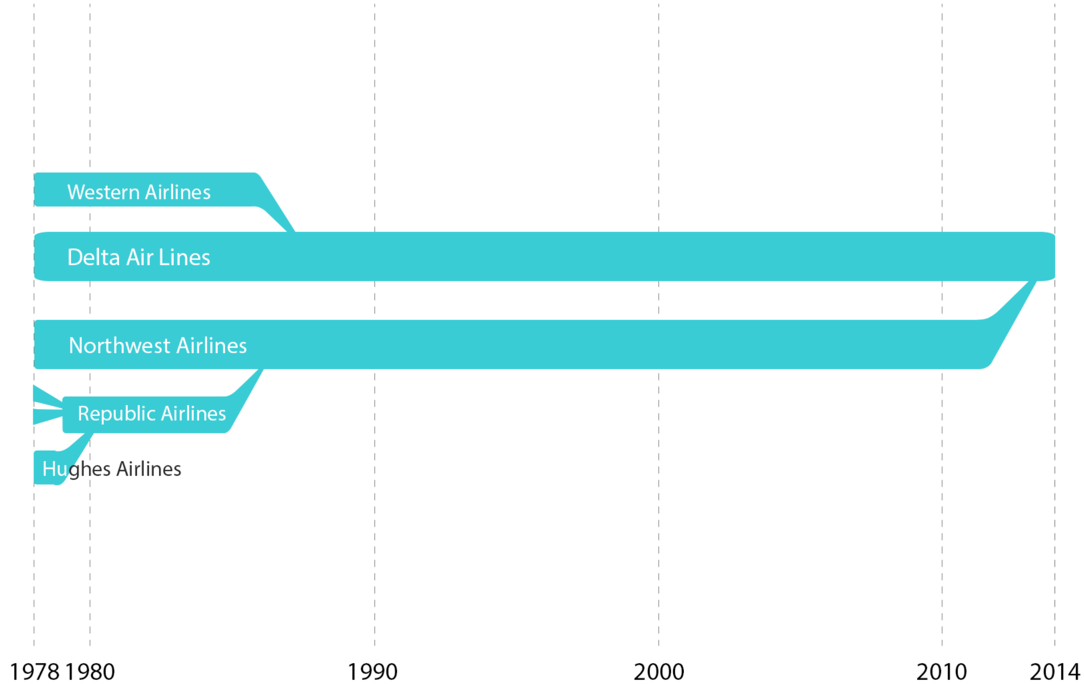
Notes: AirportCode = FAA Airport location ID. NonStopDests = Number of destinations that can be reached with a non-stop flight from the airport. OneStopDests = Number of destinations that can be reached with no more than one connection from the airport. Passenger boardings in millions. Flights in thousands. Average Fare = (inflation-unadjusted) average one-way fare.

Figure A.2: Airline Genealogy: American



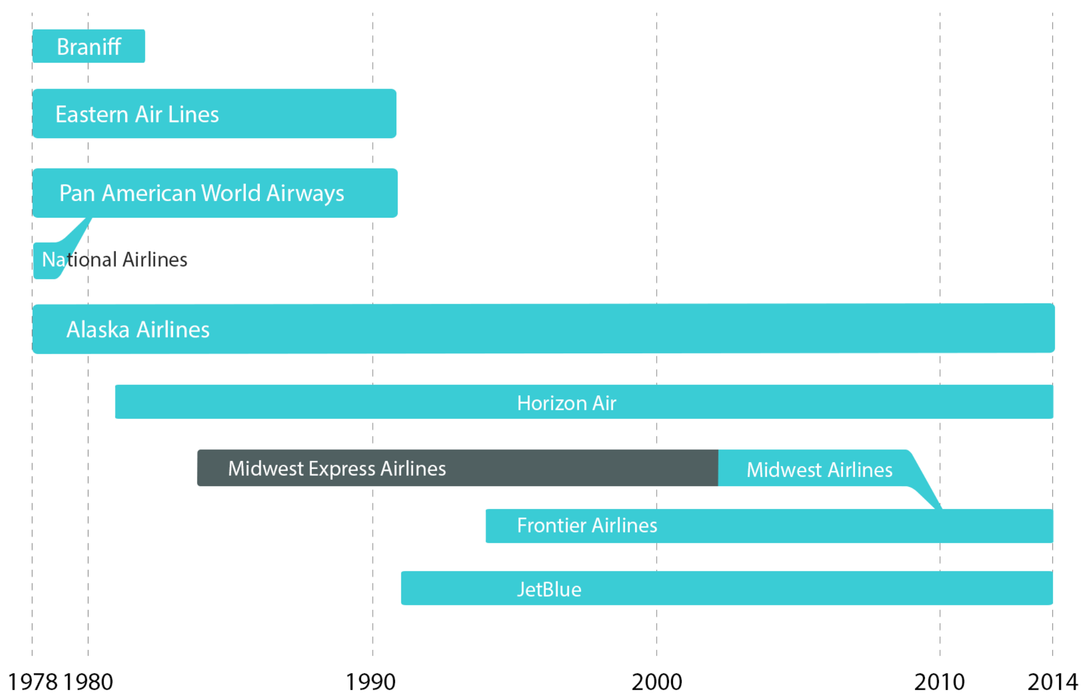
Shading corresponds to the eventual airline predecessor airlines would merge into.

Figure A.3: Airline Genealogy: Delta



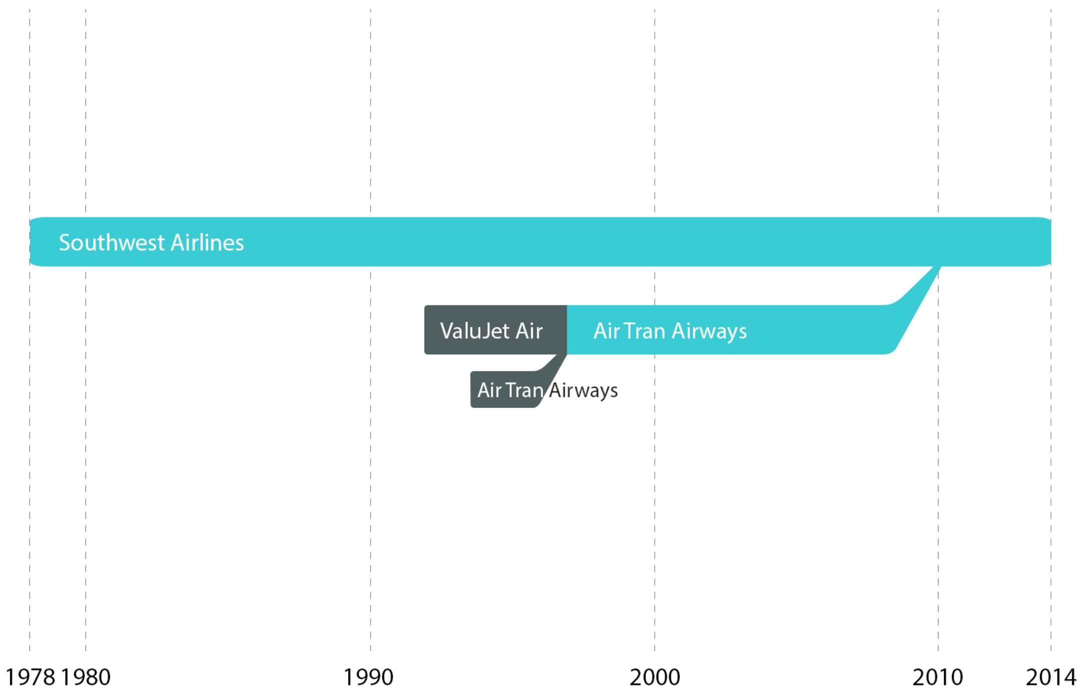
Shading corresponds to the eventual airline predecessor airlines would merge into.

Figure A.4: Airline Genealogy: Other Airlines



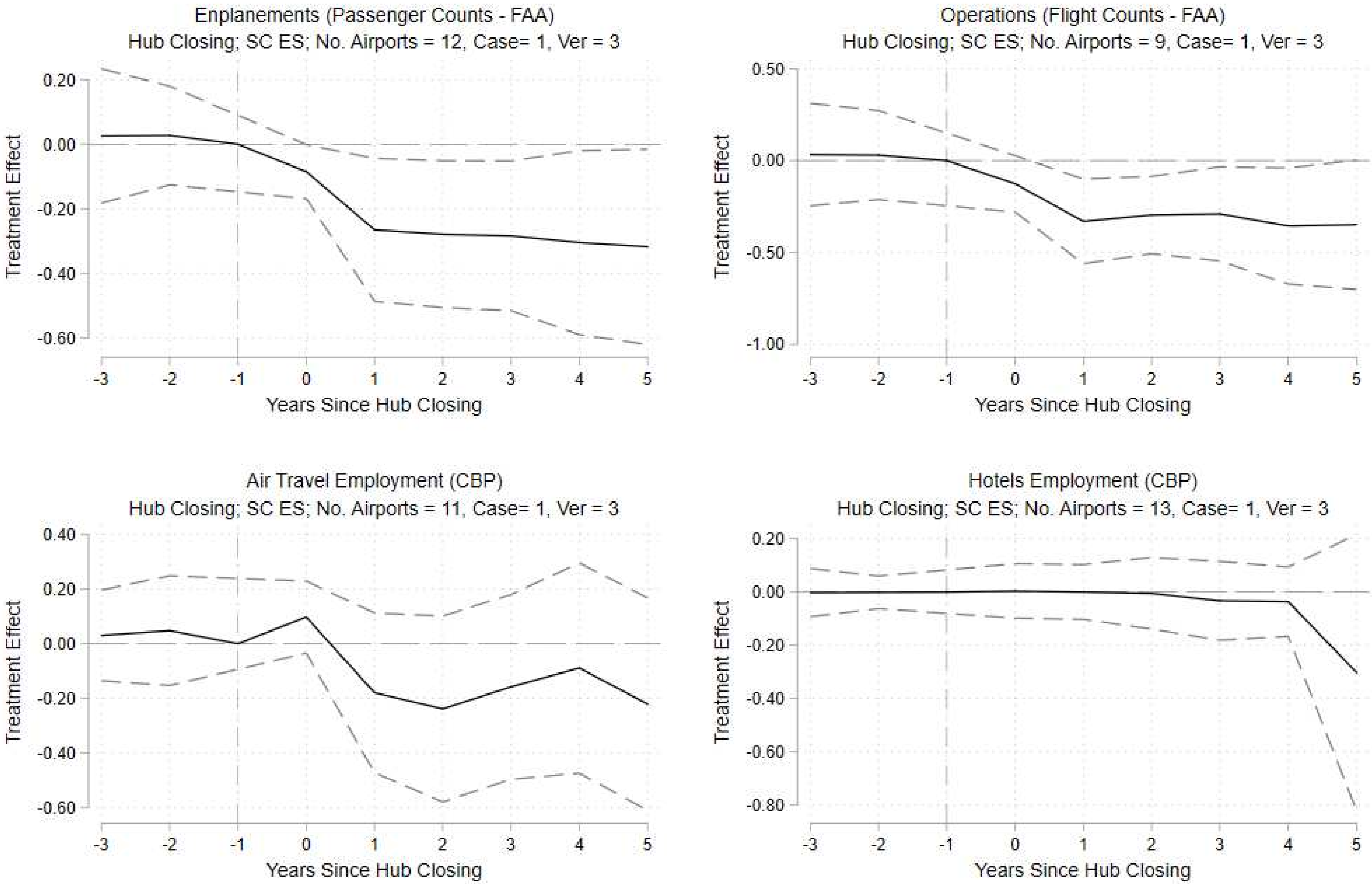
Shading correstponds to the eventual airline individual airports would merge into.

Figure A.5: Airline Genealogy: Southwest Airlines



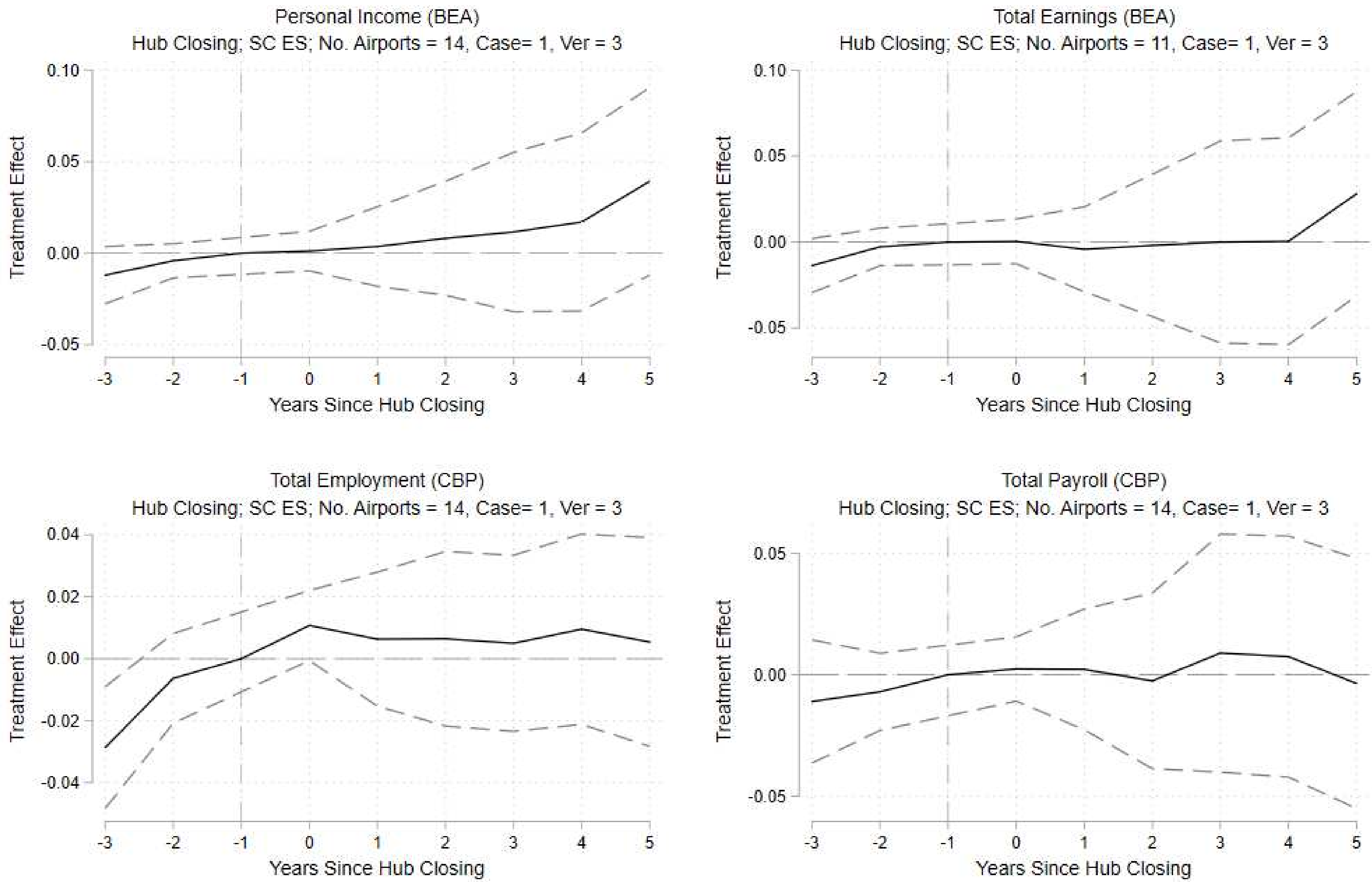
Shading correstponds to the eventual airline individual airports would merge into.

Figure A.6: Synthetic Control Event Study - Hub Closings - Air Travel Sector Outcomes



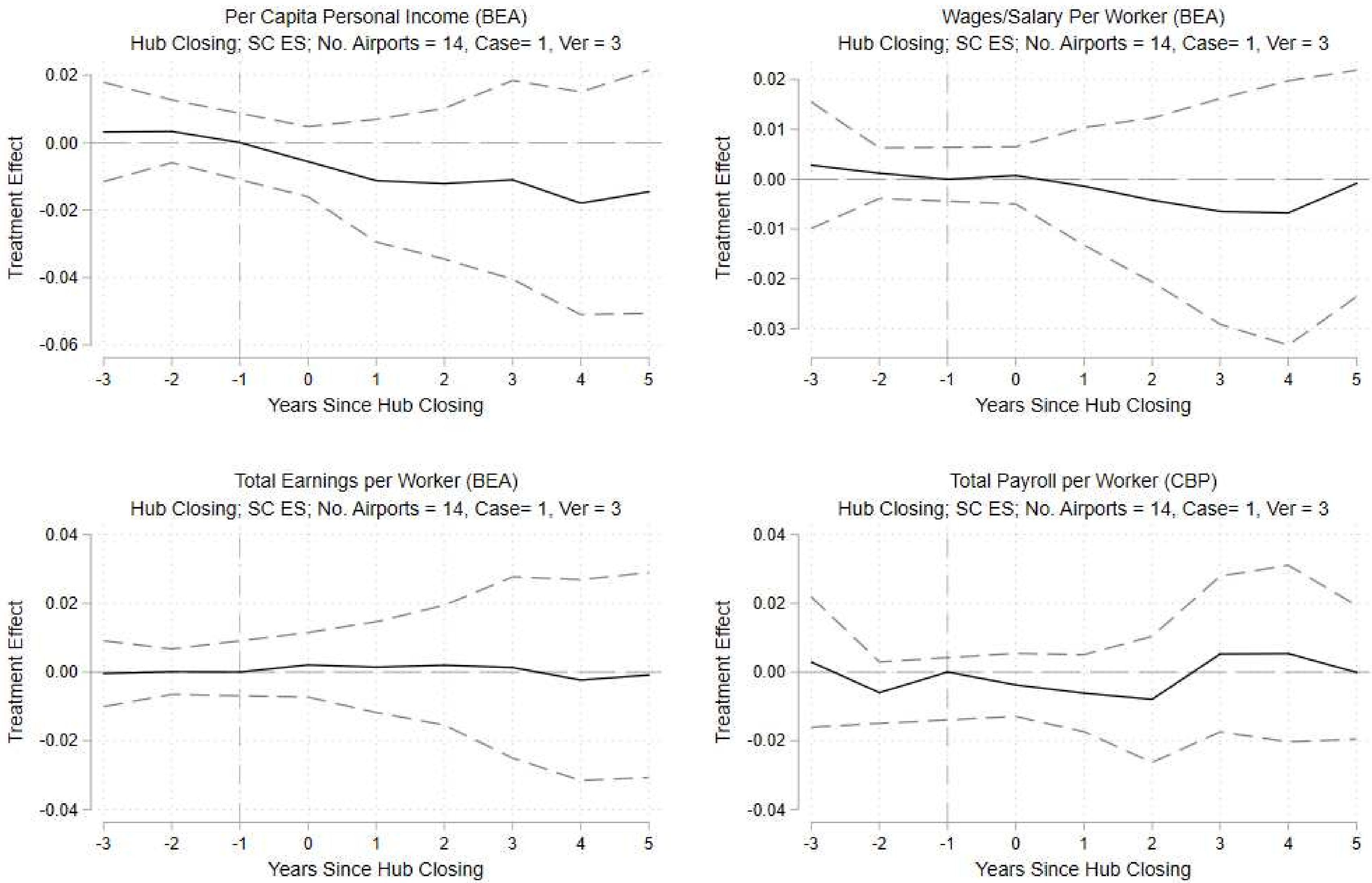
Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure A.7: Synthetic Control Event Study - Hub Closings - City Economy Output Measures



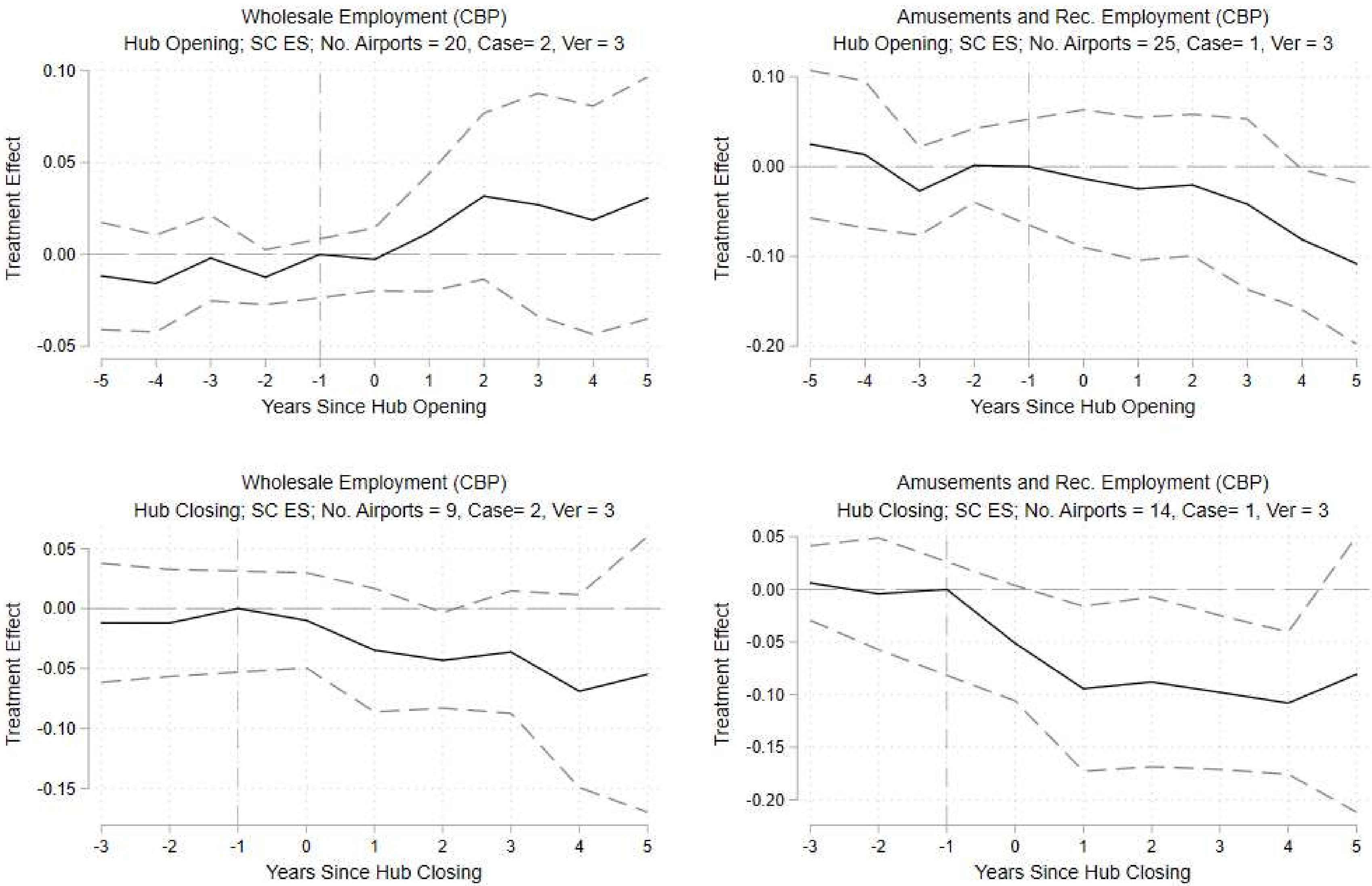
Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure A.8: Synthetic Control Event Study - Hub Closings - Wage Measures



Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.

Figure A.9: Synthetic Control Event Study - Wholesale and Amusements and Recreation Employment



Each plot presents an event study run on airports experiencing a hub opening or closing event, and their synthetically constructed counterfactuals. Please see section 3.1.2 for more details on the construction of the synthetic units, and the specifications used to construct these event study plots. Case = 1 indicates all estimated synthetic counterfactuals were used in the estimation, regardless of goodness of fit. Case = 2 refers to an estimation where only major hubs were considered, again regardless of goodness of fit. Ver = 3 indicates all variables in 3.1.2 were used in constructing the counterfactual synthetic units.