

Sheard, Nicholas

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Airport Size and Urban Growth*

Nicholas Sheard[†]

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Abstract

This paper estimates the effects of airports on economic growth in US metropolitan areas. The estimation uses a novel technique to identify the effects of changes in local airport sizes from overall changes in the air travel network. Airport size is found to have a positive effect on local employment with an elasticity of 0.03. This means that for every job created at the airport by an exogenous increase in traffic, around four and a half jobs are created outside of the airport. The effect appears to be driven primarily by a positive effect on services employment. Airport size is also found to have positive effects on local GDP, the number of firms, population size, and the employment rate. The magnitudes of the effects on population and the employment rate suggest that the jobs created by airport expansion are spread between existing residents and workers who migrate to the area. In addition, the effect on local employment is concentrated in parts of the metropolitan area that are nearer the airport.

Keywords: Transportation infrastructure, Air travel, Urban growth

JEL classification: H54, L93, R11, R42

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[†]Department of Economics, Norwegian University of Science and Technology (NTNU), N-7491 Trondheim, Norway. E-mail: nicholas.sheard@univ-amu.fr. Website: <https://sites.google.com/site/nicholassheard/>.

1 Introduction

Public spending on airports is motivated by a belief that improved air travel services will have a positive effect on economic growth in the areas that they serve. In the US, annual federal spending on the air travel network is around \$15 billion, with further contributions by state and local governments.¹ The justification for this spending almost universally includes statements about the potential of a new or improved airport to attract firms and increase employment. However, there is little empirical basis for these claims. The purpose of this paper is to clarify what effects airports have on local economic activity.

The primary exercise I conduct is to estimate the effects of airport size on employment and gross domestic product (GDP) in US metropolitan areas. These effects are of obvious importance in evaluating policy but are challenging to estimate. The main difficulty with estimating the effects of airports on local economic outcomes is that the local economy is likely to affect airport size through the demand that it creates for air travel and the actions of policy makers. In addition, both the local economy and air traffic can be simultaneously affected by external factors. An observed correlation between airport size and economic outcomes is therefore likely to capture factors other than the causal effect of airports that is of interest.

To measure the causal effect of a change in airport size on the local economy, it is necessary to find a source of variation in airport sizes that is not driven by or otherwise correlated with local economic outcomes. This is difficult in the case of airports because actual decisions about airport improvements are normally made in response to local factors, the cost of airport construction precludes conducting experiments, and air travel is only barely dependent on external factors that vary by location such as physical geography or climate. The approach I adopt is to use variation in airport size driven by overall changes in the air travel network to construct a set of instruments for changes in air travel. I then compare the changes in airport size explained by the instruments with changes in local economic outcomes to generate estimates that reflect the causal effects of airports.

The estimation uses the amount of traffic as the measure of airport size. The principal measure

¹The annual budgets of the Federal Aviation Administration from 2013 to 2015 are each between \$15 billion and \$16 billion, which is used to fund airport construction and maintenance, operations, and research and development (United States Department of Transportation, 2014).

is the number of departing flights, which is intended to reflect the physical size of the airport but also the convenience of travel – the range of destinations and the frequency of flights to a given destination – for an individual traveler. This must be taken into account in policy evaluation, as the results would not apply to infrastructure improvements that do not increase traffic. On the other hand, the results apply to any policies that attract airlines to operate at an airport, even if not associated with improvements in physical infrastructure.

The instruments are constructed using various characteristics of the air travel network and overall changes in those characteristics in a method similar to that proposed by Bartik (1991) for changes in local employment. Each instrument is calculated by taking the amount of local air traffic that fits within a certain category, then applying the national growth rate of that category to the local area. The sets of categories used are the airlines, the aircraft types, and the approximate distances of the flights. To prevent the overall growth rates from being influenced by traffic at the airports they are applied to, flights to and from a metropolitan area are excluded from the calculation of the overall growth rate applied to it.

Airport size is found to have a positive effect on local employment, with an elasticity of 0.03. This means that in a typical metropolitan area with one million residents, a 10% increase in air traffic leads to the creation of around 1,100 new jobs. There is a positive effect of airport size on GDP, also with an elasticity of 0.03, so output per worker does not change with airport size.

I find positive effects of airport size on a range of other economic outcomes including the number of firms and the employment rate, as well as on the total population. The magnitude of the effects on the employment rate and population suggest that employment increases for existing residents while some new jobs are also taken up by people who migrate to the metropolitan area. There is no measurable effect on output per worker or mean wages, which suggests either that labor supply is sufficiently elastic that an increase in the demand for labor causes employment to adjust without a substantial change in wages, or that the amenity value of the airport is sufficiently important that it affects labor supply.

From estimates of the effects on particular industries, it is clear that the effect of airports on local employment is driven by employment in particular sectors. There are positive effects on services

with an elasticity of around 0.07 and on construction with an elasticity of around 0.08, but no effect on employment in manufacturing, wholesale and retail trade, or transportation and utilities.

To further understand how the local economy is affected by changes in airport size, I study how the effects on employment and production vary by location within a metropolitan area. Airport size is found to be correlated with employment and GDP throughout the metropolitan area, but the causal effect of airports is concentrated in the parts of the metropolitan area that are nearer the airport. The correlation between airport size and employment in all parts of the metropolitan area could be explained by air traffic being driven by demand. The concentration of the causal effect in areas nearer the airport suggests that proximity is important to firms that make use of air travel.

The main contribution of this paper is in quantifying the effects of airport improvements. The literature on the effects of airports remains small, due in part to the empirical challenges involved. Green (2007), Blonigen and Cristea (2015), and McGraw (2014) estimate the effects of airports on local economic growth. These studies all find positive effects, with magnitudes somewhat larger than the estimates presented in this paper. Brueckner (2003) and Sheard (2014) estimate the effects of airports on particular sectors and find that the effects are most pronounced for service industries. LeFors (2014) estimates the effects of air accessibility – defined as the sizes of the markets flown to weighted for the cost of flying to those markets – and finds a positive effect on employment in tradable services but no effect on overall employment.

The literature on the effects of other types of transportation infrastructure is more advanced. Duranton and Turner (2012) find a positive effect of roads within a metropolitan area on employment growth and Duranton, Morrow and Turner (2014) find a positive effect on exports of heavier goods. For regional rather than urban growth, Michaels (2008) finds a positive effect of road connections, while Donaldson (forthcoming) and Donaldson and Hornbeck (forthcoming) identify positive effects of railway connections.

The second contribution of this paper is methodological, in that it presents a novel and useful method for estimating the effects of airports and other types of infrastructure. The literature on the effects of airports relies mostly on physical geography, historical policy decisions, and hub status to generate exogenous variation in infrastructure. Brueckner (2003) and Green (2007) use

distance to the geographical midpoint of the US to explain airport sizes, as more central locations are advantageous for hubs. Blonigen and Cristea (2015) use the removal of restrictions by the 1978 deregulation of US air travel to explain variation in air traffic levels. Sheard (2014) uses the 1944 National Airport Plan to instrument for current airport sizes. McGraw (2014) uses the 1922 Army Air Service Proposed System of Air Routes and 1938 Air Mail routes to instrument for smaller communities having airports. Brueckner (2003) and LeFors (2014) use hub status to instrument for airport size, as the demand for tickets that transfer through an airport should not be related to local demand, though local demand may influence airlines' decisions about where to locate their hubs. Similar techniques are employed in the work cited above on the effects of roads and railways – Redding and Turner (2015) present a detailed summary.

In contrast, the technique proposed in this paper makes use of the structure of the air travel network and broad changes in its operation to generate variation in airport size that is exogenous to local economic conditions. The technique could be used to study other consequences of airport investment and airlines' decisions about where to operate. Furthermore, it could be applied to the study of other types of transportation infrastructure such as roads, railways, waterways, and ports. In many situations the technique would be easier to apply than approaches that rely on historical data or exogenous policy changes. The technique also has advantages for policy analysis as it allows the measurement of short-term effects, whereas effects explained by geography or historical decisions may have taken decades to accumulate.

The remainder of this paper is arranged as follows. The model is outlined in Section 2. The data are presented in Section 3, with a description of how the instruments are constructed. The results of the estimation are presented in Section 4. Concluding remarks are presented in Section 5.

2 Model

This section outlines the model that is used as the basis for the estimation. The model is a simple representation of how the instruments relate to airport size and how airport size relates to local economic outcomes. For brevity the model is explained in terms of an effect of airport size on employment, though it is also used to estimate the effects on GDP and other outcome variables.

2.1 Local employment

The size of the airport in metropolitan area m at time t is denoted $A_{m,t}$. The productivity of local firms may be affected by the size of the airport, which provides access to markets to source inputs and sell products. The wage earned by each worker in metropolitan area m at time t may depend on airport size and is defined by the function $w(A_{m,t})$. The airport may also confer a direct amenity benefit to individuals in the metropolitan area, which is represented in money-metric terms by the function $g(A_{m,t})$. Wages and the amenity value are also affected by various local and time-specific factors, which I return to below.

Larger cities are assumed to be more costly to live in, in terms of housing and commuting costs, so the cost of living in metropolitan area m at time t is described by a function $c(N_{m,t}^*)$, where $c' > 0$ and $N_{m,t}^*$ is the natural level of employment.

Individuals gain utility from consumption, to a level determined by wage income less the cost of living. The factors besides the airport that determine wages, the cost of living, and amenities are combined in the permanent local factors μ_m and time-variant economy-wide factors v_t . Where $u(\cdot)$ is some monotonically increasing function, the utility of an individual living in metropolitan area m at time t is the following:

$$u(w(A_{m,t}) + g(A_{m,t}) - c(N_{m,t}^*) + \mu_m + v_t) \quad (1)$$

Individuals are assumed to migrate freely between metropolitan areas and to obtain the reservation utility \bar{u} by living elsewhere, which is thus the equilibrium level of utility. Let \bar{x} be the combined level of consumption and amenities that provides the reservation level of utility, such that $u(\bar{x}) \equiv \bar{u}$. The utility function (1) and migration condition thus imply:

$$w(A_{m,t}) + g(A_{m,t}) - c(N_{m,t}^*) + \mu_m + v_t = \bar{x} \quad (2)$$

According to (2), the number of employees in the metropolitan area is determined by the relationship between wages, the cost of living, and local amenities. A change in airport size may affect employment either through a change in productivity and thereby wages or through a change

in amenities. The cost of living changes as the population adjusts, which restores the equilibrium.

Market access for local firms is represented by the airport size $A_{m,t}$, which is measured as the level of traffic.² The main measure is the number of departing flights, which reflects the convenience of travel for a potential passenger by combining the number of destinations with the frequency of flights. To more directly reflect market access, an ‘air access’ variable is also used that weights the number of flights by the populations of the destination metropolitan areas.

The functional forms $w(A) \equiv \kappa_w \ln(A)$, $g(A) \equiv \kappa_g \ln(A)$, and $c(N) \equiv \ln(N)$ are assumed for the respective functions. The term \bar{x} is set to zero as it can be captured in the fixed effects μ_m and v_t , the sizes of which are not ultimately of interest. Making these substitutions in (2) and rearranging yields an expression for the natural level of employment $N_{m,t}^*$ in metropolitan area m at time t :

$$N_{m,t}^* = e^{\mu_m + v_t} A_{m,t}^\kappa \quad (3)$$

The term $\kappa \equiv \kappa_w + \kappa_g$ in (3) captures the combined effect of the productivity and amenity mechanisms. It would be difficult to isolate these in the estimation without introducing control variables (such as wages) that would be endogenous or imposing an overly restrictive structure. The approach I adopt is simply to estimate the effects of airport size on employment, total output (GDP), and wages, then compare the sizes of the coefficients. A larger effect on output than on employment, for example, would suggest that airports have a positive effect on productivity.

2.2 Growth in the local economy

The actual level of employment in metropolitan area m at time t is denoted $N_{m,t}$. The level of employment changes according to the difference between the current level $N_{m,t}$ and the natural level $N_{m,t}^*$ in (3) according to the following convergence condition:

$$N_{m,t+1} = N_{m,t}^{\lambda_1} N_{m,t+1}^{\lambda_2} N_{m,t}^{1-\lambda_1-\lambda_2} \quad (4)$$

²Market access of course depends on permanent factors such as physical geography, which are captured by first-differencing and the metropolitan-area-level fixed effects. Other types of infrastructure such as roads and railways are also likely to be important. However, changes in road and rail networks are not a problem for the estimation provided that they are not correlated with the changes in airport size explained by the instruments, which appears unlikely.

The change in local employment between t and $t + 1$ is influenced by the natural level of employment at all points in time over that period, but the levels at the endpoints are used as an approximation. Employment at time $t + 1$ depends on employment in the previous period, so $1 - \lambda_1 - \lambda_2 > 0$, and converges towards the natural levels of employment, so $\lambda_1, \lambda_2 > 0$. The following substitutions simplify the algebra:

$$\gamma_{2,m} \equiv (\lambda_1 + \lambda_2) \mu_m$$

$$\delta_{2,t} \equiv \lambda_1 v_t + \lambda_2 v_{t+1}$$

$$\beta_2 \equiv -(\lambda_1 + \lambda_2)$$

$$\alpha_2 \equiv -\beta_2 \kappa$$

$$\theta \equiv -\lambda_2 \frac{\alpha_2}{\beta_2}$$

Substituting (3) into (4) yields the following relationship between employment and airport size at times t and $t + 1$:

$$\frac{N_{m,t+1}}{N_{m,t}} = e^{\gamma_{2,m} + \delta_{2,t}} A_{m,t}^{\alpha_2} N_{m,t}^{\beta_2} \left(\frac{A_{m,t+1}}{A_{m,t}} \right)^{\theta} \quad (5)$$

Taking logs of both sides of (5) and introducing the notation $a = \ln(A)$ and $n = \ln(N)$:

$$n_{m,t+1} - n_{m,t} = \alpha_2 a_{m,t} + \beta_2 n_{m,t} + \theta [a_{m,t+1} - a_{m,t}] + \gamma_{2,m} + \delta_{2,t} \quad (6)$$

Equation (6) is the relationship between changes in local airport size and employment that I wish to estimate. The principal difficulty is that changes in local air traffic $a_{m,t+1} - a_{m,t}$ are likely influenced by variation in local employment $n_{m,t+1} - n_{m,t}$. I therefore instrument for the change in airport size using a set of variables that explain changes in local air traffic but are otherwise plausibly not affected by factors that correlate with changes in local employment. Further issues with the estimation of (6) are addressed below.

2.3 Structural changes in the air travel network

The instruments reflect changes in air traffic that are driven by overall changes in the air travel network. The instruments are expressed in terms of the hypothetical level of air traffic at time $t + 1$, denoted $\hat{A}_{m,t+1}$, determined by these overall changes given the actual level of traffic at time t . Using $\gamma_{1,m}$ and $\delta_{1,t}$ to denote factors specific to the metropolitan area and time, respectively, the growth in air traffic explained by the instrument satisfies:

$$\frac{A_{m,t+1}}{A_{m,t}} = e^{\gamma_{1,m} + \delta_{1,t}} A_{m,t}^{\alpha_1} N_{m,t}^{\beta_1} \left(\frac{\hat{A}_{m,t+1}}{A_{m,t}} \right)^{\eta} \quad (7)$$

The term $\frac{\hat{A}_{m,t+1}}{A_{m,t}}$ in (7) is the instrument for the growth in air traffic. It is expressed with the actual level of air traffic at time t as the basis because this is how the instruments are calculated.³ The controls for airport size and employment at time t are intended to capture systematic differences in how airports are affected depending on airport size or the overall size of the metropolitan area.⁴ Taking logs of both sides of (7) and again using $a = \ln(A)$ and $n = \ln(N)$ for the log values:

$$a_{m,t+1} - a_{m,t} = \alpha_1 a_{m,t} + \beta_1 n_{m,t} + \eta [\hat{a}_{m,t+1} - a_{m,t}] + \gamma_{1,m} + \delta_{1,t} \quad (8)$$

2.4 Estimation equations

The system of equations I estimate is derived from (6) and (8):

$$a_{m,t+1} - a_{m,t} = \alpha_1 a_{m,t} + \beta_1 n_{m,t} + \eta [\hat{a}_{m,t+1} - a_{m,t}] + \gamma_{1,m} + \delta_{1,t} + \varepsilon_{1,m,t} \quad (9)$$

$$n_{m,t+1} - n_{m,t} = \alpha_2 a_{m,t} + \beta_2 n_{m,t} + \theta [a_{m,t+1} - a_{m,t}] + \gamma_{2,m} + \delta_{2,t} + \varepsilon_{2,m,t} \quad (10)$$

The equations are estimated using periods (the time from t to $t + 1$) of one year. Though it is reasonable to expect that the effects on employment would accrue over a longer period, I test the

³The method used to calculate the instruments is detailed in Section 3.

⁴As an example, airports depreciate meaning that it is costly to maintain them at their existing levels of capacity, so airports that are large relative to the communities they serve may therefore tend to decrease in size. Then again, increasing returns to scale in airport operation may lead to more rapid growth for larger airports.

relationship with additional past rates of growth in airport size and with longer periods, and the results suggest that the effect on employment is captured almost entirely by the one-year changes.

For the system of equations (9) and (10) to be identified, the following conditions must be satisfied:

$$\eta \neq 0 \tag{11}$$

$$Cov(\hat{a}_{m,t+1} - a_{m,t}, \varepsilon_{2,m,t}) = 0 \tag{12}$$

Condition (11) is the relevance condition, which requires that the instruments explain a significant amount of the variation in airport sizes, conditional on the controls. This condition is tested statistically as part of the estimation.

Condition (12) is the exogeneity condition or exclusion restriction. It requires that the instrument affects changes in employment only through changes in airport size. While there is no statistical test for the exclusion restriction, I present three arguments in support of it. Firstly, in the description of how the instruments are calculated I detail why it is reasonable to believe that the condition holds. Secondly, I run overidentification tests that demonstrate that the second-stage residuals are indeed uncorrelated with the overidentifying instruments under the assumption that one of the instruments is valid. Thirdly, the tests of the effects of airports on employment by location within the metropolitan area serve as evidence in support of the airport affecting local employment rather than the reverse.

The system of equations (9) and (10) includes control variables for initial airport size and employment, $a_{m,t}$ and $n_{m,t}$. These are intended to account for systematic differences in airport and employment growth that correlate with the initial values. For example, an airport that is relatively small for the level of local employment may tend to be expanded. The use of the controls raises a potential concern, however, because if the estimate of α_2 or β_2 is biased, then the coefficient on the change in airport size θ would also be biased. It is therefore not clear a priori whether these controls should be included. Nevertheless, as noted by Wooldridge (2012, ch. 12), the problems that arise from including lagged dependent variables as controls are fundamentally a matter of the model being correctly specified. The controls for $a_{m,t}$ and $n_{m,t}$ are justified by basic processes of

convergence but it is less apparent why further past values should be meaningful. Furthermore, the estimate of θ is shown in Appendix B to be practically identical with and without each of the controls. A number of additional issues with the estimation are addressed in the robustness checks.

3 Data

The dataset used for the analysis is an annual panel of US air traffic, employment, and a range of other variables that reflect economic growth for the period from 1991 to 2013. The variables are assembled from several sources and aggregated by Core Based Statistical Area (CBSA) according to the December 2009 definitions. The CBSAs are defined by the Office of Management and Budget as sets of counties, where each represents an urban core and the surrounding areas with which it is integrated by commuting.

The main variables in the data are measures of air traffic and economic outcomes. The air travel data are from the T-100 segment data published by the US Bureau of Transportation Statistics (BTS), which detail air traffic by airport pair and month for all flights with at least one endpoint at a US airport. The main variables used to reflect economic growth are employment and GDP. The employment data are from the County Business Patterns, which details the number of firms, the number of employees, and aggregate payroll by year, county, and industry. The GDP measure is based on the annual state-level estimates published by the Bureau of Economic Analysis (BEA). These are apportioned to the counties within each state according to the contemporary shares of aggregate payroll in the County Business Patterns, then aggregated by CBSA. These estimates are imprecise as changes in GDP are not fully reflected in payroll, but are used because annual CBSA-level GDP figures are not available.

As the estimation uses data on yearly changes in air traffic and economic outcomes, the timing of the variables is crucial. The employment data in the County Business Patterns are measured in the week including the 12th of March of the given year, while the US Census is typically measured at the beginning of April. To align the variables and allow clearer interpretation of the results, the air traffic figures are aggregated to years ending on March 31st. That is, '1991' includes air traffic from April 1990 to March 1991. Year-on-year changes in air traffic are thus compared with

employment at the end of the year – with longer-term effects investigated by adding past rates of growth in air traffic. Where necessary, the GDP and other outcome variables are adjusted to reflect the levels at the end of March.⁵

The sample is limited to the contiguous United States – the District of Columbia and all states except for Alaska and Hawaii. The sample includes only airports that hosted at least 2,500 departing passengers – the threshold for a *Commercial Service Airport* according to the Federal Aviation Administration (FAA) – in all years from 1991 to 2013.⁶ CBSAs with no such airports are excluded and for CBSAs with multiple airports the CBSA-level air traffic is found by summing the traffic at all facilities. This yields a sample of 183 CBSAs that include a total of 200 airports. The start and end dates of the panel are determined by data availability.⁷ Figure 1 presents a map of the CBSAs and airports in the sample and Table 1 presents the main variables in the dataset.

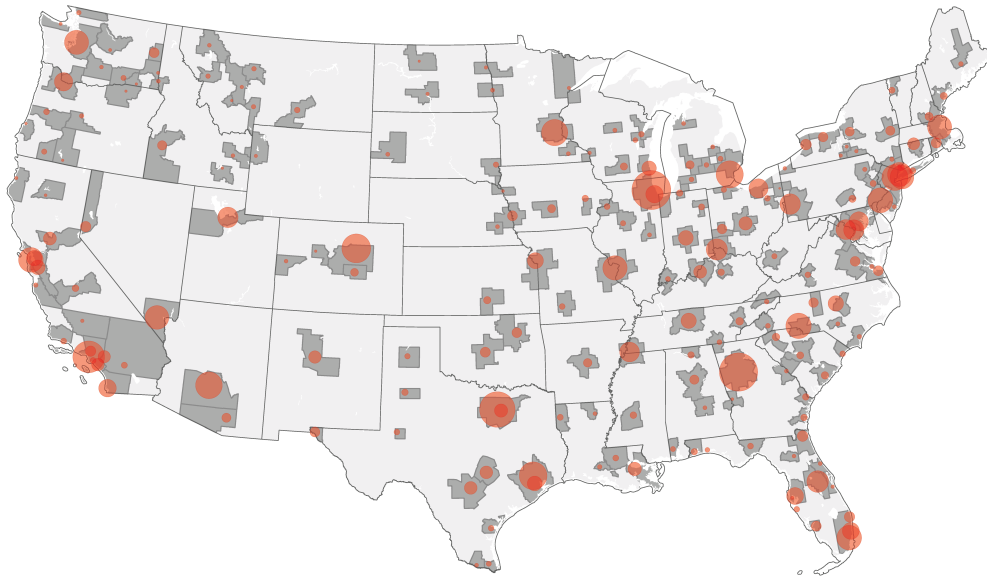


Figure 1: Map of the CBSAs and airports in the sample. The shaded areas of land represent the CBSAs. The shaded circles represent the airports, with the diameter of each circle proportional to the aggregate number of flights within the period of the sample.

⁵The state-level GDP data from the BEA are measured around the end of March and apportioned using payroll in March from the County Business Patterns. Other variables including population are from the US Census, which is currently measured around April 1st.

⁶Denver International Airport opened in 1995 and Austin–Bergstrom International Airport opened in 1999 as replacements for the main airports serving those cities. In each case the former airport was closed and its airport code reassigned to the new airport. These airports are included in the sample and treated as continuously-operating airports.

⁷The T-100 air traffic data are available starting with January 1990 and the most recent edition of the County Business Patterns is for 2013.

	Mean	Std. dev.	Minimum	Maximum
Population	1,089,425	2,019,157	15,701	19,276,994
Number of employees	443,878	829,568	5,518	7,737,401
Mean wage (\$'000)	31.10	8.62	13.83	95.14
Personal income per capita (\$'000)	29.40	8.97	9.79	117.83
Number of firms	27,578	53,547	794	547,738
Gross domestic product (GDP) (\$'bn)	46.24	105.29	0.22	1,404.60
Number of airports	1.09	0.44	1	5
Number of departing flights	43,982	86,568	112	652,006
Number of seats on departing flights	4,921,678	10,681,071	9,171	74,344,888
Number of departing passengers	3,380,745	7,533,635	4,335	56,682,984

Note: 4,209 observations of each variable, in a balanced panel of 183 CBSAs

Table 1: Summary statistics for the main variables in the data.

The principal measure used for airport size is the number of passenger flights departing from airports in the CBSA. This variable measures the physical amount of infrastructure indirectly and represents the practical convenience of the airport for a potential passenger, as it is a product of the number of destinations and the frequency of flights to those destinations. Nevertheless, the number of flights correlates with basic measures of physical airport size, as shown in Sheard (2014). The decision to measure airport size with air traffic is also motivated by the lack of detailed information about the physical features of an airport, the difficulty of quantifying these features, and the greater relevance of air traffic to the construction of the instrument.

Three alternative measures of airport size are also used: the number of seats on departing flights, the number of departing passengers, and a measure of ‘air access’. The air access variable weights the number of flights to each destination airport by the contemporary population of the metropolitan area that it serves. US and international destinations are included, so the metropolitan-area populations are from different sources. US destinations use the CBSA populations from the US Census. Canadian destinations use populations by census metropolitan area (CMA) and census agglomeration (CA) from Statistics Canada. For other countries, the data are from the UN World Urbanization Prospects, which includes metropolitan areas with populations of 300,000 or more and the capital cities of sovereign states. Destinations that do not meet the respective definition are not included in the measure.

The effects of airports on a number of other outcome variables are estimated. The annual

population and personal income per capita are from the USA Counties database. The number of firms, aggregate payroll, and mean wage are from the County Business Patterns. The employment rate is simply the number of employees divided by the total population. The numbers of new housing unit authorizations are from the USA Counties database and the house price index is from the Federal Housing Finance Agency.

3.1 Instruments

The instruments I use for changes in air traffic are related to that proposed by Bartik (1991) for local economic growth. The Bartik instrument is calculated by taking the employment shares for the industries in each area, then assuming that employment in each industry grows at its national rate of growth. The result is a variable that reflects the changes in employment that are attributable to changes in overall industry-level resources and productivity, but is unrelated to changes in factors that are specific to the local area.

The instruments used in this paper are based on similar principles. Five instruments are constructed using the following sets of categories (henceforth “categorizations”) for air traffic: (1) the airlines that operate the flights, (2) the aircraft models, (3) the aircraft classes (based on engine type and fuselage size), (4) a set of ranges for the number of seats in the aircraft, and (5) a set of ranges for the distance of the flight. The categories are listed in Appendix A. The instruments are constructed by dividing up the air traffic in a metropolitan area by one of the categorizations, then calculating what the traffic would be at the end of the period if the local traffic for each category increased at its national rate of growth.⁸ The number of seats and the distance flown are based on quantitative variables of flight characteristics; their distributions are outlined in Table 2.

⁸It is necessary to divide up the data into categories for the instruments to explain any variation in air traffic. Though the instruments are based on overall changes in the air travel network, it would not be sufficient to simply use the overall level of traffic to instrument for local changes in traffic, as such variation would be captured by the year fixed effects. Moreover, were the year fixed effects not to be included, this type of instrument would be driven by changes in overall employment and the exclusion restriction would likely be violated.

	Mean	Std. dev.	Percentile						Maximum
			Minimum	5%	25%	50%	75%	95%	
Number of seats	117.3	63.4	1	30	50	132	144	226	490
Distance (miles)	821.7	961.1	9.0	119.7	281.7	527.5	977.2	2,474.1	10,274.0

Note: 205,841,380 observations, representing individual flights over the period from 1 April 1990 to 31 March 2013

Table 2: Summary statistics for the numbers of seats and distance by flight.

The instruments are constructed as follows. Firstly, a categorization is chosen for the construction of the instrument. Then, the air traffic in metropolitan area m at time t is measured for each category c within this categorization. Separately, the overall growth rate for each category between times t and $t + 1$ is calculated from the US-level air traffic data. Finally, the overall growth rate for each category is applied to its level of air traffic in metropolitan area m at time t . Using $A_{c,m,t}$ to denote the air traffic in metropolitan area m at time t that is classified as category c , the instruments are calculated using the following formula:

$$\frac{\hat{A}_{m,t+1}}{A_{m,t}} = \sum_c A_{c,m,t} \left(\frac{\sum_{n \neq m} A_{c,n,t+1}}{\sum_{n \neq m} A_{c,n,t}} \right) \quad (13)$$

The growth rate on the left-hand side of (13) has the actual level of traffic in the denominator as the actual values are used in the construction of the instruments. The first term on the right hand side is simply the initial traffic for category c . The term in parentheses is the overall growth rate for category c . This is calculated separately for each CBSA excluding traffic that either originates or terminates in that CBSA to avoid a natural concern about the exclusion restriction. Namely, the traffic at a given airport is part of the national level of traffic. If a change in employment in a CBSA affects local air traffic, which in turn contributes to the national level of traffic, then local employment would partly determine the instrument and the exclusion restriction would be violated. Figure 2 illustrates the networks of two example categories with the flights to and from a specific CBSA excluded.

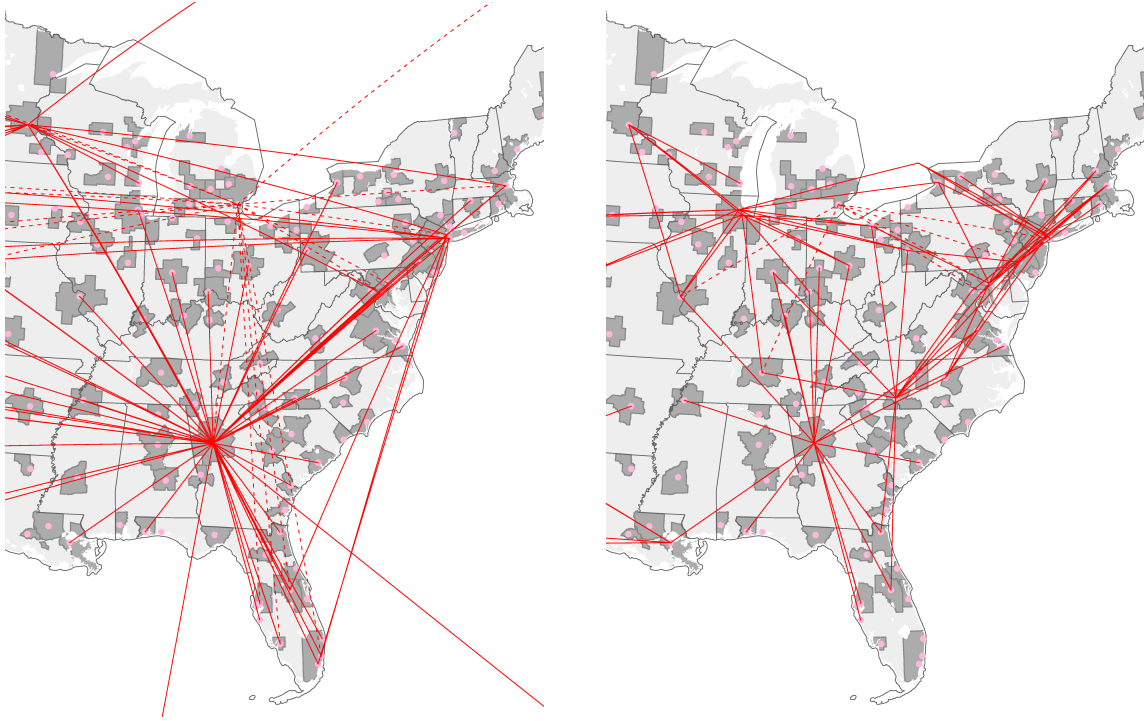


Figure 2: Networks of flights for two example categories. The map on the left represents routes (airport pairs) operated by Delta Air Lines with an average of at least 1,000 daily passengers in 2010. The map on the right represents routes between 250 and 500 miles in length with at least 1,000 daily passengers in 2010. The dots represent airports in the sample and the lines represent the routes. To calculate the overall growth rate that is applied to a CBSA the routes to and from that CBSA are excluded. To illustrate this with an example, the routes with an endpoint in the Detroit-Warren-Livonia CBSA are represented by dashed lines.

The main measure of airport size used is the number of departing flights. When the number of seats or passengers is used in the estimation, the instruments are calculated from local levels and overall growth rates of the respective measure. With the ‘air access’ measure, the instrument is calculated by applying the overall growth rates to the number of flights on each route.

The principle underlying the instruments is that growth rates in the categories are orthogonal to CBSA-specific factors. The part of the variation in local air traffic that is determined by overall growth in an airline’s traffic should not be related to changes in local conditions, in particular when traffic from the local area is excluded from the calculation of the overall growth rate applied to each observation. Rather, an airline’s overall level of traffic should influence its traffic at individual airports through determinants of its overall demand and productivity such as innovations in its methods of operation, marketing, and labor relations. When the demand or productivity of an airline increases, it tends to increase traffic at airports where it already operates as it has gates,

slots, hangar space, and employees based at those facilities.⁹

Similar reasoning applies to the three categorizations for the type of aircraft: the model, class, and number of seats. Each type of aircraft is constrained to operating at airports with facilities such as runways, aprons, hangars, and terminals capable of handling it. If the operations of a particular type of aircraft are increased, say because additional units are produced or the fuel price changes such that it becomes relatively efficient to operate, then the new flights will tend to be at airports that previously hosted that type of aircraft. Furthermore, the variation in an airport's traffic explained by the overall traffic of the aircraft it hosts could not be influenced by local factors. The instrument based on distance ranges is intended to reflect overall changes in aircraft technology and the methods of operating the air travel network, such as changes in the ranges of aircraft, the prevalence of short- and long-haul flights, and the routing of traffic through hubs.

As the number of seats and the distance flown are quantitative variables, the changes in overall traffic driven by the underlying factors should be continuous in the levels of those variables. For example, a change that makes it more practical to fly a given distance should also make it somewhat more practical to fly a slightly shorter or longer distance, and it would be possible to substitute between similar distances to some degree. There are also certain ranges with relatively few observations. To take advantage of the information in observations for similar numbers of seats or distances, the observed growth rates are smoothed for each CBSA and time span.¹⁰

The essential qualities of an instrument are that it satisfy the relevance condition (11) and the exclusion restriction (12). The relevance condition (11) is straightforward to test statistically as it simply requires a significant relationship between the instrument and changes in airport sizes, given the controls, and all of these variables are known.¹¹ The results below demonstrate that each of the

⁹The airline industry featured several large mergers during the period of the data. In some cases the airlines involved continue to operate under separate names and airline codes. In other cases the operations of the two airlines are combined and the traffic is combined under a single airline code. Where the traffic is combined under a single code, the 'airline' instruments for time periods that overlap the merger are calculated using the overall growth rate in the combined entity. The method is detailed and the mergers in the sample are listed in Appendix A.

¹⁰For the overall growth rates by the number of seats and the distance, the mean growth rates are smoothed across the category ranges. Where the observed value for the growth rate in category c is g_c and the number of observations is n_c , the smoothed value \tilde{g}_c is calculated as follows:

$$\tilde{g}_c = \frac{n_{c-2}g_{c-2} + 4n_{c-1}g_{c-1} + 6n_cg_c + 4n_{c+1}g_{c+1} + n_{c+2}g_{c+2}}{n_{c-2} + 4n_{c-1} + 6n_c + 4n_{c+1} + n_{c+2}} \quad (14)$$

¹¹The main results include all of the controls and fixed effects detailed in (9) and (10) in the estimation. However,

instruments exceeds a reasonable threshold for the relevance condition to be satisfied.

The exclusion restriction requires that an instrument only be related to changes in employment or the alternative outcome variable through its effect on the level of air traffic. This condition would be violated either if the instrument affected other factors that in turn affected the outcome variable or if both the instrument and the outcome variable were affected by some unobserved factor. Both possibilities appear unlikely. Apart from the variation in airport sizes explained by the instrument, there is no clear channel through which the concentrations of certain airlines or aircraft at an airport could influence factors for local growth. There is a concern that certain airlines or types of aircraft may operate in parts of the country where stronger employment growth is anticipated, a possible example being Southwest Airlines, but the results are shown below to be robust to the inclusion of state and regional fixed effects. Furthermore, the fact that the variation in the instruments is driven by overall growth rates eliminates the possibility of correlation with exogenous changes in other local factors that affect employment.

4 Estimation

The results from the ordinary least squares (OLS) estimation of (10) are presented in Table 3. These results show how changes in airport size are correlated with changes in employment and GDP, but as the OLS technique does not deal with the endogeneity issues they are not reliable estimates of a causal relationship. Panel A of Table 3 displays the results for the relationship between airport size and employment; Panel B displays the results for airport size and GDP. Each of the specifications exhibits a strong positive correlation.

Columns 1 through 6 of Table 3 use different arrays of the independent variables and fixed effects included in equation (10) to demonstrate how the estimation is affected by the inclusion of these variables. Column 1 shows the estimates with no fixed effects or controls. Column 2 uses CBSA fixed effects, which make little difference to the coefficient on the change in airport size. Column 3 uses year fixed effects, which decrease the magnitude of the coefficient and thus appear

the instruments are also strong when the controls for the levels of traffic and employment at the beginning of the period are excluded, and without the CBSA and year fixed effects they are substantially stronger, as shown in Appendix B.

to capture some of the correlation between changes in airport size and employment. Column 4 includes both CBSA and year fixed effects.

Airport-size measure	(1) OLS Flights	(2) OLS Flights	(3) OLS Flights	(4) OLS Flights	(5) OLS Flights	(6) OLS Flights	(7) OLS Seats	(8) OLS Pass.	(9) OLS Air access
Panel A. Dependent variable: Change in log CBSA-level employment.									
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.023 ^a (0.003)	0.023 ^a (0.003)	0.011 ^a (0.002)	0.011 ^a (0.002)	0.007 ^a (0.002)	0.010 ^a (0.002)	0.013 ^a (0.003)	0.015 ^a (0.003)	0.006 ^a (0.002)
$\ln(a_{m,t})$					-0.006 ^a (0.001)	-0.003 ^b (0.001)	-0.003 ^b (0.002)	-0.003 ^b (0.001)	-0.003 ^a (0.001)
$\ln(emp_{m,t})$						-0.085 ^a (0.007)	-0.084 ^a (0.007)	-0.084 ^a (0.007)	-0.084 ^a (0.007)
R^2	0.02	0.10	0.40	0.48	0.48	0.51	0.51	0.51	0.51
Panel B. Dependent variable: Change in log CBSA-level GDP.									
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.024 ^a (0.003)	0.024 ^a (0.003)	0.013 ^a (0.003)	0.013 ^a (0.002)	0.010 ^a (0.003)	0.012 ^a (0.003)	0.010 ^a (0.003)	0.016 ^a (0.003)	0.008 ^a (0.002)
$\ln(a_{m,t})$					-0.005 ^a (0.002)	-0.002 (0.002)	-0.005 ^a (0.002)	-0.003 ^b (0.002)	-0.000 (0.001)
$\ln(gdp_{m,t})$						-0.044 ^a (0.006)	-0.042 ^a (0.006)	-0.043 ^a (0.006)	-0.045 ^a (0.006)
R^2	0.02	0.15	0.28	0.40	0.40	0.42	0.42	0.42	0.41
CBSA fixed effects		Y		Y	Y	Y	Y	Y	Y
Year fixed effects			Y	Y	Y	Y	Y	Y	Y
Note: 4,026 observations for each regression, representing 183 CBSAs; robust standard errors in parentheses; ^a , ^b , ^c denote significance at 1%, 5%, 10%									

Table 3: OLS estimation of the relationships between airport size and employment and GDP.

Column 5 adds a control for log airport size at the beginning of the year. The coefficient is slightly negative, though not significant in every case. Column 6 adds the log levels of employment and GDP at the start of the period. The significant negative sign on the coefficient indicates that a CBSA that is initially larger tends to have a lower rate of growth. Column 6 is my preferred specification: including all variables in (10) with airport size measured as the number of flights.

Columns 7 and 8 estimate (10) using the number of seats on departing flights and the number of departing passengers, respectively, as the measure of airport size. Column 9 uses the air access measure, which weights the number of flights by the populations of destination metropolitan areas. The coefficients on airport size generated using these alternative measures are positive and similar in magnitude to those using the number of flights.

The OLS results in Table 3 demonstrate a clear, positive relationship between airport size and both employment and GDP within a metropolitan area. Whether or not air traffic affects employ-

ment or GDP, there is a positive correlation between changes in the two variables. To measure the causal effect of air traffic on local employment and GDP, I estimate the system (9) and (10) using two-stage least squares (TSLS) with the instruments detailed above.

The first stage of the estimation establishes the causal relationship between the instruments and the variation in airport size using (9). The results from the first stage are displayed in Table 4.¹² All columns use the full specification of (9) but apply different sets of instruments. The inclusion of the controls for initial airport size and employment is not crucial as the results are similar whether or not these are included, as demonstrated in Appendix B.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Airport-size measure	OLS Flights	OLS Flights	OLS Flights	OLS Flights	OLS Flights	OLS Flights	OLS Flights	OLS Flights	OLS Flights
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘airline’ instrument)	0.186 ^a (0.049)					0.164 ^a (0.044)	0.166 ^a (0.044)		0.160 ^a (0.043)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘aircraft model’ instrument)		0.153 ^a (0.041)							
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘aircraft class’ instrument)			0.498 ^a (0.070)			0.438 ^a (0.065)		0.368 ^a (0.065)	0.335 ^a (0.064)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘seats’ instrument)				0.741 ^a (0.124)					
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘distance’ instrument)					0.933 ^a (0.197)		0.792 ^a (0.183)	0.474 ^b (0.219)	0.380 ^c (0.205)
$\ln(a_{m,t})$	-0.220 ^a (0.030)	-0.215 ^a (0.031)	-0.228 ^a (0.030)	-0.228 ^a (0.030)	-0.214 ^a (0.030)	-0.228 ^a (0.030)	-0.216 ^a (0.030)	-0.223 ^a (0.030)	-0.224 ^a (0.030)
$\ln(emp_{m,t})$	0.220 ^a (0.047)	0.209 ^a (0.048)	0.228 ^a (0.048)	0.235 ^a (0.048)	0.220 ^a (0.048)	0.231 ^a (0.047)	0.224 ^a (0.047)	0.227 ^a (0.048)	0.231 ^a (0.047)
R^2	0.32	0.30	0.32	0.32	0.31	0.34	0.34	0.32	0.34
F -stat. on the instrument(s)	14.64	13.99	51.39	35.49	22.47	32.08	17.15	29.97	24.33

Note: 4,026 observations for each regression, representing 183 CSAs; robust standard errors in parentheses; *a*, *b*, *c* denote significance at 1%, 5%, 10%; all regressions include CSA and year fixed effects

Table 4: First-stage estimation of the relationships between the instruments and airport size.

The results in Table 4 demonstrate that the instruments explain a significant amount of the variation in airport size. The ‘airline’ instrument is positive and the F -statistic indicates that it is comfortably large enough to be considered a relevant instrument for airport size.¹³ The ‘aircraft

¹²The estimates in Table 4 use employment as the independent variable for the local economic outcome. The results using GDP are not shown as they are nearly identical to those in Table 4.

¹³Staiger and Stock (1997) established the customary threshold of 10 for the first-stage F -statistic. Stock and Yogo (2005) calculated critical values under the assumption of independent and identically distributed errors. With a maximal size of 15% – meaning that a Wald test of $\beta = \beta_0$ with a 5% confidence level rejects the null no more than 15% of the time – the critical values are 8.96 in the case of one instrument and one endogenous regressor and 12.83 when there are three instruments and one endogenous regressor. With a maximal size of 10% the critical values are 16.38 for one instrument and one endogenous regressor and 22.30 for three instruments and one endogenous regressor.

model’, ‘aircraft class’, and ‘number of seats’ instruments – which all reflect the type of aircraft – have positive coefficients. I suspect the ‘aircraft model’ instrument is weaker because it is too narrow a classification of aircraft type, which motivates the use of the ‘aircraft class’ instrument.¹⁴ The ‘number of seats’ instrument also reflects the type of aircraft and is strongly positive. However, I prefer the ‘aircraft class’ instrument because the information contained in the engine-type classification makes it somewhat richer. The ‘distance’ instrument is also positive and meets a reasonable threshold to be deemed relevant.

The analysis continues with the instruments constructed using the ‘airline’, ‘aircraft class’, and ‘distance’ categorizations. These instruments are each clearly relevant and their classifications are conceptually diverse: the first reflects the airline operating the flights, the second reflects the type of aircraft, and the third reflects the way that the air travel network is arranged.

Columns 6, 7, and 8 of Table 4 use pairs of the three selected instruments and column 9 uses all three. For all combinations the F -statistics are reasonably large and the coefficients on the instruments are positive in magnitude and significant. All three of these instruments therefore appear to contribute to the variation in airport sizes explained by the model.

Table 5 presents the results from the second stage of the TSLS estimation. Panel A represents the effect of airport size on local employment and Panel B represents the effect of airport size on local GDP. Columns 1 through 4 use the standard airport-size measure of the number of departing flights. Columns 1 to 3 use each of the three preferred instruments individually and column 4 uses all three in combination. Columns 5 and 6 use the number of seats on departing flights and the number of departing passengers, respectively, as the measures of airport size. Column 7 uses the air access measure for airport size.

To evaluate the relevance of the instruments, I run Kleibergen-Paap rk Wald tests. To test the overidentifying restrictions in regressions that use more than one instrument, I run Sargan-Hansen tests. To determine whether the differences between the OLS and TSLS coefficients are statistically different, I run Hausman tests. The F -statistics from the Wald tests and the p -values

¹⁴By its nature the instrument is weak for sufficiently narrow or broad categories. The narrower the category, the fewer observations there are outside of the CBSA to calculate the overall growth rate, and the more the traffic reflects idiosyncratic changes in other places rather than overall factors for the category. The broader the category, the closer the overall growth rate is to the aggregate growth in traffic for the entire US, which is captured by the year fixed effects.

from the Sargan-Hansen and Hausman tests are displayed at the bottom of each panel.

Airport-size measure	(1) TSLS Flights	(2) TSLS Flights	(3) TSLS Flights	(4) TSLS Flights	(5) TSLS Seats	(6) TSLS Pass.	(7) TSLS Air access
Panel A. Dependent variable: Change in log CBSA-level employment.							
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.026 ^a (0.009)	0.036 ^a (0.012)	0.022 ^c (0.011)	0.029 ^a (0.008)	0.037 ^a (0.012)	0.037 ^a (0.013)	0.021 ^a (0.007)
$\ln(a_{m,t})$	0.000 (0.003)	0.003 (0.003)	-0.001 (0.003)	0.001 (0.002)	0.001 (0.003)	0.001 (0.003)	0.001 (0.002)
$\ln(emp_{m,t})$	-0.089 ^a (0.007)	-0.091 ^a (0.007)	-0.088 ^a (0.007)	-0.089 ^a (0.007)	-0.089 ^a (0.007)	-0.087 ^a (0.007)	-0.088 ^a (0.007)
First-stage statistic	14.64	51.39	22.47	24.33	17.76	21.36	19.83
Overid. p -value				0.41	0.06	0.77	0.22
Hausman test p -value	0.05	0.02	0.27	0.01	0.06	0.09	0.01
Panel B. Dependent variable: Change in log CBSA-level GDP.							
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.022 ^b (0.010)	0.035 ^a (0.012)	0.018 (0.012)	0.026 ^a (0.008)	0.033 ^b (0.013)	0.036 ^a (0.014)	0.017 ^b (0.007)
$\ln(a_{m,t})$	-0.000 (0.003)	0.003 (0.003)	-0.001 (0.003)	0.001 (0.002)	-0.001 (0.003)	-0.000 (0.003)	0.002 (0.002)
$\ln(gdp_{m,t})$	-0.046 ^a (0.007)	-0.048 ^a (0.007)	-0.045 ^a (0.007)	-0.047 ^a (0.006)	-0.045 ^a (0.007)	-0.044 ^a (0.007)	-0.047 ^a (0.006)
First-stage statistic	14.53	50.90	22.10	24.05	17.61	21.00	19.54
Overid. p -value				0.27	0.14	0.48	0.12
Hausman test p -value	0.33	0.03	0.61	0.09	0.11	0.13	0.18
'Airline' instrument	Y			Y	Y	Y	Y
'Aircraft class' instrument		Y		Y	Y	Y	Y
'Distance' instrument			Y	Y	Y	Y	Y
Note: 4,026 observations for each regression, representing 183 CBSAs; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; all regressions include CBSA and year fixed effects							

Table 5: Second-stage estimation of the effects of airport size on employment and GDP.

The TSLS results in Table 5 indicate that airport size has positive effects on employment and GDP. The effects are positive for all instruments and for all measures of airport size. The magnitude of the effects vary with the choice of instrument but are around 0.03 for both employment and GDP when airport size is measured using the number of flights. Output per worker is therefore not affected, as GDP changes by the same proportion as employment, though depending on how capital adjusts there may be an effect on total factor productivity. The coefficients appear to be slightly larger when airport size is measured as the number of seats or the number of departing passengers.

The estimated effect on employment is at the low end of what previous studies have found. Green (2007) found an elasticity of 0.03 for the effect of passengers per capita on employment growth, and Blonigen and Cristea (2015) found an elasticity of between 0.07 and 0.12 for the effect

of the number of passengers on employment.

The effects on employment and GDP are smaller when airport size is measured as ‘air access’ rather than the number of flights. The difference between these measures is that the former weights the number of flights by the populations of the destination metropolitan areas. The smaller coefficients for air access suggest that the sizes of the destinations accessed by additional flights is not of primary importance. This could also be an indication of the amenity value of airports.

An increase in air traffic has a direct effect on employment, as some number of cabin and ground crew and other workers are required to operate the flights. By assuming that local employment in the air travel industry is proportional to the level of air traffic, it is possible to create a rough estimate of what the coefficient of 0.03 implies for the ratio of local jobs created within and outside of the air travel industry. According to data from the BTS, approximately 0.55% of total employment in US CBSAs in 2010 was in the air travel industry. Therefore, if local air traffic affects local employment with an elasticity of 0.03 and employment in the air travel industry increases in proportion to local air traffic, then in a CBSA with an average-sized airport the ratio of the change in overall CBSA employment to the change in CBSA employment in the air travel industry is $0.03/0.55\% \approx 5.5$. This figure can be interpreted as a multiplier that means that for every local job created in the air travel industry there are around four and a half jobs created in other industries in the CBSA.¹⁵

The TSLS coefficients on the change in airport size are larger in magnitude than the OLS coefficients for all instruments and for both employment and GDP. The results from the Hausman tests show that the differences are generally significant for employment though not for GDP. The TSLS coefficients being larger than the OLS coefficients deserves some explanation as it suggests negatively-biased OLS coefficients, the opposite of what one would expect if employment has a positive effect on airport size. However, this phenomenon is common in studies that use instrumental variables to estimate the effects of transportation infrastructure on economic outcomes. Two possible explanations offered by Duranton and Turner (2012) are that consumption amenities are missing from the estimation and correlate negatively with initial infrastructure, and that there may be reverse causality whereby employment negatively affects infrastructure. The first of these seems

¹⁵Some of the jobs outside of the air travel industry may be located at the airport. This would include retail and restaurant workers, who are not involved in flight operations or handling passengers or baggage. As a result, the ratio of the change in total employment to the change in employment at the airport would be somewhat smaller than 5.5.

unlikely here as many amenities such as weather and coastal location are time invariant and thus captured by the CBSA fixed effects. The second is more plausible, as investments in airport infrastructure may be made in response to negative shocks to employment.

The first-stage statistics indicate that all of the instruments satisfy a reasonable threshold for them to be deemed relevant, as demonstrated in the first-stage results in Table 4. The overidentification tests indicate weak rejection for the effect of the number of seats on employment and no rejection in any other case, which does not represent evidence of the overidentifying restrictions being invalid.

In the remainder of this section I study the effects of airport size on employment in more detail, then run a number of robustness checks. The appendices address further issues with the estimation. The potential role of ticket prices is explored in Appendix C. To address potential concerns about the use of the current proportions of the categories to construct the instruments, in Appendix D I reproduce the main results using traffic shares from 1991 and from the 1991-2013 total to construct the instruments.

4.1 Longer-term effects of changes in airport size

The results presented above use periods of one year for the changes in airport size, the instruments, and employment and GDP. The effects captured in the estimation thus accumulate over a period of no longer than one year. This section estimates how the effects accumulate over longer periods of time. The first part of this analysis includes lagged rates of growth in airport size as explanatory variables; the second reproduces the main results using periods for the growth variables of longer than one year.

Table 6 presents the results from OLS estimation with multiple lagged and future rates of airport growth. Column 1 is the main specification from Table 3. Columns 2 to 5 each add the airport-growth variable for one additional lagged year, with the controls for initial airport size and employment being taken at the beginning of the first period. For comparison, columns 6 to 8 include airport growth variables for future years.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged years (s)	OLS 0	OLS 1	OLS 2	OLS 3	OLS 4	OLS 0	OLS 0	OLS 0
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.010 ^a (0.002)	0.008 ^a (0.002)	0.007 ^a (0.002)	0.007 ^a (0.002)	0.008 ^a (0.003)	0.011 ^a (0.002)	0.013 ^a (0.002)	0.013 ^a (0.002)
$\ln(a_{m,t}) - \ln(a_{m,t-1})$		-0.001 (0.003)	-0.003 (0.003)	-0.004 (0.003)	-0.004 (0.003)			
$\ln(a_{m,t-1}) - \ln(a_{m,t-2})$			0.000 (0.002)	-0.001 (0.002)	-0.000 (0.002)			
$\ln(a_{m,t-2}) - \ln(a_{m,t-3})$				-0.005 ^b (0.002)	0.006 ^a (0.002)			
$\ln(a_{m,t-3}) - \ln(a_{m,t-4})$					-0.004 (0.002)			
$\ln(a_{m,t+2}) - \ln(a_{m,t+1})$						0.009 ^a (0.002)	0.009 ^a (0.002)	0.011 ^a (0.002)
$\ln(a_{m,t+3}) - \ln(a_{m,t+2})$							0.010 ^a (0.002)	0.010 ^a (0.003)
$\ln(a_{m,t+4}) - \ln(a_{m,t+3})$								0.007 ^a (0.002)
$\ln(a_{m,t-s})$	-0.003 ^b (0.001)	-0.005 ^a (0.002)	-0.006 ^a (0.002)	-0.007 ^a (0.002)	-0.006 ^a (0.002)	-0.001 (0.002)	-0.000 (0.002)	0.001 (0.002)
$\ln(emp_{m,t-s})$	-0.085 ^a (0.007)	-0.089 ^a (0.006)	-0.086 ^a (0.006)	-0.074 ^a (0.006)	-0.066 ^a (0.007)	-0.092 ^a (0.007)	-0.097 ^a (0.008)	-0.096 ^a (0.008)
R^2	0.51	0.52	0.52	0.52	0.51	0.52	0.53	0.54
Number of observations	4,026	3,843	3,660	3,477	3,294	3,843	3,660	3,477

Note: 183 CBSAs for each regression; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include year and CBSA fixed effects

Table 6: OLS estimation with lagged and future rates of airport growth.

The results in Table 6 indicate that employment growth in the current year is not related to past growth in airport size but is related to future airport growth. The relationship between airport growth and employment over the current year varies little with the inclusion of the lagged or future rates of airport growth. However, while there is no apparent relationship between employment growth in the current year and past airport growth, the coefficients on future rates of airport growth are positive and significant. This could be because changes in local employment lead to increases in airport size that accumulate over several years.

Table 7 reproduces the main TSLS estimates of the effect of airport size on employment with multiple lagged and future rates of airport growth. Columns 2 to 5 add additional lagged years and columns 6 to 8 add additional future years of airport growth to the second-stage relationship (10), with the three instruments for the respective year in each case.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged years (s)	TSLS 0	TSLS 1	TSLS 2	TSLS 3	TSLS 4	TSLS 0	TSLS 0	TSLS 0
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.029 ^a (0.008)	0.023 ^b (0.009)	0.025 ^a (0.010)	0.029 ^b (0.012)	0.032 ^b (0.013)	0.024 ^a (0.008)	0.021 ^a (0.007)	0.026 ^a (0.009)
$\ln(a_{m,t}) - \ln(a_{m,t-1})$		-0.007 (0.008)	-0.012 (0.010)	-0.013 (0.010)	-0.011 (0.015)			
$\ln(a_{m,t-1}) - \ln(a_{m,t-2})$			0.000 (0.007)	-0.001 (0.008)	-0.003 (0.009)			
$\ln(a_{m,t-2}) - \ln(a_{m,t-3})$				-0.009 (0.008)	-0.003 (0.010)			
$\ln(a_{m,t-3}) - \ln(a_{m,t-4})$					-0.009 (0.008)			
$\ln(a_{m,t+2}) - \ln(a_{m,t+1})$						-0.000 (0.010)	0.009 (0.008)	0.000 (0.009)
$\ln(a_{m,t+3}) - \ln(a_{m,t+2})$							0.004 (0.008)	0.015 ^c (0.008)
$\ln(a_{m,t+4}) - \ln(a_{m,t+3})$								-0.021 ^c (0.011)
$\ln(a_{m,t-s})$	0.001 (0.002)	-0.003 (0.002)	-0.005 ^c (0.003)	-0.006 ^c (0.003)	-0.006 ^c (0.003)	-0.001 (0.003)	0.001 (0.003)	-0.001 (0.003)
$\ln(emp_{m,t-s})$	-0.089 ^a (0.007)	-0.090 ^a (0.006)	-0.085 ^a (0.006)	-0.074 ^a (0.006)	-0.066 ^a (0.007)	-0.093 ^a (0.007)	-0.098 ^a (0.008)	-0.096 ^a (0.009)
First-stage statistic	24.33	5.07	3.81	2.08	1.07	5.07	3.81	2.08
Overid. p -value	0.41	0.11	0.66	0.51	0.59	0.35	0.00	0.02
Hausman test p -value	0.01	0.36	0.23	0.26	0.11	0.09	0.32	0.02
Number of observations	4,026	3,843	3,660	3,477	3,294	3,843	3,660	3,477

Note: 183 CBSAs for each regression; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; instrumental variable categories: airline, aircraft class, and distance; all regressions include year and CBSA fixed effects

Table 7: TSLS estimation with lagged and future rates of airport growth.

The results in Table 7 make clear that changes in employment are driven by changes in airport size over the past year, but not by earlier changes in airport size. The coefficient on airport growth over the last year varies little with the inclusion of lagged rates of growth, while the coefficients on the lagged growth rates are not statistically different from zero. Furthermore, the coefficients on future growth in airport size are not appreciably different from zero, which alleviates potential concerns about reverse causality operating through the instruments being driven by employment.

Bartik (1991) recommends selecting the appropriate number of lagged explanatory variables based on minimizing the out-of-sample prediction error. This type of exercise is trivial in the context of the results presented in Table 7, as the lagged growth rates do not have significant coefficients and thus do not contribute substantially to the variation explained by the model.

Table 8 presents the results from the estimation of the system of equations (9) and (10) using

periods for each of the growth variables of one to five years. To ensure the independence of the observations, the intervals should not overlap. This means that the sample size decreases dramatically with the period length. However, it is possible to construct multiple samples for periods longer than one year, which is done for periods of two and three years in Table 8 to check for robustness. The OLS estimates are presented in Panel A and the TSLS estimates are presented in Panel B.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Period length in years (s)	1	2	2	3	3	3	4	5
First year of sample	1991	1991	1992	1991	1992	1993	1991	1991
Panel A. OLS estimation.								
$\ln(a_{m,t+s}) - \ln(a_{m,t})$	0.010 ^a (0.002)	0.014 ^a (0.003)	0.014 ^a (0.004)	0.024 ^a (0.005)	0.021 ^a (0.006)	0.010 ^c (0.006)	0.022 ^a (0.007)	0.016 ^c (0.009)
$\ln(a_{m,t})$	-0.003 ^b (0.001)	-0.004 (0.003)	-0.008 ^b (0.003)	-0.006 (0.005)	-0.004 (0.005)	-0.019 ^a (0.006)	-0.007 (0.009)	-0.023 ^b (0.010)
$\ln(emp_{m,t})$	-0.085 ^a (0.007)	-0.174 ^a (0.015)	-0.191 ^a (0.016)	-0.274 ^a (0.021)	-0.278 ^a (0.024)	-0.292 ^a (0.027)	-0.368 ^a (0.031)	-0.455 ^a (0.034)
R^2	0.51	0.61	0.66	0.69	0.71	0.74	0.78	0.81
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.								
$\ln(a_{m,t+s}) - \ln(a_{m,t})$	0.029 ^a (0.008)	0.024 ^b (0.011)	0.033 ^b (0.013)	0.027 ^c (0.016)	0.030 (0.024)	0.035 ^c (0.021)	0.039 (0.030)	0.027 (0.022)
$\ln(a_{m,t})$	0.001 (0.002)	0.000 (0.006)	0.000 (0.007)	-0.004 (0.010)	0.001 (0.014)	-0.002 (0.014)	0.006 (0.024)	-0.014 (0.020)
$\ln(emp_{m,t})$	-0.089 ^a (0.007)	-0.177 ^a (0.015)	-0.197 ^a (0.016)	-0.275 ^a (0.022)	-0.282 ^a (0.026)	-0.304 ^a (0.029)	-0.374 ^a (0.032)	-0.458 ^a (0.034)
First-stage statistic	24.33	17.64	9.38	9.36	7.49	11.45	4.76	6.17
Overid. p -value	0.41	0.40	0.52	0.57	0.91	0.99	0.19	0.22
Hausman test p -value	0.01	0.47	0.11	0.89	0.71	0.18	0.92	0.77
Number of observations	4,026	2,013	1,830	1,281	1,281	1,098	915	732
Note: 183 CBSAs for each regression; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include year and CBSA fixed effects								

Table 8: OLS and TSLS estimation with various period lengths for the growth variables.

The OLS results in Table 8 indicate that changes in airport size are correlated with changes in local employment and GDP for all period lengths. The coefficients are increasing somewhat in magnitude with the length of the period.

The TSLS results in Table 8 do not demonstrate a clear relationship between the length of the period and the size of the effect on employment. The longer lags, having fewer observations, exhibit larger standard errors on the coefficients and lower F -statistics on the first stage. However, the magnitude of the coefficient on the change in airport size is broadly consistent across the range of period lengths. This suggests that a given change in airport size has roughly the same effect on

employment over the coming year as over a period of several years.

Taken together, the results with lagged rates of growth in airport size and with longer period lengths imply that the effect of airport size on employment accrues rapidly – mostly within one year. Changes in airport size that occurred more than a year ago do not have a measurable effect on employment growth, while the effect of a change in airport size is no larger if measured several years in the future than if measured at the end of the year. This finding endorses the use of one-year periods in the estimation. It is also somewhat surprising, as one may imagine that the effects of infrastructure take a long time to accrue. A possible explanation is that the type of variation explained by the instruments largely concerns marginal changes in traffic at well-established airports. Therefore, the effects can accrue largely through the reallocation of local factors, which occurs quickly, whereas a major investment such as a brand new airport could have a sufficiently large effect that it is only fully realized when capital and workers are drawn from other places.

4.2 Alternative measures of economic growth

The main results displayed in Table 3 use the number of employees and GDP as the measures of local economic growth. In this section I estimate the effects of airports on a range of other outcome variables, which either directly or indirectly reflect economic growth. Table 9 explores the effects of airports on the changes in seven such variables, each of which appears in log differences as the dependent variable in (10).

The results presented in Table 9 indicate that changes in airport size have positive effects on measures of economic growth besides employment and GDP. Airport size has a positive effect on the number of firms in a metropolitan area, with a magnitude smaller than the effect on the number of employees. This suggests that an increase in the size of the local airport leads to new firms being created and existing firms employing additional workers.

	(1) Number of firms	(2) Population	(3) Employ. rate	(4) Aggregate payroll	(5) Mean wage	(6) Pers. Inc. per capita	(7) New house approvals	(8) House prices
Panel A. OLS estimation.								
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.007 ^a (0.001)	0.005 ^a (0.001)	0.005 ^b (0.002)	0.008 ^a (0.003)	-0.000 (0.002)	0.002 (0.003)	0.016 (0.021)	0.020 ^a (0.006)
$\ln(a_{m,t})$	-0.001 (0.001)	0.002 ^a (0.001)	-0.006 ^a (0.001)	-0.005 ^b (0.002)	0.001 (0.001)	-0.005 ^a (0.002)	-0.032 ^c (0.016)	0.010 (0.007)
$\ln(outcome_{m,t})$	-0.054 ^a (0.004)	-0.038 ^a (0.004)	-0.122 ^a (0.010)	-0.071 ^a (0.008)	-0.161 ^a (0.015)	-0.144 ^a (0.042)	-0.274 ^a (0.018)	-0.187 ^a (0.062)
R^2	0.64	0.54	0.49	0.50	0.27	0.35	0.44	0.46
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.								
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.012 ^a (0.004)	0.008 ^a (0.002)	0.019 ^a (0.007)	0.034 ^a (0.011)	0.007 (0.006)	0.015 ^c (0.008)	0.081 (0.061)	0.007 (0.019)
$\ln(a_{m,t})$	0.000 (0.001)	0.002 ^a (0.001)	-0.003 (0.002)	0.001 (0.003)	0.002 (0.002)	-0.002 (0.002)	-0.016 (0.022)	0.007 (0.008)
$\ln(outcome_{m,t})$	-0.055 ^a (0.004)	-0.039 ^a (0.004)	-0.124 ^a (0.010)	-0.076 ^a (0.008)	-0.164 ^a (0.015)	-0.147 ^a (0.043)	-0.277 ^a (0.019)	-0.186 ^a (0.062)
First-stage statistic	23.32	23.81	23.59	24.25	23.39	22.95	20.92	17.86
Overid. p -value	0.58	0.06	0.49	0.32	0.77	0.88	0.54	0.05
Hausman test p -value	0.13	0.29	0.02	0.01	0.28	0.16	0.17	0.33
Number of observations	4,026	4,026	4,026	4,026	4,026	4,026	3,477	3,408
Number of CBSAs	183	183	183	183	183	183	183	155

Note: robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include year and CBSA fixed effects

Table 9: Relationships between airport size and various outcome variables.

The effect on the overall population size is positive. Comparing the magnitudes of the coefficients for employment and population, and considering that a mean of 41% of the individuals in the sample CBSAs are employed, the absolute increase in population following an airport expansion is two thirds as large as the absolute increase in employment.¹⁶ This appears to suggest that most of the new jobs are taken up by migrants to the area.¹⁷

The effect of the airport on aggregate payroll is positive and similar in magnitude to the effects on employment and GDP. It is thus not surprising that the effect on the mean wage, which is measured as payroll divided by employment, is not statistically different from zero. There is a weakly-significant positive effect on personal income per capita, but this may simply be because more local residents are employed.

¹⁶Employment in the sample is 41% of the total population. The elasticity of the effect of airport size on employment is $0.029/0.008 \approx 3.6$ times as large as that for the effect on the population. Following an airport expansion, the increase in the number of residents is thus $(1/3.6)/0.41 \approx 0.68$ times the increase in the number of employees.

¹⁷This is consistent with estimates from studies that assess what proportions of the jobs created by an arbitrary increase in regional employment go to existing residents and migrants. Those studies attribute around a quarter of the new jobs to increased employment of existing residents (Bartik, 1993).

The effects on house construction and prices are not clear, which may in part be due to the small sample sizes of these variables. The coefficient for the number of new house approvals is positive in magnitude but not significant. The coefficient for the house price index is not significant, though this variable is available for a subset of the metropolitan areas in the sample.

4.3 Industry-level employment

To better understand how airports affect local employment, this section estimates the effects on the levels of employment in different industries. The industry classification used by the US Census Bureau changed during the period of the data, from the Standard Industrial Classification (SIC) to the North American Industry Classification System (NAICS) and the employment data in the County Business Patterns have many suppressed values at lower levels of aggregation than the two-digit industry level. It is therefore necessary to use fairly broad definitions of industries and an appropriate mapping between the SIC and NAICS definitions. Hence the industries observed are *construction, manufacturing, wholesale and retail trade, transportation and utilities, and services*. The mapping between SIC and NAICS codes is detailed in Appendix E. The results from the estimation are presented in Table 10. As there is a discrete change in how employment is defined between 1997 and 1998, the observations that overlap this period are excluded from the estimation.

	(1)	(2)	(3)	(4)	(5)
Industry	Construc- tion	Manufac- turing	Wholesale & ret. trade	Transport. & utilities	Services
Panel A. OLS estimation.					
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.043 ^a (0.008)	0.004 (0.007)	0.008 (0.005)	0.017 ^b (0.008)	0.011 ^b (0.004)
$\ln(a_{m,t})$	-0.009 ^c (0.005)	-0.017 ^a (0.005)	-0.002 (0.003)	0.007 (0.007)	0.003 (0.003)
$\ln(emp_{m,t})$	-0.160 ^a (0.012)	-0.244 ^a (0.070)	-0.119 ^a (0.019)	-0.272 ^a (0.071)	-0.279 ^a (0.068)
R^2	0.43	0.29	0.28	0.22	0.29
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance					
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.080 ^a (0.030)	0.031 (0.029)	0.019 (0.022)	0.031 (0.035)	0.069 ^a (0.021)
$\ln(a_{m,t})$	-0.002 (0.008)	-0.012 (0.008)	0.000 (0.005)	0.010 (0.010)	0.015 ^a (0.005)
$\ln(emp_{m,t})$	-0.163 ^a (0.012)	-0.244 ^a (0.070)	-0.119 ^a (0.019)	-0.273 ^a (0.070)	-0.279 ^a (0.068)
First-stage statistic	30.62	29.65	29.72	29.84	28.33
Overid. p -value	0.04	0.54	0.71	0.51	0.25
Hausman test p -value	0.10	0.19	0.53	0.95	0.00
Number of observations	3,843	3,843	3,843	3,841	3,840
Note: 183 CBSAs for each regression; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include CBSA and year fixed effects					

Table 10: Relationships between airport size and employment in specific industries.

The results in Table 10 indicate that the measured effect of airport size on employment is driven by changes in certain industries. There is no measurable effect of airports on employment in manufacturing, wholesale and retail trade, or transportation and utilities. However, there are large positive effects on construction and on services. Given that services employment is roughly seven times as large as construction employment using these broad industry definitions, the bulk of the effect on overall employment appears to be due to increased employment in services.

The effect on services employment is intuitive as this industry often involves personal interactions and is more likely to benefit from better possibilities for air travel. The effect on construction could be related to the infrastructure and housing required by the population increase, even if the effects on housing were not clear in Table 9, but it could also be due in part to a direct effect of expanding the airport and related infrastructure. Employment in transportation and utilities may be expected to increase when air traffic increases, also through a direct effect, but the coefficient is neither positive in magnitude nor significant. The other industries that are not affected – manufacturing

and wholesale and retail trade – have less intuitive connection with air travel. The positive effect on services employment and the lack of an effect on manufacturing employment is also consistent with the findings of Brueckner (2003) and Sheard (2014).

4.4 Proximity to the airport within the metropolitan area

The results presented above indicate that airport size has a positive effect on employment and production in a metropolitan area. In this section I test whether the effects differ within the metropolitan area by proximity to the airport. For policy design it is important to understand how local airports affect employment at the metropolitan-area level.¹⁸ However, as airport improvements may be made with the goal of increasing employment near the airport, it is also useful to understand how the effects differ by neighborhood.

Given the variation in how economic activity is distributed within metropolitan areas and how far airports are located from downtown areas, estimating the effects of airports by location within a metropolitan area is not straightforward. Aggregating neighborhoods within a given distance from the airport would mean including the downtown areas of some CBSAs but not of others, which may be problematic if downtown employment is affected differently. Similar problems arise from including distance from the airport as a factor. Furthermore, it is difficult to treat the downtown areas separately as that would require an objective definition of their borders.

The approach I adopt is to divide up employment in each CBSA into segments centered on the downtown area and defined by the direction relative to the location of the airport. This approach treats downtown, suburban, and outlying areas identically except in their relative proximity to the airport. The first test divides up each CBSA along a single axis at an angle of 90° from the direction of the airport. Thus, neighborhoods a given distance from the downtown are divided into those that are relatively near and far from the airport. The second test divides up the data into three groups, along axes at 60° and 120° from the direction of the airport. Figure 3 illustrates how the segments are defined using the Minneapolis-St. Paul-Bloomington, MN-WI CBSA as an example.

¹⁸Brueckner, Lee and Singer (2014) demonstrate that the appropriate level of aggregation for passenger air travel markets is the city, rather than the airport. However, the degree to which the airport serves parts of the metropolitan area by distance to the airport is a deeper question.

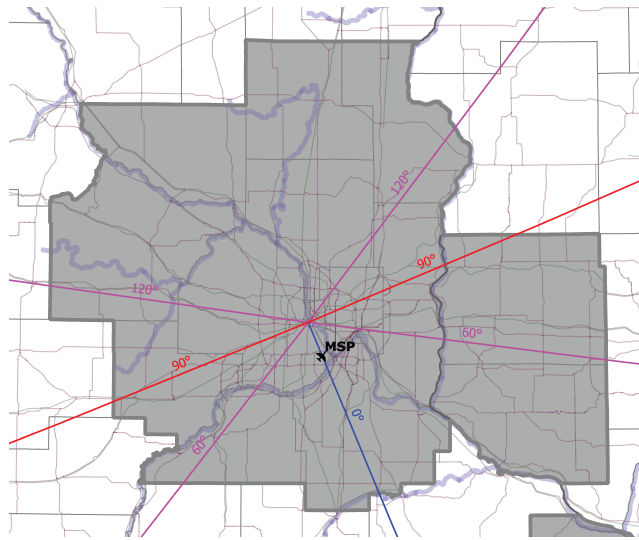


Figure 3: Map of the Minneapolis-St. Paul-Bloomington, MN-WI CBSA showing the axes centered on the CBSA midpoint at angles of 0°, 60°, 90°, and 120° to the direction of the airport. This CBSA is served by the Minneapolis-St. Paul International Airport (MSP).

To carry out the estimation, the midpoint of each CBSA is defined as the center of the downtown employment cluster of the city specified as the ‘core’ of the CBSA.¹⁹ It would be problematic to determine the appropriate direction to the airport in CBSAs with multiple commercial airports, so only CBSAs with a single airport in the main sample are used. The Denver-Aurora-Broomfield, CO and Austin-Round Rock-San Marcos, TX CBSAs are also excluded as their main airports changed locations during the period of the data. This leaves 170 CBSAs. As this exercise requires employment data at a low degree of geographical aggregation, the ZIP Code-level information from the County Business Patterns is used. The earliest available year for this dataset is 1994.²⁰

The results of the estimation are presented in Table 11. The first column presents the baseline results with the employment data aggregated to the entire CBSA. Columns 2 and 3 split the data into locations within and beyond 90° of the direction from the downtown to the airport. Columns 4

¹⁹Lacking a reliable criterion for identifying the ‘central business district’ of a metropolitan area directly from data, the CBSA midpoints were chosen by hand. The primary source of information for this exercise was the maps, satellite photos, and street-level photos on Google Maps. For each CBSA, the midpoint was chosen as the center of the densest area of business activity – in most cases the tallest cluster of office buildings – in the ‘core’ of the CBSA. By definition the ‘core’ of a CBSA is its largest urban cluster, which is the first place listed in the name of the CBSA. Where a CBSA has more than one urban cluster the largest of these is used, rather than choosing an intermediate location that may well be sparsely populated or in a body of water.

²⁰The ZIP Code-level employment data in the County Business Patterns are aggregated to the CBSA segments using a two-step process. The first step uses the ZIP Code-level employment data to find the proportion of employment in each county that is located within a given CBSA segment in a given year, from the areas of the ZIP Codes that intersect with the counties and segments. The second step takes the county-level employment data from the County Business Patterns and assigns these to the segments according to the proportions from the first step.

to 6 divide the data into three zones, divided at 60° and 120° from the direction of the airport. The OLS results are presented in Panel A and the TSLS results are presented in Panel B.

	(1)	(2)	(3)	(4)	(5)	(6)
Direction relative to airport	All	0°-90°	90°-180°	0°-60°	60°-120°	120°-180°
Panel A. OLS estimation.						
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.008 ^a (0.003)	0.010 ^a (0.004)	0.011 ^a (0.004)	0.011 ^b (0.004)	0.007 ^c (0.004)	0.017 ^a (0.006)
$\ln(a_{m,t})$	-0.005 ^a (0.002)	-0.002 (0.002)	-0.005 ^b (0.002)	-0.001 (0.003)	-0.006 ^b (0.003)	-0.002 (0.004)
$\ln(emp_{m,t})$	-0.093 ^a (0.009)	-0.130 ^a (0.012)	-0.116 ^a (0.011)	-0.144 ^a (0.015)	-0.139 ^a (0.014)	-0.146 ^a (0.023)
R^2	0.51	0.39	0.36	0.32	0.36	0.27
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.						
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.022 ^b (0.009)	0.023 ^c (0.012)	0.009 (0.018)	0.030 ^b (0.015)	0.002 (0.013)	0.016 (0.032)
$\ln(a_{m,t})$	-0.001 (0.003)	0.001 (0.004)	-0.006 (0.005)	0.003 (0.005)	-0.007 ^c (0.004)	-0.003 (0.007)
$\ln(emp_{m,t})$	-0.098 ^a (0.010)	-0.133 ^a (0.012)	-0.115 ^a (0.012)	-0.148 ^a (0.015)	-0.139 ^a (0.014)	-0.146 ^a (0.022)
First-stage statistic	13.71	13.42	13.54	13.42	13.39	13.39
Overid. p -value	0.93	0.19	0.84	0.21	0.39	0.39
Hausman test p -value	0.09	0.20	0.88	0.07	0.59	0.24
Number of observations	3,230	3,230	3,230	3,230	3,230	3,230

Note: 170 CBSAs for each regression; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include CBSA and year fixed effects

Table 11: Effects of airport size on employment within segments of a metropolitan area defined by the direction to them from the downtown area relative to the direction to the airport.

The results presented in Table 11 exhibit two clear phenomena: changes in airport size (1) correlate positively with employment in all parts of a metropolitan area and (2) primarily affect employment in areas nearer the airport. The OLS coefficients on the change in airport size are positive and significant for each CBSA segment. Moreover, they are not measurably larger for areas nearer the airport. This would be consistent with demand for air travel coming from firms and individuals throughout the CBSA and increases in employment having a positive effect on air travel. The TSLS coefficients on growth in airport size for the areas nearest the airport – between 0° and 90° and between 0° and 60° – are positive and significant, while the coefficients are smaller and not significant for other areas. This would appear to mean that the effects on CBSA-level employment are primarily due to increased employment within areas nearer the airport.

These results support the validity of the instrument. Were the instrument to be capturing some

variation in airport size that is correlated with employment but not due to the effect of the airport on employment, then a symptom could be that the measured effect applies over the entire metropolitan area. However, the effects of airports on employment measured using TSLS are concentrated in the parts of the CBSA nearest the airport, even though the OLS results indicate that airport size is correlated with changes in employment throughout the CBSA, which alleviates the concern.

4.5 Robustness checks

This section tests the robustness of the main results to a number of alternative sample selections, control variables, and geographical definitions. For brevity, these tests are run for the effects of airports on local employment only, though the results for other outcome variables exhibit similar results. The first set of robustness checks tests the implications of various alternative sample selections. The results are presented in Table 12.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	MSA	Pop. ≤ 1m	≥10,000 pass.	≥100 flights	Year ≤ 2007	No larger near apt.	Dist. inst. excl. CD	1990 MAAs	50-mile circles
Panel A. OLS estimation.									
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.009 ^a (0.002)	0.008 ^a (0.002)	0.011 ^a (0.003)	0.010 ^a (0.002)	0.009 ^a (0.002)	0.013 ^a (0.003)	0.010 ^a (0.002)	0.009 ^a (0.003)	0.009 ^a (0.002)
$\ln(a_{m,t})$	-0.003 ^b (0.001)	-0.004 ^b (0.002)	-0.003 (0.002)	-0.003 ^b (0.001)	-0.003 ^c (0.002)	-0.002 (0.002)	-0.003 ^b (0.001)	-0.003 (0.002)	-0.003 ^a (0.001)
$\ln(emp_{m,t})$	-0.082 ^a (0.007)	-0.086 ^a (0.009)	-0.089 ^a (0.007)	-0.087 ^a (0.007)	-0.082 ^a (0.010)	-0.091 ^a (0.008)	-0.085 ^a (0.007)	-0.090 ^a (0.011)	-0.078 ^a (0.006)
R^2	0.52	0.47	0.51	0.51	0.39	0.53	0.51	0.49	0.59
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.									
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.025 ^a (0.008)	0.024 ^a (0.008)	0.028 ^a (0.008)	0.028 ^a (0.008)	0.027 ^a (0.009)	0.028 ^a (0.009)	0.031 ^a (0.008)	0.018 ^b (0.008)	0.031 ^a (0.007)
$\ln(a_{m,t})$	0.001 (0.002)	0.000 (0.003)	0.001 (0.002)	0.001 (0.002)	0.002 (0.003)	0.001 (0.003)	0.002 (0.002)	-0.001 (0.002)	0.002 (0.002)
$\ln(emp_{m,t})$	-0.085 ^a (0.007)	-0.091 ^a (0.009)	-0.092 ^a (0.007)	-0.091 ^a (0.007)	-0.086 ^a (0.010)	-0.094 ^a (0.008)	-0.090 ^a (0.007)	-0.092 ^a (0.011)	-0.083 ^a (0.006)
First-stage statistic	19.86	15.24	32.36	25.62	21.25	42.62	29.10	15.24	20.28
Overid. p -value	0.50	0.25	0.26	0.32	0.52	0.56	0.59	0.71	0.01
Hausman test p -value	0.02	0.03	0.03	0.01	0.01	0.09	0.01	0.24	0.00
Number of observations	3,696	2,904	3,916	4,048	2,928	2,948	4,026	3,366	4,356
Number of metro areas	168	132	178	184	183	134	183	153	198

Note: robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; all regressions include year and CBSA fixed effects

Table 12: Robustness tests of alternative sample selection criteria.

The first robustness checks in Table 12 test whether the results are sensitive to the size of the

metropolitan area. In column 1 the sample is limited to metropolitan statistical areas (MSAs): the CBSAs with at least 100,000 inhabitants in 2009. Column 2 uses the CBSAs with at most one million inhabitants in 2010. As the coefficients on the change in airport size are similar to the main results in Tables 3 and 5, the estimates appear not to be driven by large or small CBSAs.

Columns 3 and 4 apply a pair of alternative traffic thresholds for the airports: a minimum of 10,000 departing passengers in each year (the threshold for a *Primary Airport* according to the FAA definitions) and a minimum of 100 departing flights in each year. The coefficient on airport size barely changes, indicating that the results are not sensitive to the choice of airport-size threshold.

The Global Financial Crisis that was at its most intense in 2008 was an unusual period for the US economy. To check that the results are not driven by the unusual events of this period, column 5 limits the sample to the period from 1991 to 2007. The coefficient on airport size does not change, suggesting that the results are not an artifact of the Crisis.

As air travel is generally expensive and time consuming, individuals may travel from airports in neighboring communities. To minimize the possibility of the estimates reflecting changes at nearby airports that are beyond the CBSA boundaries, column 6 uses a sample that excludes CBSAs that border a CBSA with a higher-category airport in 2010 according to the FAA definitions.²¹ This restriction decreases the sample size by around one third and increases the strength of the instruments but the OLS and TSLS coefficients remain practically unchanged, so the results are robust to the presence of large airports in nearby areas.

With the ‘distance’ instrument there is a concern about approximate distances being correlated with the region a flight operates in. For example, Los Angeles and San Francisco are similar distances from the East Coast cities and there is a lot of traffic on these routes, so flights to San Francisco are heavily represented in the instrument for flights to Los Angeles. If California experiences positive growth, then the exclusion restriction could be threatened. Column 7 excludes all flights with an endpoint in the same census division in the calculation of the overall growth rates for the ‘distance’ instrument. This makes no change to the coefficient on the change in air traffic while in fact the first-stage statistic becomes somewhat larger.

²¹The FAA airport categories are Large Hub, Medium Hub, Small Hub, Nonhub Primary, Nonprimary Commercial Service, and Reliever.

The final two robustness checks addressed in Table 12 concern the geographical aggregation of the data. To be defined as a CBSA in 2009, an area must have had a population of at least 10,000 in that year. The concern is that among the metropolitan areas near the threshold earlier in the period, only those with positive growth in recent years are included, which could bias the sample. To address this concern, column 8 reproduces the estimates with the data aggregated to Metropolitan Areas (MAs) using the June 1990 definitions. The coefficient on the growth in airport size is somewhat smaller, but still strongly significant.

A further issue with the CBSA definitions is that they are collections of counties. Counties are much larger in the Western US than in the rest of the country, so CBSAs in California tend to capture more hinterland than CBSAs in the Northeast. Furthermore, nearby urban cores are more likely to be grouped into a single CBSA in the West. To correct for any potential bias this may cause, column 9 applies a neutral geographical definition that is defined as locations within a circle of 50-mile radius around each airport that satisfies the 2,500-passenger minimum, but no nearer to any other such airport. The results using this definition are nearly identical to those obtained with the data aggregated by CBSA.

	(1)	(2)	(3)	(4)	(5)	(6)
	Year-by-census-div. fixed effects		Year-by-state fixed effects		Year-by-MSA-status fixed effects	
	OLS	TSLS	OLS	TSLS	OLS	TSLS
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.010 ^a (0.002)	0.031 ^a (0.009)	0.009 ^a (0.003)	0.021 ^a (0.008)	0.010 ^a (0.002)	0.026 ^a (0.008)
$\ln(a_{m,t})$	-0.001 (0.001)	0.004 (0.003)	0.000 (0.002)	0.003 (0.002)	-0.003 ^b (0.001)	0.000 (0.002)
$\ln(emp_{m,t})$	-0.094 ^a (0.008)	-0.099 ^a (0.008)	-0.101 ^a (0.009)	-0.104 ^a (0.008)	-0.084 ^a (0.007)	-0.088 ^a (0.007)
R^2	0.56		0.64		0.52	
First-stage statistic	21.65		16.43		20.91	
Overid. p -value	0.01		0.00		0.57	
Hausman test p -value	0.01		0.14		0.03	

Note: 4,026 observations for each regression, representing 183 CBSAs; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; all regressions include CBSA fixed effects as well as the fixed effects stated in the column titles

Table 13: Robustness tests using fixed effects that interact year by census division, state, and MSA status.

Table 13 applies a number of alternative sets of fixed effects in the estimation. One concern is that the measured effect of airport size on employment could be partly driven by regional-level changes in employment levels that somehow correlate with the instruments. To address this con-

cern, columns 1 through 4 use year-by-census-division and year-by-state fixed effects in place of the year fixed effects in the standard specification. Though the fixed effects absorb some of the variation in the first stage, the coefficient on the change in air traffic is not substantially different when they are included.

To test whether the results are driven by changes that are concentrated in small or large metropolitan areas, columns 5 and 6 of Table 13 use year-by-MSA-status fixed effects in place of the year fixed effects, where MSA status is defined according to the 2009 CBSA definitions. The results are similar to those in the standard specification.

5 Conclusion

This paper estimates the effects of changes in airport size on employment and other economic outcomes in the metropolitan area served by the airport. This topic is important for policy evaluation, as airport improvements are costly and normally conducted using public funds. Nevertheless, the existing evidence of the economic effects of airports is limited, due largely to the difficulties inherent in measuring the effects. This paper develops and applies a novel technique to measure the effects of airports using variation in overall characteristics of the air travel network.

The main findings are that airport size has positive effects on local employment and GDP, both with elasticities of around 0.03. For each job created in operating the airport by an exogenous increase in air traffic, this corresponds to approximately four and a half local jobs created in other industries. As the effects on employment and GDP are of similar magnitude, output per worker appears not to be affected by airport size. Furthermore, the effect on employment appears to be concentrated in parts of the metropolitan area that are nearer the airport.

To further understand the effects of airports on the local economy, I estimate the effects of airports on the number of firms, the local population, wages, and the employment rate. Airport size is found to have positive effects on the number of firms, population, and the employment rate, but not on wages. The effect of airport size on the population is smaller in magnitude than the effect on the number of employees, while the effect on the employment rate is also positive. The relative magnitudes suggest that some of the jobs created by an airport improvement go to migrants and

some represent increased employment for existing residents.

The estimates of the effects on employment by broad industrial sector indicate that airport size has a positive effect on service employment but no measurable effect on manufacturing employment. These results are consistent with the findings of Sheard (2014) that airport size has a positive effect on the share of tradable services but no effect on the share of manufacturing. However, it was not clear from the previous paper whether the overall level of employment was due to an overall increase in employment or simply a reallocation between sectors. The results presented here suggest more clearly that services expand without displacing manufacturing activity. I also find that airport size has a positive effect on employment in construction, but no measurable effect on wholesale and retail trade or on transportation and utilities.

The technique proposed in this paper would be straightforward to apply to further studies of the effects of airports. The technique could also be applied to other types of transportation infrastructure such as roads, railways, and ports, as well as non-transportation infrastructure such as electrical supply and communications networks. Two necessary conditions for the technique to be applicable would be (1) that the type of infrastructure is possible to quantify in terms of the level of traffic it supports and (2) that this traffic is able to be classified into categories that vary in prevalence depending on national factors.

The technique has three main advantages over alternative identification strategies. The first is the relative ease of obtaining the data required to apply it: as opposed to instruments that explain cross-sectional variation in current infrastructure, it does not require geographical or historical data that are often difficult to obtain or quantify. Secondly, to apply the technique it is not necessary to identify a large change in policy, technology, or industrial structure, which do not always present themselves. The third is that, at least in the context of airports, the instruments explain a relatively large amount of the variation in the level of infrastructure when compared with alternative techniques. Another potential advantage of the technique is that it facilitates estimating the short-term effect of changes in infrastructure, whereas techniques that rely on cross-sectional variation are often better-suited to explaining long-term effects.

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A Categorizations used to construct the instruments

The ‘airline’ instrument is constructed using the list of airlines presented in Table 14. The airlines are grouped according to the *Unique Carrier Code* assigned by the BTS, which tracks changes in airline codes over time and distinguishes different airlines that used the same code in different periods. The categorization includes only those airlines that had an average of at least 10 daily flights and 100 daily passengers in at least one year between 1991 and 2013, though naturally the exclusion of these smaller airlines makes only a slight difference to the instrument.

The numbers of flights and passengers listed in Table 14 are the aggregate amounts of traffic operated by the airline between 1991 and 2013 with an origin or destination within the contiguous United States. The list is presented in descending order of the number of flights operated.

Airline code	Airline name	Number of flights	Number of pass. ('000)	Airline code	Airline name	Number of flights	Number of pass. ('000)
WN	Southwest Airlines	20,036,711	1,838,018	VX	Virgin America	212,922	23,235
DL	Delta Air Lines	18,960,058	2,123,571	TA	TACA International Airlines	208,271	21,237
AA	American Airlines	18,571,771	2,005,317	SY	Sun Country Airlines / MN Airlines	206,450	25,130
UA	United Air Lines	14,774,548	1,636,428	K5	SeaPort Airlines	202,221	652
US	US Airways	14,556,022	1,233,842	VS	Virgin Atlantic Airways	200,909	58,738
NW	Northwest Airlines	10,198,850	982,796	PA (1)	Pan American World Airways	198,026	22,288
CO	Continental Air Lines	9,205,140	919,262	YR	Grand Canyon Airlines	193,842	2,462
MQ	American Eagle Airlines	8,416,907	256,699	C8 (1)	Chicago Express Airlines	185,095	3,879
XE	ExpressJet Airlines	6,053,023	189,996	HRZ	Allegheny Airlines	183,669	3,422
OO	SkyWest Airlines	5,834,279	208,377	CP (1)	Canadian Airlines	178,489	15,466
EV	Atlantic Southeast Airlines	5,744,363	195,395	ML (1)	Midway Airlines (Chicago, IL)	170,052	9,611
QX	Horizon Air	3,935,312	121,350	WST	West Isle Air	149,882	144
HP	America West Airlines	3,577,033	334,334	KL	KLM Royal Dutch Airlines	147,774	36,412
AS	Alaska Airlines	3,570,326	327,218	NJ	Vanguard Airlines	147,636	11,046
YV	Mesa Airlines	3,247,194	114,172	WS	Westjet	146,224	17,378
TW	Trans World Airways	3,192,912	274,421	U2	UFS	136,516	4,207
OH	Comair	2,964,008	105,357	ZX	Air Georgian	130,052	1,115
XJ	Mesaba Airlines	2,947,125	78,732	BF	MarkAir	127,673	6,736
FL	AirTran Airways Corporation	2,851,649	251,288	GQ	Big Sky Airlines	126,874	1,070
ZW	Air Wisconsin	2,627,815	97,652	UP	Bahamasair	122,281	7,308
9E	Pinnacle Airlines	2,620,446	99,497	IB	Iberia	117,273	20,613
AX	Trans States Airlines	2,407,565	51,593	AV	Avianca	116,985	13,547
B6	JetBlue Airways	1,928,812	216,997	CM	Compania Panamena	102,813	9,237
RP	Chautauqua Airlines	1,924,857	64,570	KW	Carnival Air Lines	98,199	10,439
AC	Air Canada	1,477,058	109,585	BW	Caribbean Airlines	97,012	10,401
HA	Hawaiian Airlines	1,390,725	140,655	U5	USA 3000 Airlines	95,257	11,900
17	Piedmont Airlines	1,382,326	32,662	3C	Regions Air	90,874	676
OW	Executive Airlines	1,347,280	43,551	KP	Kiwi International	75,213	6,382
9K	Cape Air	1,288,418	6,850	SR	Swissair Transport	71,366	13,737
16	PSA Airlines	1,161,813	43,814	RD	Ryan International Airlines	71,318	8,408
KH	Aloha Air Cargo	1,140,736	86,173	RG	Varig	71,009	11,605
F9	Frontier Airlines	1,120,002	109,907	KN	Morris Air Corporation	66,201	6,828
9L	Colgan Air	956,816	19,419	GL	Miami Air International	63,642	4,793
YX	Republic Airlines	935,025	56,226	N7	National Airlines	63,190	7,126
S5	Shuttle America	803,883	36,628	L3	Lynx Aviation / Frontier Airlines	62,578	2,873
ZK	Great Lakes Airlines	781,691	5,920	MG	Champion Air	60,924	7,398
DH	Independence Air	769,234	22,789	W7	Western Pacific Airlines	58,319	4,503
YX (1)	Midwest Airlines	729,720	40,580	PD	Porter Airlines	57,795	2,082
NK	Spirit Air Lines	711,179	84,203	WV (1)	Air South	50,628	3,087
TZ	ATA Airlines	657,717	87,927	5D	Aerolitoral	48,560	1,616
OE	WestAir Airlines	651,950	7,994	JJ	Transportes Aereos Meridiona	46,152	7,778
HQ (1)	Business Express	620,932	7,627	LGQ	Lineas Aereas Allegro	45,114	5,187
3M	Silver Airways / Gulfstream Int'l	600,454	6,747	IDQ	Island Airlines	43,236	280
BA	British Airways	592,124	123,594	SLQ	Sky King	41,365	3,045
QK	Air Canada Regional	579,099	17,675	PCQ	Pace Airlines	40,579	2,849
MX	Mexicana	570,664	54,047	0JQ	Vision Airlines	39,510	1,733
C5	CommutAir	439,935	7,082	T9	TransMeridian Airlines	38,443	4,772
AM	Aeromexico	437,731	37,367	NA	North American Airlines	38,231	4,483
ZV	Air Midwest	417,503	2,907	8N	Flagship Airlines	38,139	983
LH	Lufthansa German Airlines	356,750	81,851	FCQ	Falcon Air Express	33,358	2,767
QQ	Reno Air	351,058	30,156	FF	Tower Air	30,985	10,936
G7	GoJet Airlines / United Express	312,033	16,123	Y4	Volaris	30,613	3,397
G4	Allegiant Air	297,940	38,747	E9	Boston-Maine Airways	27,409	363
AL	Skyway Airlines	297,374	4,405	W9	Eastwind Airlines	25,763	1,142
CP	Compass Airlines	296,143	17,349	OMQ	Air Choice One	24,839	90
J1 (1)	Midway Airlines (Morrisville, NC)	295,780	14,887	P9	Pro Air	22,643	1,182
F8	Freedom Airlines	277,230	10,261	PN	Pan American Airways (1998–2004)	20,365	1,270
AF	Air France	276,244	59,828	EM	Empire Airlines	18,590	269
JL	Japan Air Lines	245,663	62,753	JX	Southeast Airlines	12,677	1,313
KAH	Kenmore Air Harbor	245,063	1,097	SX	Skybus Airlines	9,314	932
EA	Eastern Air Lines	221,470	17,240	1AQ	Charter Air Transport	8,055	157
TB (1)	USAir Shuttle	219,841	15,263	APN	Aspen Airways	6,981	314
KE	Korean Air Lines	216,871	44,813	BE	Braniff International Airlines	6,832	667
JM	Air Jamaica	213,511	24,669	A7 (1)	Air 21	5,935	217
J7	Valujet Airlines	212,960	14,023	ZA	Access Air	4,261	202

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1 April 1990 and 31 March 2013; the numbers in parentheses in the airline codes are defined by the BTS to differentiate airlines that used the same code at different times

Table 14: List of airlines used to calculate the ‘airline’ instrument.

For time periods that overlap mergers and acquisitions, a common growth rate for all airlines

involved is calculated based on the aggregate level of traffic for the combined entity. That is, if airline *A* acquires airline *B* and all subsequent traffic is coded for airline *A*, then the growth rate applied to both airlines for a period overlapping the merger is the traffic coded as airline *A* at the end of the period divided by the sum of the traffic for airlines *A* and *B* at the beginning of the period. The mergers between airlines in the data where the traffic is subsequently coded as a single airline and the growth rates are calculated in this way are listed in Table 15. Other mergers between airlines in the data – where the traffic is coded separately – are listed in Table 16.

Transition period	Airline retaining code and name		Airline made defunct	
1998-1999	FL	AirTran Airways Corporation	J7	Valujet Airlines
1999-2001	AA	American Airlines	QQ	Reno Air
2000-2002	AC	Air Canada	CP (1)	Canadian Airlines
2002-2003	AA	American Airlines	TW	Trans World Airways
2007-2009	US	US Airways	HP	America West Airlines
2009-2011	DL	Delta Air Lines	NW	Northwest Airlines
2011-2013	BW	Caribbean Airlines	JM	Air Jamaica
2011-2013	UA	United Air Lines	CO	Continental Air Lines

Table 15: List of mergers and acquisitions for which subsequent traffic is classified with a single code.

Year of merger	Airline 1		Airline 2	
2005	OO	SkyWest Airlines	EV	Atlantic Southeast Airlines
2009	AV	Avianca	TA	TACA International Airlines
2010	WN	Southwest Airlines	FL	AirTran Airways Corporation
2013	AA	American Airlines	US	US Airways

Table 16: List of mergers and acquisitions for which subsequent traffic continues to be classified separately.

The ‘aircraft model’ instrument is constructed using the list of aircraft models presented in Table 17. To be included in the categorization, a model must have been used for an average of at least one daily flight and one daily passenger in at least one of the years between 1991 and 2013. The air traffic variables are the aggregates of all flights with an origin or destination in the contiguous US and the models are listed in alphabetical order.

Index	Aircraft model	Number of flights	Number of pass. ('000)	Index	Aircraft model	Number of flights	Number of pass. ('000)
1	Aérospatiale/Aeritalia ATR 42/72	3,734,637	119,756	49	Bombardier CRJ100/200	14,995,659	532,104
2	Aérospatiale-BAC Concorde	25,207	1,322	50	Bombardier CRJ700/705/900	5,377,450	293,076
3	Airbus A300-100/200	201,089	31,246	51	British Aerospace BAe-146	1,304,075	60,142
4	Airbus A300-600	609,265	111,598	52	British Aerospace BAe-ATP	208,073	6,374
5	Airbus A310-200	41,680	5,644	53	British Aerospace Jetstream	1,869,052	20,949
6	Airbus A310-300	143,790	19,480	54	Cessna 172/180/182/185	74,496	73
7	Airbus A318	162,496	13,845	55	Cessna 205/206/207/209/210	1,682,231	2,670
8	Airbus A319	5,550,291	513,649	56	Cessna 208	1,309,676	4,956
9	Airbus A320-100/200	8,218,822	917,535	57	Cessna 402	1,326,797	6,202
10	Airbus A321	690,409	98,362	58	Cessna Citation II	2,409	17
11	Airbus A330-200	530,450	112,678	59	Cessna Citation X	4,088	13
12	Airbus A330-300	48,029	12,073	60	Convair CV-580	8,276	233
13	Airbus A340	29,973	5,625	61	De Havilland DHC2	369,641	877
14	Airbus A340-200	339,395	69,904	62	De Havilland DHC3	151,090	911
15	Airbus A340-300	65,966	13,457	63	De Havilland DHC6	440,826	4,832
16	Airbus A340-500	32,538	5,504	64	De Havilland DHC7	65,525	1,743
17	Airbus A340-600	69,773	17,345	65	De Havilland DHC8	5,749,585	164,031
18	Airbus A380-800	18,032	7,077	66	Dornier 228	15,087	205
19	Beechcraft Baron	11,471	16	67	Dornier 328	810,925	16,054
20	Beechcraft King Air	35,896	142	68	Embraer 110	97,083	630
21	Beechcraft Super King Air	4,021,891	33,133	69	Embraer 120	3,916,078	65,271
22	Boeing 707-100	4,734	350	70	Embraer 135/140/145	13,275,236	449,850
23	Boeing 707-300	6,335	651	71	Embraer 170/175	2,077,723	112,645
24	Boeing 717-200	2,709,478	231,422	72	Embraer 190	870,343	65,662
25	Boeing 727-100	398,243	26,095	73	Fairchild F-27	95,847	2,147
26	Boeing 727-200/231	9,614,565	875,769	74	Fairchild Swearingen Metroliner	791,807	7,204
27	Boeing 737-100/200	9,749,656	671,642	75	Fokker 70/100	2,518,773	150,147
28	Boeing 737-300	20,053,739	1,745,613	76	Fokker F28	823,209	33,446
29	Boeing 737-400	3,387,335	315,085	77	Grumman G-73 Mallard	12,775	141
30	Boeing 737-500	4,479,101	350,481	78	Gulfstream G150/G200/G450	2,585	8
31	Boeing 737-600	6,685	578	79	Gulfstream II/III/IV/V	3,799	15
32	Boeing 737-700	8,226,762	812,615	80	Ilyushin 62	10,565	875
33	Boeing 737-800	5,098,599	598,796	81	Ilyushin 96	3,127	340
34	Boeing 737-900	494,216	69,498	82	Lockheed L-1011	747,619	147,978
35	Boeing 747-100	331,772	95,569	83	McDonnell Douglas DC-8	46,569	5,444
36	Boeing 747-200/300	698,555	185,998	84	McDonnell Douglas DC-9	30,456,248	2,525,228
37	Boeing 747-400	1,567,185	427,460	85	McDonnell Douglas DC-10	1,469,915	284,541
38	Boeing 747-400F	9,447	30	86	McDonnell Douglas MD-11	301,535	55,830
39	Boeing 747C	52,270	10,619	87	McDonnell Douglas MD-90	507,170	55,073
40	Boeing 747SP	40,931	6,972	88	Nihon YS-11	5,127	72
41	Boeing 757-200	11,916,956	1,599,392	89	Pilatus Britten-Norman BN2/A	160,246	679
42	Boeing 757-300	411,944	77,241	90	Pilatus PC-12	87,689	339
43	Boeing 767-200	1,429,846	191,517	91	Piper PA-18/23/28/31/32/34/39	1,180,533	2,829
44	Boeing 767-300	3,270,458	553,533	92	Piper PA-30/31T	24,615	63
45	Boeing 767-400	335,059	70,270	93	Quest Kodiak 100	808	5
46	Boeing 777-200/233	1,414,251	294,400	94	Saab 340	5,223,423	95,338
47	Boeing 777-300/333	69,207	17,149	95	Shorts 330/360	303,723	4,992
48	Boeing 787-800	1,294	207				

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1 April 1990 and 31 March 2013

Table 17: List of aircraft models used to calculate the ‘aircraft model’ instrument.

The categories used to construct the ‘aircraft class’ instrument are listed in Table 18. These are based on the *Aircraft Type Group* variable specified in the BTS data. To give a finer classification of aircraft size, the groups for the jet aircraft are broken down by the numbers of seats in the aircraft.

Index	Aircraft class	Number of flights	Number of pass. ('000)
0	Piston, 1-Engine/Combined Piston/Turbine	2,864,534	5,609
1	Piston, 2-Engine	2,162,350	9,017
2	Piston, 3-Engine/4-Engine	2,739	0
3	Helicopter/STOL	22,227	44
4	Turbo-Prop, 1-Engine/2-Engine	28,591,090	541,039
5	Turbo-Prop, 4-Engine	83,399	2,118
6.1	Jet, 2-Engine, 1-99 seats	42,091,107	1,728,492
6.2	Jet, 2-Engine, 100-149 seats	82,965,874	7,095,221
6.3	Jet, 2-Engine, 150-199 seats	28,356,018	3,530,172
6.4	Jet, 2-Engine, 200+ seats	7,105,435	1,310,968
7.1	Jet, 3-Engine, 1-99 seats	18,454	467
7.2	Jet, 3-Engine, 100-149 seats	9,998,032	901,465
7.3	Jet, 3-Engine, 150-199 seats	2,371	73
7.4	Jet, 3-Engine, 200+ seats	2,516,585	488,286
8.1	Jet, 4-Engine/6-Engine, 1-99 seats	1,313,716	60,175
8.2	Jet, 4-Engine/6-Engine, 100-199 seats	57,114	4,109
8.3	Jet, 4-Engine/6-Engine, 200-299 seats	519,571	101,160
8.4	Jet, 4-Engine/6-Engine, 300-399 seats	2,390,793	641,851
8.5	Jet, 4-Engine/6-Engine, 400+ seats	349,804	102,646

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1 April 1990 and 31 March 2013

Table 18: List of aircraft classes used to calculate the ‘aircraft class’ instrument.

The ‘number of seats’ instrument is constructed using the set of ranges presented in Table 19.

Index	Number of seats		Number of flights	Number of pass. ('000)
	Minimum	Maximum		
1	1	4	154,565	138
2	5	9	6,357,313	19,459
3	10	24	6,820,493	59,223
4	25	49	45,616,274	1,325,744
5	50	99	18,200,971	942,394
6	100	149	92,995,676	7,998,435
7	150	199	28,383,733	3,532,606
8	200	299	10,042,170	1,877,605
9	300	399	2,460,001	659,001
10	400	499	380,017	108,303

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1 April 1990 and 31 March 2013

Table 19: List of ranges used to calculate the ‘number of seats’ instrument.

The ‘distance’ instrument is constructed using the set of ranges of distance flown in miles presented in Table 20. A handful of flight segments in the data are longer than 10,000 miles; these are simply excluded.

Index	Distance (miles)		Number of flights	Number of pass. ('000)
	Minimum	Maximum		
1	0	100	13,186,645	235,231
2	100	250	40,272,006	1,880,905
3	250	400	37,004,129	2,232,524
4	400	550	24,659,270	1,751,100
5	550	700	20,449,501	1,591,331
6	700	850	13,343,155	1,096,692
7	850	1,000	14,322,146	1,364,480
8	1,000	1,250	15,009,701	1,551,327
9	1,250	1,500	6,944,294	769,536
10	1,500	1,750	7,417,769	926,418
11	1,750	2,000	3,453,194	442,532
12	2,000	2,500	5,257,621	702,708
13	2,500	3,000	1,923,468	297,109
14	3,000	3,500	984,534	183,279
15	3,500	4,000	1,936,888	382,792
16	4,000	4,500	1,740,967	353,673
17	4,500	5,000	927,054	176,041
18	5,000	6,000	1,373,630	320,918
19	6,000	7,000	762,452	187,388
20	7,000	8,000	249,216	63,779
21	8,000	9,000	55,414	11,365
22	9,000	10,000	6,471	626

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1 April 1990 and 31 March 2013

Table 20: List of distance ranges used to calculate the ‘distance’ instrument.

B Alternative TSLS specifications

Table 21 presents the results for the TSLS estimation of (9) and (10) with different selections of fixed effects and controls. Column 1 uses no fixed effects and no controls for the initial number of flights or employment. Columns 2 through 4 add the year and CBSA fixed effects. Columns 5 through 7 add the controls for initial levels of air traffic and employment.

The results in Table 21 suggest that the inclusion of year and CBSA fixed effects are important for the estimation, but that the initial number of flights and employment controls make little difference. Without the fixed effects the instruments are far stronger, suggesting idiosyncratic differences between years and CBSAs. In particular, not including the year fixed effects leads to far stronger instruments and a larger coefficient in the second stage. This is likely due to changes in the US economy that influence both the instruments and employment changes, which makes the year fixed effects necessary. Not including the CBSA fixed effects also leads to stronger instruments but somewhat smaller coefficients in the second stage. The controls for initial air traffic and

employment make little difference to the estimates in either the first or the second stage.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. First-stage estimation.							
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$	0.148 ^a	0.151 ^a	0.154 ^a	0.156 ^a	0.159 ^a	0.157 ^a	0.160 ^a
(‘airline’ instrument)	(0.044)	(0.044)	(0.047)	(0.047)	(0.043)	(0.047)	(0.043)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$	0.186 ^a	0.195 ^a	0.166 ^a	0.186 ^a	0.328 ^a	0.187 ^a	0.335 ^a
(‘aircraft class’ instrument)	(0.058)	(0.065)	(0.061)	(0.069)	(0.065)	(0.069)	(0.064)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$	0.802 ^a	0.837 ^a	0.669 ^a	0.657 ^a	0.383 ^c	0.659 ^a	0.380 ^c
(‘distance’ instrument)	(0.092)	(0.106)	(0.125)	(0.213)	(0.208)	(0.212)	(0.205)
$\ln(a_{m,t})$					-0.217 ^a		-0.224 ^a
					(0.030)		(0.030)
$\ln(emp_{m,t})$						0.099 ^c	0.231 ^a
						(0.054)	(0.047)
R^2	0.21	0.23	0.22	0.24	0.34	0.24	0.34
Panel B. Second-stage estimation. Instrumental variable categories: airline, aircraft class, and distance.							
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.080 ^a	0.097 ^a	0.018 ^a	0.029 ^a	0.031 ^a	0.027 ^a	0.029 ^a
	(0.008)	(0.009)	(0.006)	(0.009)	(0.009)	(0.008)	(0.008)
$\ln(a_{m,t})$					-0.001		0.001
					(0.002)		(0.002)
$\ln(emp_{m,t})$						-0.089 ^a	-0.089 ^a
						(0.007)	(0.007)
First-stage statistic	138.60	107.71	36.39	16.63	23.32	16.76	24.33
Overid. p -value	0.05	0.01	0.22	0.42	0.34	0.38	0.41
Hausman test p -value	0.00	0.00	0.25	0.02	0.00	0.05	0.01
CBSA fixed effects		Y		Y	Y	Y	Y
Year fixed effects			Y	Y	Y	Y	Y
Note: 4,026 observations for each regression, representing 183 CBSAs; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size							

Table 21: TSLS results with and without the year and CBSA fixed effects and the controls for the initial levels of airport size and employment.

C Ticket prices

Increased traffic at an airport can be related to increased competition and therefore lower ticket prices. If the measured effect of airport size on local employment is actually due to the change in prices rather than increased schedules, then the interpretation would be different. To evaluate to which degree the results reflect the effect of ticket prices, Table 22 reproduces the main results using the instruments based on the number of flights but otherwise uses ticket prices in place of airport size. The first-stage results are presented in Panel A and the second-stage results in Panel B. Two measures of ticket prices are used: columns 1 to 4 use the mean fare per ticket that originates or terminates at the airport; columns 5 to 8 use the mean fare per mile of those tickets.

The analysis in Table 22 uses the DB1B ticket data from the BTS, which includes information about ticket prices and is available from January 1993. Three smaller CBSAs had no ticket-price information for some years and were therefore excluded, leaving a sample of 180 CBSAs.

Ticket-price measure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean fare per ticket				Mean fare per mile			
Panel A. First-stage estimation.								
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘airline’ instrument)	-0.003 (0.006)			-0.002 (0.006)	0.002 (0.005)			0.002 (0.005)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘aircraft class’ instrument)		-0.040 ^b (0.018)		-0.075 ^a (0.022)		-0.019 (0.016)		-0.035 ^c (0.019)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘distance’ instrument)			0.020 (0.035)	0.116 ^a (0.044)			0.005 (0.034)	0.047 (0.043)
$\ln(price_{m,t})$	-0.238 ^a (0.016)	-0.238 ^a (0.016)	-0.237 ^a (0.016)	-0.236 ^a (0.016)	-0.238 ^a (0.017)	-0.239 ^a (0.017)	-0.239 ^a (0.017)	-0.237 ^a (0.017)
$\ln(emp_{m,t})$	0.033 ^c (0.020)	0.033 ^c (0.020)	0.033 ^c (0.020)	0.033 ^c (0.020)	0.041 ^b (0.019)	0.041 ^b (0.019)	0.041 ^b (0.019)	0.041 ^b (0.019)
R^2	0.45	0.45	0.45	0.46	0.50	0.50	0.50	0.50
Panel B. Second-stage estimation.								
$\ln(price_{m,t+1}) - \ln(price_{m,t})$	-1.599 (3.486)	-0.393 ^c (0.236)	1.576 (2.920)	-0.099 (0.106)	2.417 (7.223)	-0.785 (0.694)	6.268 (43.809)	-0.119 (0.227)
$\ln(price_{m,t})$	-0.364 (0.827)	-0.078 (0.057)	0.390 (0.695)	-0.008 (0.025)	0.595 (1.730)	-0.170 (0.167)	1.514 (10.462)	-0.011 (0.054)
$\ln(emp_{m,t})$	-0.044 (0.120)	-0.084 ^a (0.014)	-0.149 (0.101)	-0.094 ^a (0.009)	-0.197 (0.299)	-0.066 ^b (0.034)	-0.354 (1.789)	-0.093 ^a (0.013)
First-stage statistic	0.23	4.93	0.32	4.12	0.12	1.56	0.02	1.17
Overid. p -value				0.00				0.00
Hausman test p -value	0.01	0.01	0.00	0.40	0.01	0.01	0.00	0.96

Note: 3,420 observations for each regression, representing 180 CBSAs; robust standard errors in parentheses;
 a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size

Table 22: TSLS results with ticket prices used as the dependent variable in the first stage and as the endogenous regressor in the second stage.

The results in Table 22 suggest a weak relationship, if any, between the instruments and ticket prices. The first-stage results indicate that only one of the instruments explains a significant amount of variation in one of the measures of ticket prices. Furthermore, the second-stage coefficient on the change in ticket prices in that case is somewhat negative, indicating that the measured effect of airport size on employment is not capturing an effect of decreased ticket prices. The variation in airport size explained by the instruments therefore appears not to drive significant changes in ticket prices. Though one would normally expect traffic and ticket prices to be related, the lack of a relationship could be an indication that the type of variation explained by the instruments is not related to ticket prices.

D Alternative shares for instrument calculation

A potential concern about the instruments is that the share for each category is calculated at the beginning of each period and these shares may change in some way that correlates with economic growth. To address this concern, Table 23 reproduces the main estimates for the effect of airport size on employment using two alternative sets of category shares in the calculation of the instruments. The first is the shares at the respective airports in 1991. The second is the shares calculated on aggregate traffic from 1991 to 2013. Naturally, neither of these sets of shares changes over the period of the data for a given airport. Therefore, any systematic relationship between say initial airline shares and employment growth should be captured in the CBSA-level fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Base year for instruments	1991	1991	1991	1991	All yrs	All yrs	All yrs	All yrs
Panel A. First-stage estimation.								
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘airline’ instrument)	0.259 ^a (0.078)			0.143 ^b (0.056)	0.250 ^a (0.055)			0.173 ^a (0.043)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘aircraft class’ instrument)		0.205 ^a (0.034)		0.051 ^b (0.022)		0.585 ^a (0.064)		0.248 ^a (0.060)
$\ln(\hat{a}_{m,t+1}) - \ln(a_{m,t})$ (‘distance’ instrument)			1.120 ^a (0.117)	0.979 ^a (0.145)			1.134 ^a (0.118)	0.684 ^a (0.131)
$\ln(a_{m,t})$	-0.047 ^a (0.010)	-0.038 ^a (0.010)	-0.044 ^a (0.010)	-0.053 ^a (0.010)	-0.039 ^a (0.010)	-0.040 ^a (0.010)	-0.044 ^a (0.010)	-0.044 ^a (0.010)
$\ln(emp_{m,t})$	0.050 ^a (0.010)	0.043 ^a (0.010)	0.045 ^a (0.009)	0.055 ^a (0.010)	0.040 ^a (0.009)	0.044 ^a (0.009)	0.045 ^a (0.009)	0.045 ^a (0.009)
R^2	0.18	0.17	0.22	0.24	0.20	0.21	0.22	0.25
Panel B. Second-stage estimation. Instrumental variable categories: airline, aircraft class, and distance.								
$\ln(a_{m,t+1}) - \ln(a_{m,t})$	0.038 ^b (0.016)	0.018 (0.018)	0.015 (0.010)	0.021 ^b (0.010)	0.027 ^a (0.010)	0.018 ^c (0.010)	0.014 (0.010)	0.021 ^a (0.007)
$\ln(a_{m,t})$	0.004 (0.004)	-0.002 (0.004)	-0.002 (0.003)	-0.000 (0.003)	0.001 (0.003)	-0.001 (0.003)	-0.002 (0.003)	-0.001 (0.002)
$\ln(emp_{m,t})$	-0.095 ^a (0.008)	-0.087 ^a (0.008)	-0.086 ^a (0.007)	-0.091 ^a (0.008)	-0.089 ^a (0.007)	-0.087 ^a (0.007)	-0.086 ^a (0.007)	-0.088 ^a (0.007)
First-stage statistic	8.44	25.39	23.31	17.10	18.30	61.55	23.84	29.83
Overid. p -value				0.45				0.56
Hausman test p -value	0.07	0.65	0.59	0.19	0.05	0.40	0.67	0.08
Number of observations	3,738	4,017	4,026	3,738	4,025	4,026	4,026	4,025
Note: 183 CBSAs for each regression; robust standard errors in parentheses; a , b , c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include CBSA and year fixed effects								

Table 23: TSLS results for the effect of the number of flights on employment using 1991 shares and the shares on all years in the calculation of the instruments.

The results in Table 23 are consistent with the main results presented above, indicating that the results are not an artifact of the changes in the shares. Some values of the instruments calculated

using the 1991 shares are missing for later years, as in those years the airports hosted only airlines or aircraft types that had not been in operation in 1991.

The F -statistics for the instruments in Table 23 are similar in magnitude to those in the main results, so the instruments remain strong with this type of specification. The coefficients on airport size in the second stage are somewhat smaller in Table 23 than in the main results, which is consistent with airport size affecting employment and these shares generating instruments that explain less of the relevant variation in airport sizes. Nevertheless, the coefficients are significant and positive when using these alternative instruments.

E Industry classification from SIC and NAICS codes

Table 24 presents the classification of the employment data from the County Business Patterns into industries according to the SIC and NAICS codes.

Industry	SIC codes	NAICS codes
Construction	15-17 ("Construction")	23 ("Construction")
Manufacturing	20-39 ("Manufacturing") 50-51 ("Wholesale Trade")	31-33 ("Manufacturing") 42 ("Wholesale Trade")
Retail trade	52-59 ("Retail Trade")	44-45 ("Retail Trade")
Transportation	40-49 ("Transportation & Public Utilities")	22 ("Utilities") 48-49 ("Transportation and Warehousing")
Services	60-67 ("Finance, Insurance, Real Estate") 70-89 ("Services")	51 ("Information") 52 ("Finance and Insurance") 53 ("Real Estate and Rental and Leasing") 54 ("Professional, Scientific, and Technical Services") 55 ("Management of Companies and Enterprises") 56 ("Administrative and Support Services") 81 ("Other Services (except Public Administration)")

Table 24: Industry definitions from the two-digit SIC and NAICS classifications.