Airports and Urban Sectoral Employment*

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Abstract

This paper estimates the effects of airport infrastructure on relative sectoral employment at the metropolitan-area level, using data from the United States. To address the potential endogeneity in the determination of airport sizes, the 1944 National Airport Plan is used to instrument for the current distribution of airports. Airport size is found to have a positive effect on the employment share of tradable services, controlling for overall local employment, but no measurable effect on manufacturing or most non-tradable sectors. The effect of airport size on overall local employment is practically zero, suggesting that airports lead to specialization but not growth at the metropolitan-area level. The implied elasticity of tradable-service employment with respect to airport size is approximately 0.22. The results are relevant to the evaluation of airport construction or improvement projects that aim to benefit the local economy by making travel to and from the metropolitan area more convenient.

Keywords: air travel, services trade, transportation infrastructure

JEL classification: F14, H54, R41

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1 Introduction

Passenger aviation is dependent for its operation on an extensive network of airports that allow flights to take off and land, the storage and maintenance of aircraft, and passengers to transfer to other modes of transportation. Airports are costly to construct and the land they occupy has a sizable opportunity cost. The construction or improvement of airports is commonly financed by public funds and arguments made for the expansion of airport capacity regularly cite the effects on the local economy, suggesting a perceived public interest in the quality of the local air connection.[1] It remains unclear, however, whether airports actually attract activity to the local area or whether cities with stronger growth or larger service sectors simply have larger airports in response to demand for air travel. The lack of natural experiments or other obvious sources of exogenous variation makes it difficult to measure the effects of airports on local employment and other economic outcomes and as a result these effects have not been reliably quantified.

This paper estimates the effects of airport infrastructure on the employment shares of particular sectors at the metropolitan-area level. That is, the primary aim is to determine the effects of airports on relative employment in those sectors. To relate these effects to absolute numbers of employees, an attempt is made to estimate the effect of airports on overall local employment. The analysis is conducted for metropolitan areas in the United States of America (henceforth the "US") and uses passenger air traffic as the measure of airport size. To address the problem of airport sizes being determined by factors endogenous to sectoral composition, the analysis uses the 1944 National Airport Plan to instrument for airport sizes in 2007. Sectoral employment is a fundamental outcome variable as it reflects the importance of the air connection for attracting productive activity in specific industries, some of which are the explicit targets of airport development policies. The findings are informative about the effects of airports on the local economy but also contribute to the broader body of research on the effects of transportation infrastructure.

[1]To indicate the replacement value of a major airport and the degree of public funding, Denver International Airport is the most recent major US airport to have been built, opening in 1995, and was constructed at a cost of $4.8 billion, $4.4 billion of which was from public funds (General Accounting Office, 1995). Improvements currently underway to Chicago's O'Hare International Airport are estimated at more than $13 billion (Federal Aviation Administration, 2005). The costs of constructing the proposed new London airport in the Thames Estuary, including the rail link to the city, are currently estimated at £50 billion (Thames Hub team, 2011).

To identify the effect of airports on local sectoral employment, it is necessary to find a source of variation in airport sizes that is otherwise exogenous to local employment shares. The 1944 National Airport Plan satisfies these criteria. It was the first national plan for the US airport network to come into effect and strongly influenced the subsequent development of airports as, since the Civil Aeronautics Act of 1938, inclusion in the most recent version of the National Airport Plan has been a prerequisite for federal spending on airports and updates to the plan are made incrementally. The persistence of sites developed in the past has been ensured by the increasing costs of acquiring land to expand airports or to construct new facilities. In addition, the 1944 National Airport Plan is plausibly exogenous to factors besides airports that influence current productive activities, for two primary reasons. Firstly, the authors stated the criteria they used to plan the allocation of airports and these are unrelated to factors for contemporary or current industry-level production. And secondly, controlling for population and regional differences, the planned airports were uncorrelated with contemporary industry shares.

The effect of airport size on relative employment is estimated for a range of industries including manufacturing, services, construction, and retail and wholesale trade. Airport size is found to have a positive effect on the employment shares of services that could be considered to be 'tradable', but no measurable effect on manufacturing or 'non-tradable' services. Of the remaining sectors, only retail trade appears to be affected by airports.

The interpretation of these results is that air travel facilitates face-to-face contact, aiding the delivery of tradable services, so their production tends to be located in metropolitan areas with larger airports and presumably exported to other places. Manufacturing also involves the production of tradable goods but personal travel plays a less prominent role in their production and delivery, so it has less reason to be located near a large airport and appears not to be affected. Non-tradable products must be produced near their customers, so airport size should not be directly relevant to their location.

To test whether the increase in employment in tradable services represents additional jobs in the metropolitan area or a reallocation of labor from other sectors, a similar technique is used to provisionally estimate the effects of airport size on the employment rate and on the growth in metropolitan-area employment. No significant effect on either outcome is evident. This suggests that the effect of airports on sectoral employment is driven more by the reallocation of labor within a metropolitan area than by changes in the overall level of employment. Metropolitan areas with larger airports specialize in the production of tradable services, but do not increase in size as a result.

Based on the estimated relative coefficients and the effect on overall employment, the elasticity of the absolute number of employees in tradable services with respect to airport size is approximately 0.22. This means that a 10% increase in the air traffic in a metropolitan area with a million residents would lead to around 1,650 additional service jobs.

Despite the vast public spending on airports, only a handful of studies have attempted to measure the effects of airports on the broader economy using techniques that treat the inherent endogeneity in airport size. This type of exercise involves substantial empirical challenges. Unlike other modes of transportation, air travel is barely subject to the constraints of physical geography and its infrastructure is not route-specific. These characteristics make it difficult to identify the effects of airports using the techniques that are applied to other types of transportation infrastructure.

Brueckner (2003) estimates the effect of airports on overall and industry-specific employment in US metropolitan areas using the status of airports as airline hubs and geographical centrality to instrument for air traffic levels. Both instruments have potential weaknesses: 'hub' status implies a substantial increase in traffic but is driven by an endogenous choice on the part of airlines that may respond to sectoral employment, while the 'centrality' instrument is not strong. In contrast, the instrument used in this paper clearly explains a substantial amount of the variation in the current distribution of airports and is more plausibly exogenous to other factors for current employment. However, the results from the two exercises are largely consistent: Brueckner (2003) finds a positive effect of airport size on service employment, with an elasticity somewhat smaller than that found in this paper, and no effect on manufacturing employment.

Other papers estimate the effect of airports on local economic growth. Green (2007) finds that airports have a positive effect on economic growth, though the use of physical airport size and industry-level employment to instrument for air traffic makes the results questionable. Blonigen and Cristea (2012) exploit the 1978 deregulation of the US airline industry as a source of variation in air traffic levels. They find a positive effect of airports on growth, in particular for communities at either end of the size distribution. This paper estimates the effect of airports on growth but, in contrast to these previous studies, finds that the effect of airports on growth is unmeasurably small.

The infrastructure required for air travel differs fundamentally from surface-based transportation in that it is concentrated almost entirely at rather than between the nodes of the network.[2] That said, this paper is related to a broader body of research on the importance of transportation infrastructure. In particular, the identification strategy employed here is informed by recent work on the effects of roads by Baum-Snow (2007), Michaels (2008), Duranton and Turner (2011; 2012), and Duranton, Morrow, and Turner (forthcoming), each of which uses the federal highway plan from 1944 or 1947 to instrument for current roads. Further research includes studies of the effects of railways (Donaldson, forthcoming; Donaldson and Hornbeck, 2011) and ports (Clark, Dollar, and Micco, 2004). Relative to these modes of transportation, air travel is fast for long trips and impractical for short trips. As such, the results presented in this paper reflect a particular type of accessibility, but one that helps to complete the picture of how accessibility affects the local economy.

The analysis proceeds as follows. A simple theoretical model is presented in Section 2 to frame the empirical analysis. The data are described in Section 3, including a detailed description of the 1944 National Airport Plan. Section 4 presents the results of the empirical estimation and a number of robustness checks. Some concluding remarks are presented in Section 5.

2 Model

The model presented here is intended as a simple representation of the mechanisms that explain the current allocation of airports and relate current airports to relative sectoral employment. Consistent with the aims of the paper, the model has multiple sectors and aggregates employment by

[2]This was not always the case. In the early days of flight, regularly-operated routes or 'airways' were marked with bonfires, later replaced by light and then radio beacons, and lined with emergency landing fields (Komons, 1978). Some airfields were constructed primarily as refueling stops for long-haul flights. Modern navigation technology, increased ranges and reliability of aircraft, and the overall prevalence of airfields made these facilities obsolete by the early 1990s (Bilstein, 2001).

metropolitan area. The model derives from the theoretical framework of Redding and Venables (2004) and Duranton, Morrow, and Turner (forthcoming) but is simplified somewhat as the lack of data on trade flows for services necessitates a less detailed treatment of market access. The model therefore represents the delivery of products more crudely, with exporting behavior inferred from the production in a given metropolitan area relative to the size, wealth, and other characteristics of its population.

The set-up of the model is as follows. The economy is comprised of M metropolitan areas, indexed by m, and I industries, indexed by i. Each metropolitan area produces a distinct variety of each industry's product. The sole factor of production is labor, which moves freely between sectors and metropolitan areas and is allocated where it earns the highest real return. Workers each supply a single unit of labor inelastically, derive utility exclusively from consumption, and have identical preferences. The remainder of this section presents the model in detail.

2.1 Consumption

Individuals gain utility from the consumption of the products generated in the economy. Let $x^i_{m,n}$ denote the consumption by an individual in metropolitan area n of the variety produced by industry i in metropolitan area m. All individuals in the economy have identical preferences represented by the following utility function, in which the constant $\sigma > 1$ is the elasticity of substitution:

$$U = \left[\sum_{m=1}^{M} \sum_{i=1}^{I} \left(x^i_{m,n} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

The producer price for industry i in metropolitan area m is denoted p^i_m. Transportation costs are assumed to be of the iceberg variety, with $\tau^i_{m,n} \geq 1$ units of industry i's product shipped from m for every unit that arrives in n, implying a consumer price of $\tau^i_{m,n} p^i_m$ for individuals in n. The number of workers in metropolitan area n is denoted L_n and the local wage is denoted w_n. The overall budget constraint of individuals in metropolitan area n is therefore:

$$\sum_{m=1}^{M} \sum_{i=1}^{I} \tau^i_{m,n} p^i_m x^i_{m,n} \leq w_n L_n \tag{2}$$

The maximization of (1) subject to (2) and prices $\left\{p_m^j\right\}_{j\in\{1,\ldots,I\}}$ yields the demand in metropolitan area n for the variety of industry i's output produced in metropolitan area m, including the amount used to pay for transportation:

$$x_{m,n}^i = \frac{\left(\tau_{m,n}^i\right)^{1-\sigma}\left(p_m^i\right)^{-\sigma}}{P_n^{1-\sigma}} w_n L_n \tag{3}$$

The term P_n is the index of consumer prices faced by individuals in metropolitan area n:

$$P_n = \left[\sum_{m=1}^{M}\sum_{j=1}^{I}\left(\tau_{m,n}^j p_m^j\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{4}$$

Summing (3) over all destinations yields the aggregate demand for the output of industry i in metropolitan area m:

$$X_m^i = \left(p_m^i\right)^{-\sigma}\sum_{n=1}^{M}\frac{\left(\tau_{m,n}^i\right)^{1-\sigma}}{P_n^{1-\sigma}} w_n L_n \tag{5}$$

2.2 Labor allocation

The indirect utility of an individual in metropolitan area m who earns income w_m is defined as the real wage ϖ, which is found by substituting the demand of a single individual (3) and the price index (4) into the utility function (1):

$$\omega = \frac{w_m}{P_m} \tag{6}$$

Labor moves between industries and metropolitan areas to capture any potential advantage in individual utility. The equilibrium distribution of labor therefore requires the real wage (6) to be equal for all workers in the economy, hence the absence of metropolitan area or industry notation for ϖ. As the price index faced by all local residents is identical, the equality of real wages also implies the uniformity of nominal wages within a metropolitan area.

The amount of labor used by industry i in metropolitan area m is denoted L_m^i. The constraint on the allocation of labor within each metropolitan area is simply:

$$\sum_{i=1}^{I} L_m^i \leq L_m \tag{7}$$

2.3 Production

All industries produce using labor as the sole input. The production function has the same form for each industry and metropolitan area:

$$Y_m^i = e^{\frac{1}{\sigma-1}\beta^i Z_m} \cdot L_m^i \tag{8}$$

The term Z_m is a vector of local geographical, climate, and demographic factors that may affect overall industry-level productivity in metropolitan area m. The factors in Z_m influence the local productivity of industry i according to β^i. The wage in metropolitan area m, which must be uniform across industries as local labor markets are competitive, is denoted w_m. Competitive labor markets also imply that labor in each industry receives its marginal product, so producer prices must satisfy:

$$p_m^i = e^{-\frac{1}{\sigma-1}\beta^i Z_m} \cdot w_m \tag{9}$$

2.4 Transportation costs

The transportation cost parameter $\tau_{m,n}^i$ is assumed to be able to be decomposed into three underlying components as follows:

$$\tau_{m,n}^i = \tau_m^i \cdot \tau_{m,n} \cdot \tau_n \tag{10}$$

The origin component $\tau_m^i \equiv t_o^i(a_m) \geq 1$ is specific to industry i and represents the cost of initiating a shipment from m as a function of the aggregate local airport size a_m. The route component $\tau_{m,n} \equiv t_r(d_{m,n}) \geq 1$ reflects the cost of transporting the product between the two metropolitan areas and is dependent on the distance $d_{m,n}$ between m and n. The destination component $\tau_n \equiv t_d \geq 1$ reflects the cost of delivery in n. The latter two components are assumed to be identical for all industries, so the effects of distance and the relevant infrastructure on these parts of the route are uniform across industries.[3]

The origin component $\tau_m^i \equiv t_o^i(a_m)$ is assumed to take the following specific functional form in terms of airport size:

$$\tau_m^i \equiv t_o^i\left(q_m^i\right) = \left(a_m\right)^{\frac{\theta^i}{1-\sigma}} \tag{11}$$

The parameter $\theta^i \geq 0$ defines the degree to which passenger air travel is used in the delivery of industry i's products. The levels of a_m are normalized to be a fraction of the maximum aggregate airport size, to ensure that $\tau_m^i \geq 1$. For simplicity, surface-transportation infrastructure is not treated explicitly, but rather the cost of shipping products by land is assumed to be captured by the distance between the origin and the destination. Though roads and railways naturally affect transportation costs, the importance of say road type or the number of lanes is not so clear, and the lack of data on trade flows means that a more detailed treatment would be of limited use.[4] To check the sensitivity of the results to the inclusion of this type of infrastructure, the effects of roads and ports in the origin metropolitan area are explored in the robustness checks.

2.5 Equilibrium

Setting demand (5) equal to supply (8) and substituting in the expressions for the real wage (6), producer prices (9), and the transportation cost (10) yields the following expression for employment in industry i in metropolitan area m:

$$L_m^i = e^{\beta^i Z_m}\left(\tau_m^i\right)^{1-\sigma} \varpi^{1-\sigma} \sum_{n=1}^{M} \left(\tau_{m,n} \cdot \tau_n\right)^{1-\sigma} \left(\frac{w_n}{w_m}\right)^{\sigma} L_n \tag{12}$$

Substituting the decomposition of the origin transportation costs (11) into (12) and collecting everything that is invariant in i into the term $\Omega_m \equiv \varpi^{1-\sigma} \sum_{n=1}^{M} \left(\tau_{m,n} \cdot \tau_n\right)^{1-\sigma} \left(\frac{w_n}{w_m}\right)^{\sigma} L_n$:

[3] The size of the destination airport is assumed not to influence the transportation costs. This assumption is necessitated by the lack of data on trade flows, which rules out fitting the sizes of the destination airports in the final estimation equation. However, the set of potential destination airports is similar for each origin airport, differing only by the origin airport itself that is absent in each case. Accessibility depends on an aggregate of the distances to and sizes of all potential destinations. Therefore, as there are many hundreds of airports in the network, not modeling the sizes of destination airports is unlikely to imply a substantial bias in the measure of accessibility by origin.

[4] In any case, Duranton, Morrow, and Turner (forthcoming) show that a monotonic function of distance is a decent, if imperfect, approximation for the costs of road transportation in the US.

$$L_m^i = e^{\beta^i Z_m} (a_m)^{\theta^i} \Omega_m \tag{13}$$

To proceed from here it is convenient to introduce a reference sector with parameters $\bar{\beta}$ and $\bar{\theta}$ that reflect the mean effects of local productivity factors and airports across all industries such that:

$$L_m = \sum_{j=1}^{I} e^{\beta^j Z_m} (a_m)^{\theta^j} \Omega_m = e^{\bar{\beta} Z_m} (a_m)^{\bar{\theta}} \Omega_m \tag{14}$$

Dividing each side of (13) by the respective side of (14) yields an expression for the proportion of workers in metropolitan area m who are employed by industry i, as a function of local productivity factors and transportation infrastructure:

$$\frac{L_m^i}{L_m} = \frac{e^{\beta^i Z_m} (a_m)^{\theta^i}}{e^{\bar{\beta} Z_m} (a_m)^{\bar{\theta}}} \tag{15}$$

Taking logs of both sides of (15) yields the following linear relationship between the employment share of industry i in metropolitan area m and the underlying factors:

$$\ln\left(\frac{L_m^i}{L_m}\right) = \left[\theta^i - \bar{\theta}\right] \ln(a_m) + \left[\beta^i - \bar{\beta}\right] Z_m \tag{16}$$

Equation (16) is the basic form of the relationship between industry-level employment and the underlying factors that is estimated below. As the airport size a_m may be influenced by the concentration of particular industries, it is instrumented for using the 1944 National Airport Plan. In the following the normalized coefficients $\tilde{\theta}_2^i \equiv \theta^i - \bar{\theta}$ and $\tilde{\beta}_2^i \equiv \beta^i - \bar{\beta}$ are used, which reflect the effect of each factor on industry i relative to the overall effect on all industries.

The assumption of the existence of the reference sector described in (14) implies that the employment shares of industries in (15) are scale-independent, in the sense that an exogenous change in overall employment would not change the industry shares. As this could be restrictive, a control for aggregate employment is introduced to address the potential bias from metropolitan-area sizes being correlated with the concentration of certain industries.

2.6 System of equations to be estimated

The model is estimated in two stages. The first stage fits a reduced-form equation that uses the 1944 National Airport Plan to predict the aggregate sizes of airports in 2007. The second stage takes these predicted airport sizes and estimates their effect on contemporary industry shares, using the relationship derived in (16). A constant term, 2007 aggregate employment L_m, and extensive controls for geography, climate, and demographic factors, as the local productivity factors Z_m, are included in each expression. To distinguish the two cross sections of airport data, the notation $a_{m,1944}$ is used to denote the value of the airports planned in 1944 for metropolitan area m. The system of equations that is estimated is the following:

$$\ln(a_m) = \alpha_1 + \xi_1 \ln(a_{m,1944}) + \lambda_1 \ln(L_m) + \beta_1 Z_m + \varepsilon_{1,m} \tag{17}$$

$$\ln\left(\frac{L_m^i}{L_m}\right) = \alpha_2^i + \tilde{\theta}_2^i \ln(a_m) + \lambda_2^i \ln(L_m) + \tilde{\beta}_2^i Z_m + \varepsilon_{2,m}^i \tag{18}$$

The measure of airport size in (18) is the absolute level of traffic while employment in industry i is measured as a proportion of total employment in m. The relationship is scaled in this way because the level of traffic is intended to represent the convenience of delivering a unit of those products that make use of passenger air travel. As such, it is not the number of departures or seats per resident that is important, but rather the convenience of the set of available schedules. The latter is reflected by the breadth of destinations and the frequency of departures, which are combined in the number of departing flights.

The estimation of (17) and (18) uses controls for aggregate employment, as discussed above. The system therefore represents the effects on the employment shares controlling for the level of overall employment, and the results should be interpreted as such. In the event that overall CBSA employment L_m is constant, the coefficient $\tilde{\theta}_2^i$ represents the elasticity of local employment in industry i with respect to airport size a_m.

For the effect of air travel on sectoral employment to be identified by (17) and (18), the following conditions must be satisfied:

$$\xi_1 \neq 0 \tag{19}$$

$$Corr\left(a_{m,1944}, \varepsilon^{i}_{2,m}\right) = 0 \tag{20}$$

The first of these is the relevance condition (19), which requires that the number of planned airports in 1944 explain a significant amount of the variation in the level of air traffic in 2007, given the controls. This condition is verified by running weak identification tests.

The second condition is the exogeneity condition or exclusion restriction (20), which requires that the planned airports affect current sectoral employment only through their effect on current airport size. If this condition is violated, the estimated coefficient on a_m will be inconsistent. Though it is not possible to test this condition statistically, there are several reasons to believe that it is satisfied by the 1944 National Airport Plan, which are detailed in the following section.

3 Data

The empirical analysis in this paper uses US data compiled from several sources and aggregated by Core Based Statistical Area (CBSA) using the November 2007 definitions. CBSAs are defined by the Office of Management and Budget as contiguous groups of counties, where each group represents an urban core and surrounding areas with which it is highly integrated. The sample is limited to CBSAs in the 48 contiguous states and the District of Columbia. The sample is further restricted to CBSAs that hosted at least 1,000 departures of passenger flights in 2007, which excludes many smaller communities that are apparently served by larger airports outside of the CBSA boundaries. This leaves 290 CBSAs, which represent approximately 75% of the US population.

The population figures in the dataset are from the decennial census conducted by the United States Census Bureau for each of the relevant years. The information about existing and proposed airports in 1944 is from the National Airport Plan of that year authored by the Civil Aeronautics Administration, which is explained in detail below. The airport traffic levels in 2007 are from the T-100 segment data from the US Bureau of Transportation Statistics. The employment figures are from the 2007 County Business Patterns. The 1940 and 1950 demographic variables are from the 1950 Census and the 2007 demographic variables are from the USA Counties database. The geographical and climate data are from the relevant federal agencies. Table 1 gives a summary of the land area, population, and airport statistics.

	Mean	Std. dev.	Minimum	Maximum
Land area (square miles)	3,159	3,115	211	27,555
1940 population	288,239	861,440	4,745	11,950,188
2010 population	801,384	1,761,345	17,398	18,897,084
Number of existing airports in 1944	4.9	6.0	0	44
Number of proposed airports in 1944	9.5	12.3	1	123
Number of commercial airports in 2007	1.8	1.6	1	15
Number of departing flights in 2007	33,314	81,970	1,003	633,633
Number of departing passengers in 2007	2,568,816	7,299,862	1,898	56,404,489
Number of destinations in 2007	16	31	1	186

Note: 290 observations of each variable

Table 1: Summary of the land area, 1940 and 2010 population, and airport variables in the dataset by CBSA.

Table 1 displays summary statistics for a number of CBSA-level airport measures. The first of these are the numbers of existing and proposed airports in the 1944 National Airport Plan. The remaining measures are the number of airports that host passenger flights, the number of departing passenger flights, the number of departing passengers, and the number of destination airports flown to at least daily in 2007.

The measure of airport size in 2007 used in the analysis is the number of departing flights, which is intended to represent both the amount of physical infrastructure and the accessibility of the location via air travel. These concepts are closely related. Capacity constraints and the high cost of construction lead to a close relationship between the physical size of an airport and the level of traffic, as demonstrated in Appendix A. The number of flights reflects accessibility as it combines the number of destinations with the frequency of flights to those destinations, the latter capturing both the convenience of schedules and the downward pressure on prices that results from competition.

The employment data from the 2007 County Business Patterns are the numbers of employees in a selection of 2-digit North American Industry Classification System (NAICS) industries and the total number of employees for each CBSA. Table 2 gives a summary of these employment variables along with the labor force figures from the Bureau of Labor Statistics.[5] All industries that represent at least 1% of overall employment are included in the sample and these industries represent 98.7% of total employment in the sample CBSAs.[6] For a small proportion of CBSA-industry pairs the employment figures are suppressed in the County Business Patterns; in each such case the suppressed value was estimated from the number of establishments and overall county and industry-level employment using the method described in Appendix B.[7]

Employment by industry in 2007	Mean	Std. dev.	Minimum	Maximum
Construction (23)	20,221	41,023	201	354,663
Manufacturing (31-33)	30,757	64,163	99	622,376
Wholesale Trade (42)	17,156	45,348	77	490,563
Retail Trade (44-45)	41,727	84,959	1,040	860,243
Transportation and Warehousing (48-49)	12,005	28,958	74	304,050
Information (51)	10,177	29,199	69	322,194
Finance and Insurance (52)	19,417	52,054	134	633,580
Real Estate and Rental and Leasing (53)	6,556	16,991	97	183,952
Professional, Scientific, and Technical Services (54)	24,413	68,843	115	680,488
Management of Companies and Enterprises (55)	9,380	25,765	0	266,890
Administrative and Support and Waste and Rem. Services (56)	23,478	55,366	45	514,641
Educational Services (61)	8,655	24,717	12	285,044
Health Care and Social Assistance (62)	44,631	101,010	1,086	1,250,642
Arts, Entertainment, and Recreation (71)	5,614	13,612	67	144,558
Accommodation and Food Services (72)	31,321	62,351	621	532,150
Other Services (except Public Administration) (81)	15,286	34,370	191	364,122
Total employment	324,897	733,181	4,643	7,671,171
Labor force	340,176	767,628	5,021	8,024,387

Note: 290 observations of each variable; the employment figures are the numbers of employees during the week including March 12th, 2007

Table 2: Summary of the 2007 CBSA-level employment variables.

The analysis distinguishes between 'tradable' and 'non-tradable' industries. An industry is considered to be 'tradable' if a substantial proportion of its output can feasibly be produced in one location and consumed in another. This includes *manufacturing* (31-33) and the group of service industries hereafter referred to as *tradable services* (51-54). For comparison, these are analyzed alongside the industry referred to as *non-tradable services* (81). The second part of the analysis

[5]The labor force in each CBSA is calculated as the aggregate employment in the County Business Patterns divided by one minus the unemployment rate published by the Bureau of Labor Statistics. Though the Bureau of Labor Statistics publishes labor force statistics, the employment figures it publishes do not match those in the County Business Patterns, so this approach is used to maintain a common basis.

[6]The 2-digit NAICS industries not included are industries 11 ("Agriculture, Forestry, Fishing and Hunting"), 21 ("Mining, Quarrying, and Oil and Gas Extraction"), and 22 ("Utilities").

[7]The highest proportions of suppressed employment figures by industry are 17.0% for industry 55 ("Management of Companies and Enterprises"), 6.1% for industry 61 ("Educational Services"), and 5.3% for industry 51 ("Information"). For all other industries the proportion of CBSAs for which the values are suppressed is less than 2%.

treats the service sectors 51 to 56 individually. The third part of the analysis investigates the eight remaining 2-digit NAICS industries featured in Table 2. The determination of which industries are 'tradable' or 'non-tradable' is detailed in Appendix C.

The employment data exhibit a positive correlation between the size of a CBSA in terms of total employment and the employment share of tradable services, so larger metropolitan areas tend to have larger concentrations of these types of services. This is part of the reason why the estimation of (18) is run using a control for total employment. For manufacturing and non-tradable services, no such correlation exists. These relationships are plotted in Appendix D.

The elevation data, used to calculate the 'elevation' and 'ruggedness' variables, are from the National Elevation Dataset of the United States Geological Survey.[8] The annual heating and cooling degree days and the average wind speed are from the National Oceanic and Atmospheric Administration.

A map of the 290 CBSAs included in the sample and the proposed airports in the 1944 National Airport Plan is shown in Figure 1. The map makes clear that the sample CBSAs include populated areas in all parts of the contiguous US. Indeed, the 290 CBSAs include parts of all 48 of the contiguous states and the District of Columbia. The airports in the 1944 National Airport Plan are also spread across the country, the only obvious geographical bias being for more densely-populated areas. A map of the sample CBSAs and commercial airports in 2007 is shown in Figure 2. From this map it is clear that the sample includes all of the larger airports in the contiguous US.

[8]The elevation variable is measured at the midpoint of the CBSA, defined as the mean location of the 2010 population. The ruggedness variable is calculated as the standard deviation of the elevations of an array of points including the midpoint and eight evenly-spaced points on each of two circles centered on the midpoint: one with a radius of three miles and the second with a radius of ten miles.

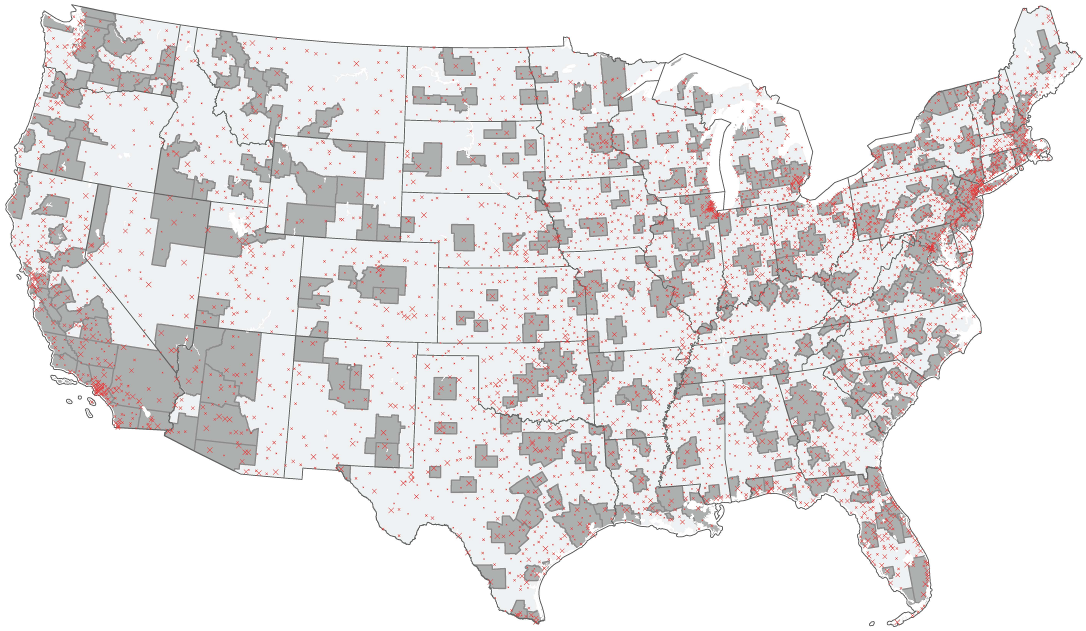

Figure 1: Map of the 290 CBSAs in the sample (shaded) and the proposed airports in the 1944 National Airport Plan (marked with crosses, the sizes of which reflect the specified airport classes).

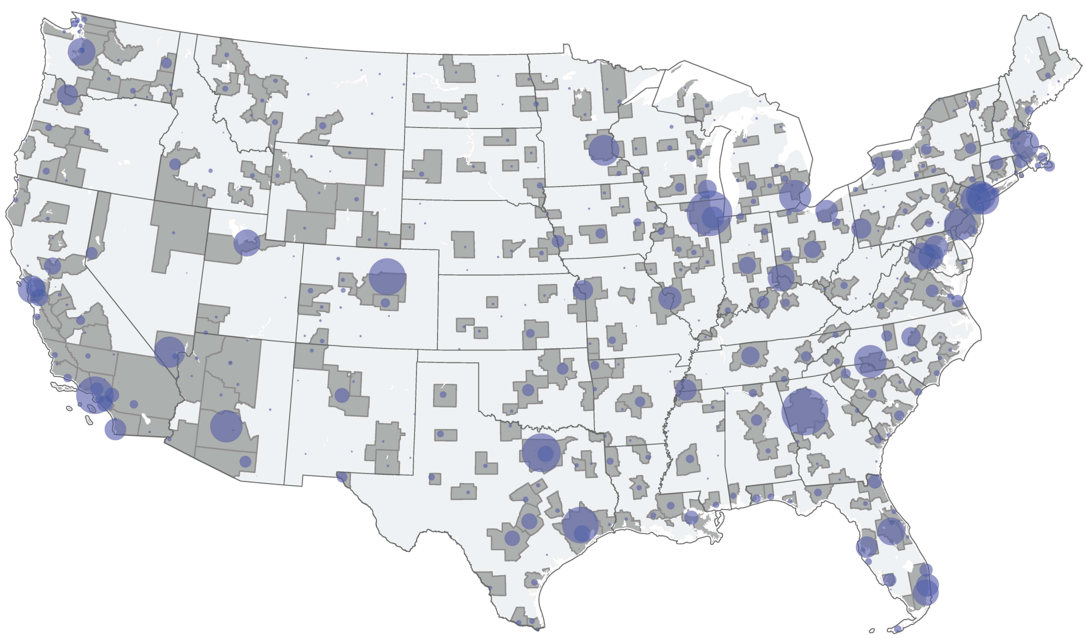

Figure 2: Map of the 290 CBSAs in the sample (shaded) and commercial airports in 2007 (shaded circles, with diameters proportional to the numbers of departing passenger flights in 2007).

3.1 1944 National Airport Plan

The empirical strategy used in this paper involves instrumenting for air traffic in each metropolitan area in 2007 using the 1944 National Airport Plan of the Civil Aeronautics Administration (CAA). This was the first national plan for the US air travel network to be approved by Congress, after the Civil Aeronautics Act of 1938 established the CAA, directed it to author a plan for the nation's airports, and specified that federal funds could only be used for airports in the most recently-approved version of the plan. Federal funds were to cover up to half the costs of all but the very largest of these projects, for which local governments were to take a larger share.[9]

The 1944 National Airport Plan (for the remainder of this section, the "Plan") lists 6,305 proposed airports in the 48 contiguous states and the District of Columbia. 2,950 of the airports were existing facilities and 3,355 were to be newly built. Of the existing airports, 491 were to be improved and 72 downgraded. The location of each airport is given as the name of the nearest town or city and in some cases as the actual facility. These locations were converted into ZIP codes used to assign the airports to 2007 CBSAs. The current and proposed airport sizes are given as a class on an increasing scale from 1 to 5: class 1 airports were appropriate only for private or other small aircraft; class 5 airports had capacity for the largest aircraft then in operation as well as those anticipated for the coming years.[10] Table 3 summarizes the numbers of airports in the Plan by class.

		Planned airports by class specified in the 1944 National Airport Plan					
Airport class	Existing in 1944	At same class	Improved	Down-graded	New facilities	Total proposed	Imputed value per airport ($)
1	988	636	-	40	1,921	2,597	68,641
2	807	673	299	29	1,197	2,198	277,784
3	441	386	127	3	138	654	748,697
4	408	389	52	0	79	520	1,032,047
5	306	303	13	-	20	336	2,412,832
Total	2,950	2,387	491	72	3,355	6,305	

Table 3: Numbers of existing and proposed airports by class in the 1944 National Airport Plan and imputed value of each class of airport.

The Plan specifies projected improvement costs, but gives only the broad 'class' category for the

[9]The federal shares of projects of different sizes were established by the Federal Airport Act, which was passed along with the 1944 National Airport Plan in 1946 (Wilson, 1979).

[10]For more detail on how the airport classes are defined, see the introductory text of the 1944 National Airport Plan and Chapter 1 of Wilson (1979).

existing and proposed sizes of each facility. The class categories are a coarse and apparently non-linear measure of the actual amount of infrastructure. To obtain a more meaningful measure of the proposed airport sizes, the projected improvement costs are used to impute the replacement value of a representative airport of each class. These values are displayed in the rightmost column of Table 3 and the technique used to derive them is detailed in Appendix E. The imputed replacement values are then applied as the value of each existing airport according to the specified class, to which the projected improvement costs are added to obtain an estimate of the proposed value of each completed airport.

To be a relevant instrument, satisfying condition (19), the Plan must explain a significant amount of the variation in 2007 air traffic levels. This is reasonable due to the importance of the Plan in determining which airports would be developed and the persistence in airport locations. Though the approval of funds in principle did not always lead to improvements being made, much of the airport construction in the decades following the Second World War was conducted according to the Plan. The US air network grew rapidly during this period.[11] The large fixed investment involved in establishing a new airport, not least to acquire a substantial amount of ever-scarcer land, creates persistence in airport locations (Redding, Sturm, and Wolf, 2011).[12] The F-statistics from the weak identification tests are sufficiently large for the instrument to satisfy the relevance condition (19). In addition, a survey of current airports indicates that, at least of the larger airports in the Plan, the vast majority were eventually built.[13]

The exogeneity condition or exclusion restriction (20) requires that the instrument affect industry shares only through the allocation of airports, conditional on the controls. The Plan credibly satisfies this condition for four principal reasons. Firstly, the stated criteria for the selection of sites, detailed in Appendix F, are not related to sectoral composition or factors for the future growth of particular sectors. Secondly, the Plan was drawn up after only preliminary consultation with state and local governments (Wilson, 1979), minimizing the possibilities for local politicians and busi-

[11]In 1941 there were fewer than 2,500 airfields of all types in the US. By the end of 1945 there were around 4,000 and by 1955 there were nearly 7,000 Federal Aviation Agency (1960).

[12]Indeed, with few exceptions, the current major US airports had already been established as airfields by the late 1940s (Daley Bednarek, 2001).

[13]The Plan specifies 99 class-4 and -5 airports to be built on new sites. In 2011, airports had been built on 80 of these 99 sites.

nesses to influence the distribution of airports to suit particular industries. Thirdly, air travel was at an early stage of development in 1944 and its extent, manner, and cost were vastly different from today (Bilstein, 2001), so even if the Plan had been intended to reflect future growth or industrial composition its relation to current needs would be limited. Fourthly, with basic controls, the data show no significant relationship between airports in the Plan and contemporary demographic and economic variables such as the rate of schooling, age, income, or the employment shares of manufacturing or services. This is reassuring as any of these variables could be persistent or reflect unobserved factors that influence current sectoral concentrations, violating (20) if they correlate with the Plan. To minimize the potential for such persistent or unobserved factors to bias the coefficients, these variables are all used as controls in the regressions.

4 Results

4.1 Ordinary least squares results

The results from the ordinary least squares (OLS) estimation of (18) for manufacturing, tradable services, and non-tradable services are displayed in Table 4. This technique does not address the potential endogeneity of the airport size measure and the results should therefore not be interpreted as the effects of an exogenous change in airport size. Rather, these results are included to show the overall relationship between air traffic and industry-level employment, given the overall level of employment.

The coefficients for the three industries are shown in separate panels in Table 4. The columns represent separate regressions with a range of different controls. The controls are intended to reduce potential omitted variable bias by capturing exogenous factors that are likely to be correlated with the local productivity of at least one industry and may be correlated either with current airport sizes or with the instrument. Formally, these controls correspond to the term Z_m in the estimation equations (17) and (18).

All regressions include the log 1940 population, to control for the overall size of the CBSA at the time the 1944 National Airport Plan was authored, along with physical-geography and climate controls. The physical geography variables include the log area of each CBSA and its square, indicator variables for location adjacent to the Pacific or Atlantic coast or the shore of one of the Great Lakes, the log of the mean size of the counties that comprise a CBSA, elevation, and ruggedness. The coastline indicators are to control for coast-specific factors such as the possibility of establishing ports. The mean county size variable is intended to treat potential biases that result from systematic differences in county sizes across the US. Counties are generally larger in the more-recently developed parts of the country, particularly to the west of the Great Plains, with the result that western CBSAs are necessarily larger in area and encompass larger rural hinterlands. In the west of the country, metropolitan areas were also built differently, have younger industry, and are spaced further apart. A bias could result from any of these factors being correlated with current industrial production. The elevation and ruggedness variables control for the effects of terrain on air travel and industrial concentration. The climate variables include average wind speed and annual heating and cooling degree days.

To control for any additional regional differences, column 2 introduces census-division fixed effects. Column 3 introduces log population from the decennial censuses from 1910 to 1930, to control for possible variation due to the path of development in 1940. To control for the demographic variation between the CBSAs at the time of the 1944 National Airport Plan, column 4 introduces measures of school attainment and enrollment in 1940 and the log median income in 1950. To ensure that the results are not simply a reflection of current demographics, column 5 introduces the proportions of the 2007 population that are below 18 years of age, above 65 years of age, high-school educated, and college educated, as well as the mean 2007 income. To more thoroughly account for any permanent or persistent factors for sectoral employment that may correlate with the 1944 National Airport Plan, column 6 introduces controls for the log employment shares of manufacturing and services in 1940.

Columns 7 through 9 use three different measures of market access as additional controls. The first of these is a sum of the aggregate incomes of the other CBSAs weighted by the negative exponential of the distance to them according to the function e^{-d}, where d is the distance in thousands of miles. The second simply sums the aggregate incomes of all other CBSAs within 500 miles. The third estimates an equation for the total CBSA employment in 2007 using a fourth-order polynomial of the distance to weight the populations and income levels of other CBSAs, then calculates market access using the estimated coefficients.[14] Columns 7 through 9 each use the full set of controls from column 6.

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS
Panel A. Dependent variable: Manufacturing employment share in 2007									
ln($departures_{2007}$)	-0.122^{b}	-0.101^{c}	-0.087	-0.086	-0.055	-0.059	-0.042	-0.056	-0.053
	(0.059)	(0.061)	(0.060)	(0.056)	(0.053)	(0.051)	(0.050)	(0.051)	(0.050)
R^2	0.34	0.38	0.40	0.46	0.51	0.54	0.55	0.54	0.55
Panel B. Dependent variable: Tradable services employment share in 2007									
ln($departures_{2007}$)	0.078^{a}	0.074^{a}	0.075^{a}	0.075^{a}	0.049^{b}	0.048^{b}	0.041^{c}	0.045^{b}	0.044^{b}
	(0.024)	(0.024)	(0.025)	(0.025)	(0.021)	(0.021)	(0.022)	(0.021)	(0.021)
R^2	0.48	0.50	0.52	0.53	0.64	0.64	0.65	0.65	0.65
Panel C. Dependent variable: Non-tradable services employment share in 2007									
ln($departures_{2007}$)	0.008	0.014	0.008	0.003	-0.004	-0.004	-0.002	-0.006	-0.006
	(0.017)	(0.018)	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)	(0.019)	(0.019)
R^2	0.10	0.17	0.19	0.22	0.28	0.28	0.28	0.29	0.29
Physical geography, climate	Y	Y	Y	Y	Y	Y	Y	Y	Y
Census divisions	N	Y	Y	Y	Y	Y	Y	Y	Y
$\{\ln(pop_t)\}_{t\in\{1910,\ldots,1930\}}$	N	N	Y	Y	Y	Y	Y	Y	Y
1940 education; 1950 income	N	N	N	Y	Y	Y	Y	Y	Y
2007 ages, education, income	N	N	N	N	Y	Y	Y	Y	Y
1940 manuf. & service shares	N	N	N	N	N	Y	Y	Y	Y
2007 market access measure	-	-	-	-	-	-	1	2	3

Note: 290 observations for each regression; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%

Table 4: OLS estimates of the effect of airport size on the employment shares of manufacturing, tradable services, and non-tradable services in 2007.

Table 4 exhibits no relationship between air traffic and the employment share of manufacturing, at least after the introduction of extensive controls. There is a positive relationship between air traffic and the employment share of tradable services that is strongly significant for most specifications. That is, CBSAs that host more air traffic in 2007 have larger concentrations of tradable-service employment. There appears to be no relationship between the number of departures from a metropolitan area and the employment share of non-tradable services.

[14]The equation estimated by least squares is:

$$\ln(L_m) = \ln\left(\sum_{n\neq m}\left(\beta_0^d + \beta_1^d d_{m,n} + \beta_2^d d_{m,n}^2 + \beta_3^d d_{m,n}^3 + \beta_4^d d_{m,n}^4\right)\cdot\left(pop_n \cdot inc_n^{\beta^{inc}}\right)\right) \tag{21}$$

where $d_{m,n}$ is the distance between the CBSAs m and n, pop_n is the population in n in 2007, inc_n is the mean income in n in 2007, and the βs are the coefficients.

4.2 Instrumental variables results

The results from the two-stage least squares (TSLS) estimation of (18) are displayed in Table 5. The instrument used in the first stage (17) of each specification is the value of proposed airports in the CBSA according to the 1944 National Airport Plan. These regressions use the same sets of controls as in the OLS estimates presented in Table 4. The results for each industry are displayed in a separate panel in Table 5, with the *p*-values of Hausman tests on the exogeneity of the measure of air traffic in 2007. The *F*-statistics from the weak identification tests of the instrument are displayed at the bottom of the table.

	(1) TSLS	(2) TSLS	(3) TSLS	(4) TSLS	(5) TSLS	(6) TSLS	(7) TSLS	(8) TSLS	(9) TSLS
Panel A. Dependent variable: Manufacturing employment share in 2007									
$\ln(departures_{2007})$	-0.368	-0.187	-0.226	-0.062	-0.092	-0.033	0.083	0.004	0.045
	(0.293)	(0.294)	(0.294)	(0.243)	(0.234)	(0.224)	(0.263)	(0.233)	(0.233)
Hausman test *p* -value	0.35	0.75	0.61	0.92	0.87	0.90	0.62	0.79	0.66
Panel B. Dependent variable: Tradable services employment share in 2007									
$\ln(departures_{2007})$	0.249^{b}	0.210^{c}	0.257^{b}	0.217^{b}	0.229^{b}	0.231^{b}	0.219^{b}	0.205^{b}	0.199^{b}
	(0.111)	(0.111)	(0.114)	(0.104)	(0.096)	(0.096)	(0.109)	(0.097)	(0.095)
Hausman test *p* -value	0.10	0.20	0.09	0.15	0.04	0.03	0.07	0.07	0.08
Panel C. Dependent variable: Non-tradable services employment share in 2007									
$\ln(departures_{2007})$	-0.019	0.087	0.105	0.078	0.102	0.105	0.139	0.085	0.092
	(0.091)	(0.093)	(0.096)	(0.086)	(0.084)	(0.084)	(0.103)	(0.085)	(0.085)
Hausman test *p* -value	0.76	0.39	0.26	0.35	0.17	0.15	0.12	0.24	0.21
Physical geography, climate	Y	Y	Y	Y	Y	Y	Y	Y	Y
Census divisions	N	Y	Y	Y	Y	Y	Y	Y	Y
$\{\ln(pop_t)\}_{t\in\{1910,\ldots,1930\}}$	N	N	Y	Y	Y	Y	Y	Y	Y
1940 education; 1950 income	N	N	N	Y	Y	Y	Y	Y	Y
2007 ages, education, income	N	N	N	N	Y	Y	Y	Y	Y
1940 manuf. & service shares	N	N	N	N	N	Y	Y	Y	Y
2007 market access measure	-	-	-	-	-	-	1	2	3
First-stage statistic	16.46	15.01	14.45	13.78	14.09	15.06	10.97	12.70	13.20

Note: 290 observations for each regression; robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%

Table 5: TSLS estimates of the effect of airport size on the employment shares of manufacturing, tradable services, and non-tradable services in 2007.

The estimated coefficients for manufacturing employment are presented in Panel A of Table 5. Airport size appears not to have an effect on manufacturing employment, as the relevant coefficient is not significant for any of the specifications. The lack of an effect of airport size on manufacturing employment may not be obvious, as air travel should facilitate contact between producers and customers. Business-class air travel has been linked to trade in certain types of products (Cristea,

2011) and improved air connections could be expected to lead to closer personal and cultural ties, which have been associated with increased trade (Rauch, 2001; Rauch and Trindade, 2002). Indeed, the first six specifications in Table 5 each have a coefficient on airport size that is negative in magnitude, which may reflect a degree of substitution to the expanded tradable-service sector. This potential explanation is explored in more detail through the analysis of air traffic and manufacturing shipments between pairs of metropolitan areas in Appendix H.

The coefficients for the effect of airport size on the employment share of tradable services are displayed in Panel B of Table 5. The coefficient on air traffic is positive and significant for each of the specifications, indicating that air traffic has a positive effect on employment in tradable services. The interpretation drawn from the model is that a CBSA with a larger airport has better market access for the delivery of tradable services, so more of them are produced locally and some are transported to other locations. As the coefficients represent changes in the employment shares controlling for overall employment, the increase could come from workers moving between industries, previously unemployed residents entering the industry, or workers being attracted to the metropolitan area. The results presented below for the effect of airport size on overall employment suggest that the additional employees are predominantly workers who would have been employed locally in other industries, as CBSA-level employment appears not to be influenced by airport size.

The estimated coefficients correspond to the elasticities of absolute employment with respect to passenger air traffic for a constant level of overall employment. A further implication of the result that airport size does not affect overall employment is thus that the coefficients in Panel B of Table 5 are equivalent to the elasticities of the absolute number of employees in tradable services with respect to air traffic. The elasticity is therefore around 0.22, which implies that a 10% increase in the air traffic in a CBSA with a million residents would lead to around 1,650 additional service jobs.

The inclusion of additional controls has a moderate effect on the magnitude of the coefficient. The demographic controls appear to reduce the magnitude, which is intuitive as workers in different industries have different characteristics so these controls absorb part of the effect. It is nonetheless important to control for these factors to avoid the results simply being driven by the characteristics of people who settle in places with larger airports. Similarly, the controls for market access appear to somewhat reduce the magnitude and significance of the coefficient.

The TSLS coefficients for the effect of air traffic on the employment share of tradable services presented in Table 5 are larger in magnitude than the OLS coefficients in Table 4. The results of the Hausman tests displayed in Table 5 indicate that these differences are significant when extensive controls are used, but only weakly significant when controlling for market access. The test therefore offers weak evidence that the hypothesis of air traffic levels being exogenous should be rejected. However, the low significance of some of the Hausman tests could be due to multiple sources of endogeneity that by chance are roughly zero in aggregate. As such, it should not be taken to mean that endogeneity in air traffic levels need not be treated.

Though the Hausman tests are not strong in every case, the point estimates for the effect of airports on the employment share of tradable services are larger in the TSLS estimation than the OLS, which would appear to reflect a negative overall bias in the OLS results. A positive bias in the OLS coefficients could obviously result from the effect of industry-driven demand on air travel. Two explanations for a negative bias in the OLS results are apparent. Firstly, the effects on industries may take a long time to accumulate, so airport improvements conducted in the 1940s and 1950s could exhibit a larger effect on sector shares than improvements carried out in recent decades. Secondly, the difference could reflect the construction of airports in locations where they are simply less effective in promoting service production. Duranton and Turner (2012) found that the estimated effect of highways on growth is larger when instrumenting for highways. They propose the explanation that a low rate of growth causes more roads to be built in a metropolitan area, which they present evidence of and which would lead the OLS estimates to be biased downwards. An analogous interpretation could apply here: randomly-allocated airports could have a larger effect on production of tradable services than those allocated by the government, which builds airports disproportionately in areas perceived as being in need of stimulus that tend to be persistently poor locations for service production.

Panel C of Table 5 displays the coefficients for the employment share of non-tradable services. The coefficients on airport size are small in magnitude and statistically insignificant for all of the specifications, indicating no measurable effect of air travel on employment in this sector. The result is intuitive as the services in this category are impractical to transmit between locations, so the distribution of their production should closely match that of their consumption. Were airports to attract residents with particular tastes, this could lead to more local consumption of services and thereby a measurable effect on relative employment in non-tradable services. Though the services are of different types, the lack of any effect of airports on non-tradable services suggests that the measured effect on tradable services is not simply driven by airports attracting residents who demand more of those services.

The F-statistics from the weak identification tests for the instrument are reported at the bottom of Table 5. These are above a reasonable threshold to reject the hypothesis of the instrument being weak for all specifications. The relevance of the instrument appears therefore not to be in question. The relationship between the instrument and 2007 air traffic is detailed in Appendix G, which presents the results from the estimation of the first stage (17).

4.3 Tradable and non-tradable services at the 2-digit level

This section investigates the effects of airports on the employment shares of tradable and non-tradable services in more detail by estimating the effects on each of the individual 2-digit service industries. For comparison, the analysis includes sectors 51 to 54, which are classified as 'tradable', sectors 55 and 56, which are not classified, and sector 81, which is classified as 'non-tradable'. Equation (18) is estimated using both OLS and TSLS for each of these 2-digit industries and the results are shown in Table 6, with the OLS results in Panel A and the TSLS results in Panel B. Each regression includes the full range of controls from Table 4 and Table 5, but without the market-access variables, and therefore corresponds to the specifications in column 6 of each of those tables.

	(1) Information (51)	(2) Finance & ins. (52)	(3) Real estate (53)	(4) Prof., sci., tech. (54)	(5) Management (55)	(6) Admin. & support (56)	(7) Other services (81)
Panel A. OLS estimation. Dependent variable: Industry-level employment share in 2007							
ln(*departures* $_{2007}$)	0.074^b	0.054	0.066^a	0.025	0.011	-0.063^c	-0.004
	(0.031)	(0.039)	(0.025)	(0.029)	(0.071)	(0.033)	(0.019)
R^2	0.39	0.39	0.62	0.64	0.59	0.57	0.28
Panel B. TSLS estimation. Dependent variable: Industry-level employment share in 2007							
ln(*departures* $_{2007}$)	0.162	0.374^b	0.230^c	0.116	-0.596	-0.099	0.105
	(0.156)	(0.168)	(0.118)	(0.136)	(0.363)	(0.151)	(0.084)
First-stage statistic	15.06	15.06	15.06	15.06	13.36	15.06	15.06
Hausman test *p* -value	0.55	0.03	0.12	0.49	0.07	0.80	0.15
Number of observations	290	290	290	290	288	290	290

Note: robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%; each regression uses the full set of controls from the main results table, including physical geography, climate, census divisions, 1910 to 1930 population, 1940-1950 and 2007 demographic variables, and 1940 manufacturing and service shares, but no market access measures

Table 6: OLS and TSLS estimates of the effect of airport size on the employment share of each 2-digit tradable services industry in 2007.

The results displayed in Table 6 are consistent with the overall results for tradable and non-tradable services presented in Table 4 and Table 5. The individual 2-digit tradable-services industries naturally have a larger proportion of variation that is not explained by the variables in the model, so their standard errors are larger than those for the aggregated tradable-services sector. However, the magnitudes of the coefficients for the individual and aggregated sectors are consistent.

From the results displayed in Table 6, the estimated effect of airport size on tradable-services employment appears to be driven largely by industries 52 ("Finance and Insurance") and 53 ("Real Estate and Rental and Leasing"), which exhibit positive and significant coefficients in the TSLS estimation. The coefficients on airport size for industries 51 ("Information") and 54 ("Professional, Scientific, and Technical Services") are also positive in magnitude but not significant. Were any of these 2-digit industries to be excluded from the set of tradable services, the coefficient on airport size for that industry in Table 5 would be weaker.

Comparing the OLS and TSLS results in Table 6, the TSLS coefficients are larger in magnitude for all four 'tradable' sectors. However, the Hausman test would only reject the hypothesis of their being the same for industry 52, is close to rejecting at a low level of significance for industry 53, and would not reject for industries 51 and 54.

For industries 55 and 56, which are not classified, the OLS results are close to zero. There is no correlation for industry 55 (“Management of Companies and Enterprises”) and a weak negative correlation for industry 56 (“Administrative and Support and Waste and Remediation Services”). The TSLS results indicate that airport size does not have an effect on either of these industries: the relevant coefficients are negative in sign but not significant in either case. Were either of these industries to be classified as ‘tradable’, the measured effect of airport size on this group of industries would be weaker.

The results for the single ‘non-tradable’ sector, industry 81 (“Other Services (except Public Administration)”), are of course identical to the results displayed in Table 4 and Table 5 and are not significantly different from zero.

4.4 Other industries

The remaining industries in the NAICS generally have less intuitive connection with air travel than the tradable sectors. It is nonetheless interesting to investigate the relationship between airport size and relative employment in these industries. Table 7 gives the OLS and TSLS results for the estimation of (18), with the OLS coefficients displayed in Panel A and the TSLS coefficients displayed in Panel B. Once again the regressions include the full range of controls but with no market-access variables and so correspond to column 6 of Table 4 and Table 5.

	(1) Construction (23)	(2) Wholesale Trade (42)	(3) Retail Trade (44-45)	(4) Transp. & Wrh. (48-49)	(5) Educational Serv. (61)	(6) Health Care, Social As. (62)	(7) Arts, Ent., Recr. (71)	(8) Accom. & Food (72)
Panel A. OLS estimation. Dependent variable: Industry-level employment share in 2007								
ln(*departures* $_{2007}$)	0.009	0.043	0.017	0.078^{c}	-0.180^{a}	-0.015	0.060	0.036^{c}
	(0.025)	(0.031)	(0.011)	(0.045)	(0.063)	(0.018)	(0.047)	(0.020)
R^2	0.60	0.50	0.68	0.30	0.49	0.60	0.45	0.53
Panel B. TSLS estimation. Dependent variable: Industry-level employment share in 2007								
ln(*departures* $_{2007}$)	0.002	-0.093	0.152^{b}	-0.037	-0.361	0.039	0.257	0.078
	(0.113)	(0.146)	(0.062)	(0.178)	(0.300)	(0.088)	(0.230)	(0.104)
First-stage statistic	15.06	15.06	15.06	15.06	15.06	15.06	15.06	15.06
Hausman test *p* -value	0.95	0.34	0.01	0.51	0.52	0.52	0.36	0.66
Number of observations	290	290	290	290	290	290	290	290

Note: robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%; each regression uses the full set of controls from the main results table, including physical geography, climate, census divisions, 1910 to 1930 population, 1940-1950 and 2007 demographic variables, and 1940 manufacturing and service shares, but no market access measures

Table 7: OLS and TSLS estimates of the effect of airport size on the employment share of each additional 2-digit industry in 2007.

The results in Table 7 suggest that the employment shares of the majority of the industries have no relationship to airport size. The OLS results show a negative correlation between airport size and the employment share of industry 61 ("Educational Services"). There is a positive correlation between airport size and the employment shares of industries 48-49 ("Transportation and Warehousing") and 72 ("Accommodation and Food Services"), which is reasonable as each of these industries is related to airports and air travel.

The TSLS results in Table 7 indicate that the airports have a positive effect on the employment share of industry 44-45 ("Retail Trade") but no measurable effect on any of the other industries. The measured effect on retail trade suggests the possibility that airport size affects the types of individuals who reside in the metropolitan area, which affects local demand and thereby industry-level employment. However, the lack of significant coefficients for the other sectors suggests that the effects of airports on the demand characteristics of local residents are not substantial and widespread.

4.5 Employment rate and overall growth

This section presents estimates of the effect of airport size on overall employment at the CBSA level. This is done firstly by estimating the effects of airport size on the employment rate – defined as the proportion of the labor force that is engaged in employment – and then on the rate of growth of total CBSA employment. These estimates can be used to assess whether the increase in the relative employment of the tradable-service sector is due to additional jobs being added to the metropolitan area or simply employees moving from other industries. If the airport has a positive effect on either measure of employment, then the change in absolute industry-level employment is greater than what is suggested by the coefficients for relative employment presented above. The use of a historical instrument is less well-suited to the estimation of these variables than to the estimation of employment shares, as it is more susceptible to endogeneity problems from omitted variables and does not explain dynamic variation in airport sizes in later years.[15] Nonetheless, these tests are informative about the effect on overall employment and the literature does not present a reliable answer as an alternative.

To estimate the effect of airport size on the CBSA employment rate, the system of equations (17) and (18) is estimated with the log employment rate in 2007 as the dependent variable in the second stage. As total CBSA employment is the numerator of the employment rate, the size of the labor force in 2007 better represents the basis for the measure and is used in place of the total employment term L_m on the right-hand sides of (17) and (18). The results of the OLS and TSLS estimation are shown in Table 8, with the same set of controls used for the columns as in Table 4 and Table 5.

[15]This creates issues for the measurement of the base for each measure: the employment rate may not be well measured because the size of the labor force reacts over the long term along with employment, while the effects of historical airport construction may be more on the level rather than the growth of employment. At the same time, testing the effect on employment growth over a period closer to 1944 would be difficult due to the lack of detailed data on air travel and, as growth over the immediate period is more easily predictable than technology and sectoral specialization several decades hence, subject to greater concern about the exclusion restriction.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. OLS estimation. Dependent variable: Employment rate in 2007									
ln(*departures* $_{2007}$)	0.002^c	0.003^b	0.002^c	0.002^c	0.001	0.001	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.36	0.51	0.55	0.56	0.62	0.62	0.65	0.65	0.65
Panel B. TSLS estimation. Dependent variable: Employment rate in 2007									
ln(*departures* $_{2007}$)	0.008	0.007	0.009^c	0.009	0.012^b	0.011^b	0.007	0.007	0.008^c
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
First-stage statistic	16.83	15.30	14.83	14.15	14.46	15.42	11.12	12.87	13.38
Hausman test p -value	0.28	0.36	0.15	0.16	0.02	0.02	0.15	0.14	0.10
Physical geography, climate	Y	Y	Y	Y	Y	Y	Y	Y	Y
Census divisions	N	Y	Y	Y	Y	Y	Y	Y	Y
$\{\ln(pop_t)\}_{t\in\{1910,...,1930\}}$	N	N	Y	Y	Y	Y	Y	Y	Y
1940 education; 1950 income	N	N	N	Y	Y	Y	Y	Y	Y
2007 ages, education, income	N	N	N	N	Y	Y	Y	Y	Y
1940 manuf. & service shares	N	N	N	N	N	Y	Y	Y	Y
2007 market access measure	-	-	-	-	-	-	1	2	3

Note: 290 observations for each regression; robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%

Table 8: OLS and TSLS estimates of the effect of airport size on the rate of employment in 2007.

The results displayed in Table 8 for the effect of airport size on the employment rate are not clear. The OLS results exhibit a weak positive correlation between the level of air traffic and the employment rate in 2007 for the specifications with few controls, but this correlation disappears when extensive controls are introduced. The TSLS results exhibit no effect of air traffic on the employment rate for the specifications with few controls, a significantly positive effect with a low magnitude when extensive controls are introduced, then practically no effect when the market-access variables are included. The evidence in Table 8 is therefore ambiguous, as it would be consistent with a larger airport either having no effect on or reducing unemployment.

To estimate the effect of airport size on the growth in total CBSA employment, the system of equations (17) and (18) is estimated with log growth in employment as the dependent variable in the second stage. Growth in employment is measured over several four-, eight-, and twelve-year periods between 1999 and 2011 and is calculated as total employment at the end of the period divided by total employment at the beginning of the period. In each regression the control L_m on the right-hand sides of (17) and (18) is the total employment in the earlier year. This technique is similar to that employed by Duranton and Turner (2012) to estimate the effect of urban highways on employment growth. To keep the estimates consistent, the sample in each regression is limited to CBSAs with at least 1,000 departing flights in the earliest year of the relevant period. Each regression uses the full range of controls used in column 6 of Table 4 and Table 5. For the period 2007-2011, the regressions are also run using the three market-access terms introduced in Table (4). The results of the estimation are displayed in Table 9.

	(1) 1999-2003	(2) 1999-2007	(3) 1999-2011	(4) 2003-2007	(5) 2003-2011	(6) 2007-2011	(7) 2007-2011	(8) 2007-2011	(9) 2007-2011
Panel A. OLS estimation. Dependent variable: Growth in employment over specified period									
ln(*departures* $_{1999}$)	-0.007	-0.010	-0.004						
	(0.007)	(0.009)	(0.009)						
ln(*departures* $_{2003}$)				-0.007	0.003				
				(0.006)	(0.008)				
ln(*departures* $_{2007}$)						0.006	0.004	0.004	0.004
						(0.005)	(0.005)	(0.004)	(0.005)
R^2	0.39	0.60	0.58	0.52	0.44	0.49	0.50	0.56	0.57
Panel B. TSLS estimation. Dependent variable: Growth in employment over specified period									
ln(*departures* $_{1999}$)	0.047	0.001	0.045						
	(0.038)	(0.046)	(0.054)						
ln(*departures* $_{2003}$)				-0.035	-0.004				
				(0.033)	(0.039)				
ln(*departures* $_{2007}$)						0.014	0.004	-0.010	-0.008
						(0.023)	(0.026)	(0.023)	(0.022)
First-stage statistic	8.41	8.41	8.41	9.08	9.08	15.06	10.97	12.70	13.20
Hausman test *p* -value	0.13	0.81	0.33	0.35	0.87	0.70	0.99	0.52	0.57
2007 market access measure	-	-	-	-	-	-	1	2	3
Number of observations	245	245	245	302	302	290	290	290	290

Note: robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%; each regression uses the full set of controls from the main results table, including physical geography, climate, census divisions, 1910 to 1930 population, 1940-1950 and 2007 demographic variables, and 1940 manufacturing and service shares

Table 9: OLS and TSLS estimates of the effect of airport size on the growth of total CBSA employment over various periods from 1999 to 2011.

The results displayed in Table 9 indicate no measurable effect of airport size on employment growth. The OLS results exhibit no significant correlation between airport size and employment growth for any of the periods, whether or not the market-access terms are included. Similarly, for all periods studied, the TSLS results exhibit no significant effect of airport size at the beginning of the period on employment growth over the period. Though in the interests of space the regressions with the market-access terms are only displayed for the estimation for the 2007-2011 period in Table 9, the coefficient on air traffic is not significant for any of the periods when these terms are applied.

The results in Table 9 contrast with the findings of Blonigen and Cristea (2012) that a larger airport has a substantial positive effect on local population, employment, and per-capita income. As their results are in terms of proportional changes in the growth rates of air traffic and the outcome variables, it is difficult to compare the magnitudes with the results in this section. However, the relevant coefficients in their analysis are all significant at the 1% level. The difference between the two sets of results could be due to a lack of precision in the estimates presented here for reasons outlined above, to differences between the sources of underlying variation and the resulting treatment effects, or to unresolved simultaneity bias in their estimates.

The findings outlined in this section suggest that the effect of airport size on overall CBSA employment is at best small. While the results in Table 8 may reflect a weak effect of airport size on the rate of employment, Table 9 exhibits no effect on employment growth. It appears therefore that while metropolitan areas with larger airports specialize in the production of tradable services, they do not become larger overall. The measured effects of airport size on industry shares appear to be due more to the allocation of factors between industries within a metropolitan area, rather than bringing local residents into the workforce or attracting workers to the metropolitan area from elsewhere. There is a clear parallel here with the findings of Duranton, Morrow, and Turner (forthcoming), who show that urban highways affect the weight but not the value of exports. The implication there is that metropolitan areas with more highways specialize in the production of heavier goods but do not produce more in aggregate.

4.6 Robustness

Table 10 presents the results of additional robustness checks on the TSLS results presented in Table 5. These robustness checks include a number of alternative specifications, sample restrictions, and additional control variables. For each, the TSLS results for the employment shares of manufacturing and tradable services are presented in separate panels. For brevity, the results for non-tradable services are not displayed. Each regression uses the full range of controls with the exception of the market-access terms, as in column 6 of Table 5.

The first three robustness checks use alternative measures of 2007 airport size as the endogenous regressor. Recall that the measure used above is the number of departing flights from the CBSA, which is intended to capture the air accessibility of the CBSA. To check whether the results are sensitive to the choice of airport size measure, a number of alternatives are tested. In Table 10, column 1 uses the number of departing passengers from the CBSA, column 2 uses the number of departing flights from only the largest airport in the CBSA, and column 3 uses the number of destinations flown to directly and at least daily from the CBSA.

To test for the possible effects of choosing a different definition for the instrument, column 4 includes a constant, log 1940 CBSA population, and census-division fixed effects in the estimation of the existing 1944 airport values. This accounts for the higher cost of land in more heavily populated areas and potential regional differences in the sizes of existing airports within each class.

To test the effects of restricting the sample size, column 5 restricts the sample to CBSAs with at least 50,000 residents in 2010, and column 6 restricts the sample to CBSAs with at most one million residents.

To check the effects of alternative modes of transportation, several controls are used for other types of transportation infrastructure. Column 7 uses 2007 highway miles in the CBSA, column 8 uses 2007 road miles, and column 9 uses the number of ports.

The final robustness check partially addresses the potential implications of the relative locations of the CBSAs by treating the availability of airports in nearby CBSAs. One implication of testing CBSAs as separate entities is that airports outside of the CBSA boundaries, which may in fact affect air accessibility, are ignored. Were the presence of larger airports outside of the CBSA boundaries to be correlated with industrial composition, perhaps by being related to the form of the regional market, then this would threaten the exclusion restriction. Column 10 removes from the sample any CBSA that is contiguous with another CBSA with a higher-category airport in 2007 according to the Federal Aviation Administration system of classification.[16]

[16]This system groups commercial airports into one of five broad categories: “Large Hub”, “Medium Hub”, “Small Hub”, “Nonhub Primary”, or “Nonprimary Commercial Service”.

	(1) TSLS	(2) TSLS	(3) TSLS	(4) TSLS	(5) TSLS	(6) TSLS	(7) TSLS	(8) TSLS	(9) TSLS	(10) TSLS
	Number of pass.	Main airport	Number of dests.	Pop. & reg. in instr.	2010 pop ≥ 50K	2010 pop ≤ 1 million	Highways	Roads	Ports	No larger near apts.
Panel A. Dependent variable: Manufacturing employment share in 2007										
ln(*passengers* $_{2007}$)	-0.025									
	(0.171)									
ln(*departures_main* $_{2007}$)		-0.034								
		(0.234)								
ln(*destinations* $_{2007}$)			-0.028							
			(0.192)							
ln(*departures* $_{2007}$)				-0.023	-0.155	0.113	-0.028	-0.172	-0.031	-0.308
				(0.243)	(0.294)	(0.288)	(0.200)	(0.230)	(0.227)	(0.320)
Hausman test *p*-value	0.86	0.86	0.93	0.83	0.83	0.57	0.87	0.63	0.90	0.48
Panel B. Dependent variable: Tradable services employment share in 2007										
ln(*passengers* $_{2007}$)	0.178^b									
	(0.074)									
ln(*departures_main* $_{2007}$)		0.241^b								
		(0.101)								
ln(*destinations* $_{2007}$)			0.198^b							
			(0.081)							
ln(*departures* $_{2007}$)				0.229^b	0.241^c	0.231^b	0.204^b	0.237^b	0.236^b	0.267^b
				(0.102)	(0.141)	(0.117)	(0.088)	(0.102)	(0.097)	(0.128)
Hausman test *p*-value	0.04	0.03	0.04	0.06	0.11	0.10	0.06	0.03	0.03	0.08
First-stage statistic	11.54	13.47	17.87	10.95	6.32	10.75	17.20	12.24	14.55	11.37
Number of observations	290	290	290	286	264	239	290	290	290	198

Note: robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%; each regression uses the full set of controls from the main results table, including physical geography, climate, census divisions, 1910 to 1930 population, 1940 proximity, and 1940-1950 and 2007 demographic variables, but no market access measures

Table 10: Robustness checks of the TSLS estimates of the effect of airport size on the employment shares of manufacturing and tradable services in 2007.

The results presented in Table 10 indicate that the main TSLS results are robust to a wide range of alternative factors and specifications. The coefficients for manufacturing are not significant in any of the specifications whereas the coefficients for tradable services are all positive and significant. As the coefficients for manufacturing are not statistically different from zero in each case, their interpretation is trivial. The remainder of this section therefore focuses on the coefficients for tradable services.

For each of the alternative definitions of airport size used in Table 10, the results are consistent with the standard specification used in Table 5. The magnitude of the coefficient on the number of passengers is smaller than that on the number of flights, suggesting that it is indeed the number of plane movements rather than the size of the aircraft that is important. The other two alternative measures of airport size yield coefficients similar in magnitude and statistical significance to the baseline results.

The inclusion of the log 1940 population and census-division fixed effects in the imputation of the existing 1944 airport values makes little difference to the coefficients. The restrictions on 2010 population reduce the significance of the coefficient for tradable services, though the magnitudes are similar to the base case. The lower significance of the coefficients would appear to be due to the smaller sample sizes that result from the population restrictions. In these cases the first-stage statistics are also lower.

The inclusion of 2007 highway or road miles as controls makes little difference, besides reducing the magnitude of the coefficient somewhat in the case of highway miles. The inclusion of the number of ports only slightly changes the coefficient.

Removing CBSAs that border CBSAs with larger airports increases the magnitude of the coefficient somewhat, indicating that the presence of neighboring airports could serve as a source of attenuation bias. However, the reduced sample size leads to slightly lower statistical significance for the instrument in the first stage and airport size in the second stage.

5 Conclusion

Large transportation infrastructure projects are apparently undertaken with the understanding that the new infrastructure will have positive effects on the broader economy. The empirical evidence for these effects remains limited, however, due largely to the difficulty of treating the endogeneity in decisions about infrastructure improvements. This is particularly true of the literature on airport infrastructure, in which only a handful of studies take the endogeneity problems seriously. The present paper contributes to this literature by investigating the effects of airport infrastructure on the sectoral composition of local employment.

The results of the analysis confirm the intuitive notion that airports promote activity in the service sector. A metropolitan area that has more airport infrastructure because of an exogenous historical allocation of airports is found to specialize more in the production of tradable services. The elasticity of employment in tradable services with respect to air traffic is approximately 0.22, which is somewhat larger than that estimated by Brueckner (2003). A positive effect is also evident for retail trade. There is no measurable effect on the employment shares of the remaining industries.

These effects are measured controlling for total metropolitan-area employment, though the effect of airport size on overall employment was found not to be statistically different from zero. While a larger airport causes a metropolitan area to specialize in service industries that benefit from the air connection, it does not appear to cause the metropolitan area to expand in size.

The interpretation of these results is that passenger air travel is important for the production of tradable services, but not for the production of manufactures or the various non-tradable goods and services. Tradable services, which can be delivered to other locations partly by use of air travel, are therefore produced disproportionately in metropolitan areas that are more accessible by air and exported to other locations. Air travel may allow manufacturing firms to make contact with customers and may be useful in established business relationships, but is a relatively minor factor in that industry and so manufacturing shows no clear pattern of locating near larger airports. The non-tradable products must be consumed in close proximity to where they are produced, so it is natural that their employment shares are not affected by air travel. The unmeasurably small effect of airports on aggregate metropolitan-area employment suggests that the additional employees in the tradable-services industry come predominantly from reallocation within rather than between metropolitan areas.

An alternative explanation for the measured positive effect of airports on tradable services would be that a larger airport is related to tradable services indirectly – for example because a better airport attracts residents who have stronger preferences for consuming services – though the airport does not aid their production or delivery directly. However, this would not explain why the effect of airports is most prominent for tradable services and not significantly different from zero for most of the non-tradable sectors. The positive estimated effect of airports on the employment share of retail trade could be due to demographic changes driven by the size of the airports, but this is the only non-tradable sector for which there is such an effect. The lack of measured effects of airport size on other industries supports the interpretation that air travel is a positive factor in the production of tradable services because better air connections aid their production and delivery.

The finding that improved airports increase service employment is instructive but comes with a number of caveats. Firstly, the positive effect does not apply to non-tradable services, on which there is no measurable effect. Secondly, the estimates of the effect on overall employment suggest that the increase represents specialization rather than additional jobs for the local area. And thirdly, as the observed effect is based on variation in airport sizes that is driven by historical data, the effect could well take some time to accumulate. There is also the question of whether the magnitude of the effect justifies the outlay for a new or improved airport, a question that the findings presented in this paper do not provide an answer. However, the results presented here contribute to the understanding of the benefits of such projects and thereby provide valuable insight for the design of infrastructure policy.

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A Appendix

This appendix details the relationship between current physical airport sizes and traffic levels in the data. The airport size measures are from the Federal Aviation Administration for May 2011 and include the number of runways, aggregate runway length, aggregate runway area, and aggregate land area of airports. The data are aggregated by CBSA, with a handful of CBSAs excluded because the information on airport size measures was not available. Table 11 displays the coefficients on the airport size measures from OLS regressions that use the (log) number of departures in 2007 as the dependent variable. The columns use different sets of controls.

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS
Panel A. Dependent variable: Number (log) of departures in 2007							
Number (log) of runways in 2011	1.288[a]	0.753[a]	0.227[a]	0.228[a]	0.153[b]	0.127[c]	0.142[c]
	(0.124)	(0.104)	(0.072)	(0.073)	(0.071)	(0.071)	(0.074)
R^2	0.307	0.612	0.792	0.792	0.815	0.835	0.844
Panel B. Dependent variable: Number (log) of departures in 2007							
Total length (log) of runways in 2011	1.649[a]	1.071[a]	0.445[a]	0.450[a]	0.327[a]	0.293[a]	0.325[a]
	(0.092)	(0.106)	(0.091)	(0.092)	(0.095)	(0.096)	(0.097)
R^2	0.494	0.679	0.805	0.805	0.822	0.840	0.850
Panel C. Dependent variable: Number (log) of departures in 2007							
Total area (log) of runways in 2011	1.632[a]	1.077[a]	0.444[a]	0.449[a]	0.342[a]	0.310[a]	0.333[a]
	(0.084)	(0.110)	(0.098)	(0.099)	(0.100)	(0.104)	(0.102)
R^2	0.550	0.685	0.804	0.805	0.823	0.841	0.851
Panel D. Dependent variable: Number (log) of departures in 2007							
Total land area (log) of airports in 2011	1.315[a]	0.837[a]	0.429[a]	0.438[a]	0.361[a]	0.290[a]	0.296[a]
	(0.077)	(0.078)	(0.072)	(0.072)	(0.078)	(0.076)	(0.074)
R^2	0.489	0.668	0.816	0.817	0.832	0.845	0.854
$\ln(pop_{1940})$	N	Y	N	N	N	N	N
$\ln(pop_{2010})$	N	N	Y	Y	Y	Y	Y
Physical geography	N	N	N	Basic	Y	Y	Y
Climate	N	N	N	N	N	Y	Y
Census divisions	N	N	N	N	N	N	Y

Note: 279 observations for each regression; robust standard errors in parentheses; *a*, *b*, *c* denote significance at 1%, 5%, 10%

Table 11: Regression coefficients for relationship between 2007 air traffic and 2011 airport size measures by CBSA.

The results in Table 11 are consistent with a strong, positive relationship between physical airport size and the level of traffic at the airport. For each of the physical size measures and for each set of controls, the coefficient on the size measure is positive and strongly significant. When the controls are introduced the *R*-squared on each measure grows to above 80%, indicating that physical airport size along with the controls explains a large proportion of the variation in traffic levels. This is also evident from the plots of the physical size measures against the air traffic levels presented in Figure 3.

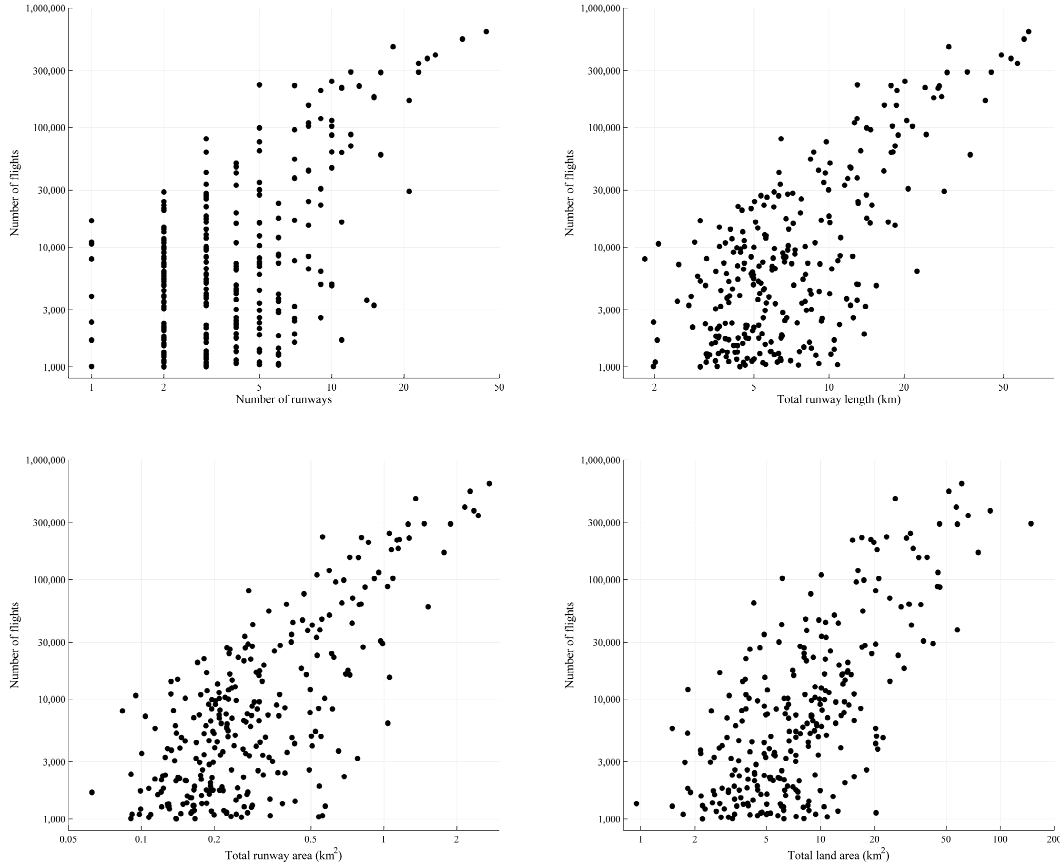

Figure 3: Plots of 2007 air traffic against 2011 airport size measures by CBSA.

B Appendix

This appendix details the method used to estimate the suppressed values for the numbers of employees by CBSA-industry combination in the County Business Patterns. The method is comprised of three steps. The numbers of employees are estimated using county-level data and then aggregated to the CBSA level, which makes use of a greater amount of information, in particular as employment figures are suppressed for some CBSA-industry pairs even though the equivalent figures are stated for some of the constituent counties.

The first step applies to those counties for which industry-level employment is suppressed for exactly one industry. In these cases, the value is identified by simply subtracting the other industry-level figures from the total level of employment in the county. These values are included in the dataset before the second step is carried out.

The second step involves the estimation of missing values from the numbers of establishments and from county- and industry-level characteristics. The following equation is fitted, where $L_{k,i}$ is the (log) number of employees and $E_{k,i}$ is the (log) number of establishments in county k and industry i, X_k is a fixed effect for county k, X_i is a fixed effect for industry i, and $\varepsilon_{k,i}$ is an error term:

$$L_{k,i} = \beta_E E_{k,i} + X_k + X_i + \varepsilon_{k,i} \tag{22}$$

The coefficients found from the estimation of (22) are used to predict each of the suppressed employment figures. The non-suppressed and predicted employment figures are then aggregated to the CBSAs.

The third step is the truncation of the predicted employment figures to fit within the bounds implied by the data suppression flags at the CBSA level. For each suppressed value in the County Business Patterns, a data suppression flag is given that specifies a range of values within which the actual value lies. If a predicted CBSA-level employment figure exceeds the upper or lower limit of this range, then it is truncated to equal the respective limit.

C Appendix

This appendix details the classification of industries as 'tradable' or 'non-tradable', according to the criterion that a substantial proportion of the output could feasibly be produced in one location and consumed in another.

Manufacturing is considered to be 'tradable' as it involves the production of goods that are readily transported substantial distances.

The classification of service industries into 'tradable' and 'non-tradable' is inherently subjective, but the delimitation of NAICS categories conforms reasonably well to the definition of tradability stated above. NAICS industries 51 to 54 are considered to be tradable, as a large part of the services included in each are practically possible and not excessively expensive to deliver to distant customers.[17] It is important to note that passenger air travel can facilitate the delivery of these ser-

[17]Tradability is evident for industries 51 ("Information", mostly publishing and journalism) and 52 ("Finance and Insurance"). Industry 53 ("Real Estate and Rental and Leasing") is less obvious as many of the services provided

vices. The appropriate classification of NAICS industries 55 and 56 is unclear, as they include small shares of apparently tradable services, many of which involve tasks such as telephone support that appear to be unrelated to transportation. In addition, there is substantial ambiguity in the division between industries 55 and 56 and possibly between these and other industries. Industries 55 and 56 are therefore treated separately.[18] NAICS industry 81 is comprised almost entirely of activities that do not satisfy the criterion for tradability and is therefore considered to be non-tradable.[19]

The remaining industries are largely non-tradable and unrelated to passenger aviation, with industries 71 and 72 being notable exceptions as they include components of tourism and personal travel. A further caveat is that industries 48-49 include transportation, which has a particular spatial nature but is not 'tradable' in the sense that its services are inherently location-specific.

D Appendix

Figure 4 displays plots of the employment shares of the three main industries studied against total metropolitan-area employment in 2007. There is no significant relationship between total employment and the employment shares of manufacturing or non-tradable services, but a positive relationship between total employment and the employment share of tradable services.

by real estate agents are site-specific. However, the portfolios of real estate lessors sometimes include buildings from outside of their local areas. In addition, the industry grouping also includes real estate investment trusts (REITs), which are essentially fund managers, and lessors of specialized equipment and intangible assets such as patents, trademarks, and brand names, all of which could be leased to distant clients. Industry 54 ("Professional, Scientific, and Technical Services") fits the definition of tradability as it involves high-skill activities such as legal representation and engineering that are often provided by consultants.

[18]The activities of industry 55 ("Management of Companies and Enterprises") are grouped into (1) establishments that own controlling stakes in companies or enterprises and (2) the administration and management of a firm. The activities in the first group appear to be tradable, though it is questionable whether they would require face-to-face contact and therefore passenger air travel. The activities in the second group include tasks that could effectively be transported within a firm to the locations where it does business, which would fit the definition of tradability. However, the difficulty of classifying these tasks suggests the possibility of measurement error. Industry 56 ("Administrative and Support and Waste Management and Remediation Services") largely involves tasks that must be provided on-site, such as security, waste collection, and office administration, but also tasks that could be provided to different locations, such as telephone support. Furthermore, the distinction between industries 55 and 56 is not clear, as management and administration would be classified in industry 55 if they are provided to other establishments within the firm but to industry 56 if they are provided to the same establishment.

[19]Industry 81 ("Other Services (except Public Administration)") involves four broad categories of services delimited by their three-digit industry codes: (811) repair and maintenance of vehicles, equipment, and personal and households goods; (812) personal and laundry services including hairdressing, funeral services, dry cleaning, and parking; (813) religious and advocacy organizations; and (814) domestic workers. With a small number of possible exceptions, for instance the repair of particular technical machinery, these services would not be feasible to deliver over any substantial distance.

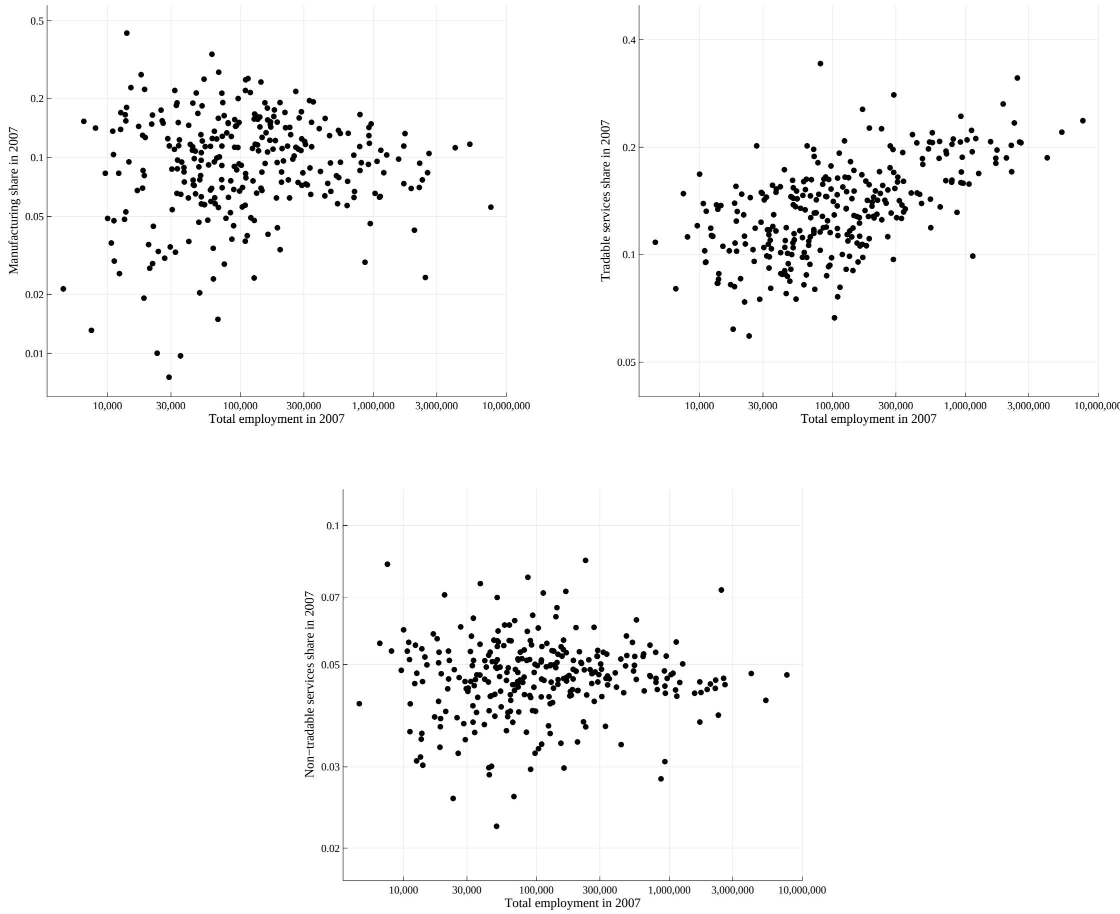

Figure 4: Plots of employment shares of manufacturing, tradable services, and non-tradable services against total CBSA employment in 2007.

E Appendix

This appendix details the method for imputing the existing values of airports of each of the five classes from the projected improvement costs in the 1944 National Airport Plan. Each observation is an airport that is to be improved to a higher class or built from scratch. The logic variable I_a^x indicates whether airport a is to be improved over class increment x. That is, an airport that is to be improved from class 2 to class 4, for example, is counted as being improved on the increments between classes 2 and 3 and between classes 3 and 4, but not on the other increments. The coefficients $\{f^x\}_{x=1,...,5}$ represent the costs of improving an airport over each of the five class increments. These coefficients are estimated by fitting a model with fixed effects for the increments and no intercept. This combines the costs of improving airports over single and multiple increments, weighted by the numbers of observations. The following equation, in which C_a is the projected cost of the project and ε_a is an error term, is fitted using ordinary least squares:

$$C_a = f^1 I_a^1 + f^2 I_a^2 + f^3 I_a^3 + f^4 I_a^4 + f^5 I_a^5 + \varepsilon_a \tag{23}$$

As there is no intercept in (23), the coefficient f^1 represents the replacement value of a class 1 airport, $f^1 + f^2$ represents the replacement value of a class 2 airport, and so on. Table 12 details the estimated coefficients and the estimated replacement values by class, which are simply the cumulative sums of the incremental coefficients.

Class	Incremental coefficient	Imputed value
1	68,641	68,641
2	209,143	277,784
3	470,913	748,697
4	283,350	1,032,047
5	1,380,785	2,412,832

Table 12: Incremental coefficients and imputed replacement values by class.

F Appendix

The preamble to the 1944 National Airport Plan explains the criteria used by the authors in choosing where airports were needed and what sizes of facilities should be constructed. The stated criteria have little apparent relationship to factors for 2007 industrial composition. The primary concerns were to connect civilians to the budding air network, the main criterion being population distribution, and to meet potential military needs. The preamble states the following:

> In the formulation of the plan, population was used as the primary basis of airport distribution, since the need for airports is directly related to population and area. The suggested class of the airport was determined by the relative importance of the locality as a center of a trading area, its function in the national airport system, and its importance to existing and proposed air routes. In areas of high population density, airports were located to render maximum utility with a minimum number.

The preamble goes on to give a number of justifications for the 1944 National Airport Plan as a public works project. These include the creation of jobs in the construction and operation of the airports, the value of the facilities for national defense or for emergency relief, reduced transportation costs, and the stimulation of investment. The type of investment envisaged is stated explicitly and is limited to businesses that are either part of the aviation industry or located at the airport, suggesting that the effects on particular industries elsewhere in the city were not an important concern.

G Appendix

Table 13 displays the results from the estimation of equation (17), the first-stage relationship between the log value of proposed airports in the 1944 National Airport Plan and the log number of departures in 2007. The estimation uses the same sets of controls as in Table 4 and Table 5.

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS
$\ln(airports_{1944})$	0.221^a	0.223^a	0.218^a	0.228^a	0.228^a	0.232^a	0.205^a	0.224^a	0.227^a
	(0.054)	(0.058)	(0.057)	(0.062)	(0.061)	(0.060)	(0.062)	(0.063)	(0.062)
$\ln(total\_emp_{2007})$	1.200^a	1.215^a	1.242^a	1.221^a	1.161^a	1.163^a	1.133^a	1.163^a	1.164^a
	(0.073)	(0.075)	(0.077)	(0.079)	(0.113)	(0.115)	(0.113)	(0.114)	(0.115)
$\ln(population_{1940})$	-0.357^a	-0.357^a	-1.009^a	-0.968^b	-0.871^b	-0.934^b	-0.849^b	-0.919^b	-0.935^b
	(0.080)	(0.089)	(0.379)	(0.398)	(0.409)	(0.408)	(0.391)	(0.402)	(0.405)
Physical geography, climate	Y	Y	Y	Y	Y	Y	Y	Y	Y
Census divisions	N	Y	Y	Y	Y	Y	Y	Y	Y
$\{\ln(pop_t)\}_{t\in\{1910,\dots,1930\}}$	N	N	Y	Y	Y	Y	Y	Y	Y
1940 education; 1950 income	N	N	N	Y	Y	Y	Y	Y	Y
2007 ages, education, income	N	N	N	N	Y	Y	Y	Y	Y
1940 manuf. & service shares	N	N	N	N	N	Y	Y	Y	Y
2007 market access measure	-	-	-	-	-	-	1	2	3
R^2	0.86	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88
F-statistic for $\ln(airports_{1944})$	16.46	15.01	14.45	13.78	14.09	15.06	10.97	12.70	13.20

Note: 290 observations for each regression; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%

Table 13: First-stage coefficients for the effect of planned 1944 airports on 2007 air traffic.

The coefficients displayed in Table 13 reflect that for each of the specifications, the number of planned airports is a strong factor in the level of air traffic in 2007. The coefficient on airport size is positive and significant at the 1% level for all specifications. Figure 5 plots the actual versus predicted numbers of departures obtained from the estimation of (17) using the standard specification and the full range of controls. It therefore corresponds to the results displayed in column 6 of Table 13.

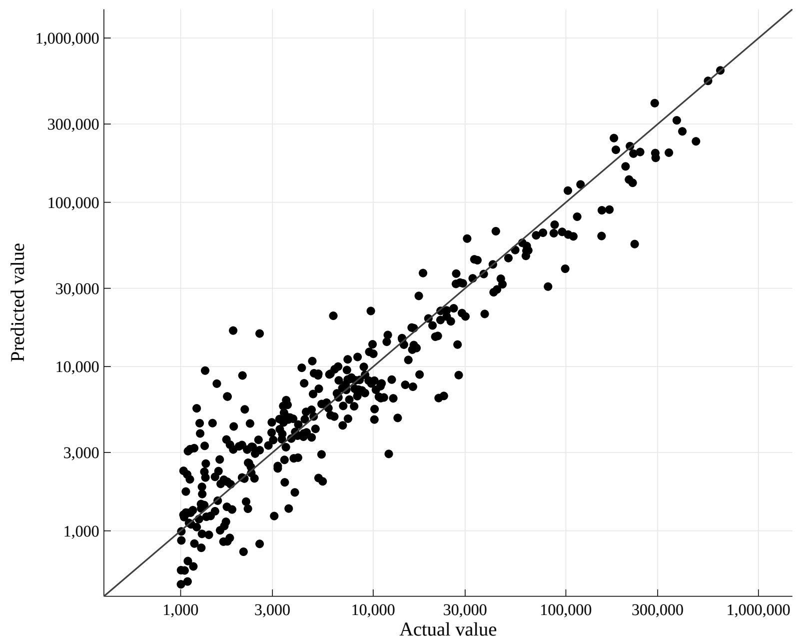

Figure 5: Actual versus predicted numbers of departures by CBSA in 2007 from the first-stage estimation.

H Appendix

This appendix explores the connection between passenger air travel and manufacturing in more detail. There are reasons to believe that air travel would have a positive effect on manufacturing, as it facilitates contact between producers and potential customers. On the other hand, the coefficients for the effect of airport size on manufacturing in Table 5 are insignificant but negative in sign. To test for a direct relationship between air connections and manufacturing trade it is possible to fit a gravity-style model for the trade on pairs of metropolitan area.

By its nature, air travel requires a substantial amount of fixed infrastructure at the nodes of the network whereas the links are comprised of essentially homogeneous and non-congestible airspace. Therefore, the combination of distance and origin- and destination-level factors should characterize the difficulty of operating flights between any pair of metropolitan areas. Furthermore, if manufacturing trade is directly related to air travel, then air traffic patterns should readily adjust in response to demand from the manufacturing industry. This could cause a positive bias, if there is some external factor that affects both air traffic and manufacturing, but a lack of an observed relationship between air traffic and manufacturing flows would suggest these that two phenomena are unrelated.

The analysis uses information from the Commodity Flow Survey (CFS), which details commodity shipments by pair of locations in the US. The geographical unit of observation in the CFS is the Commodity Flow Survey Place (CFSP). The CFSPs are generally larger geographical areas than the CBSAs, though in some cases the two definitions coincide. The commodities in the CFS are classified by Standard Classification of Transported Goods (SCTG) code. A list of the SCTG codes that are classified here as manufacturing is included in Table 14. The information on air travel is from the T-100 segment data and DB1B coupon data published by the US Bureau of Transportation Statistics, aggregated by CFSP. The segment data describe plane movements, so that a flight with a connection would be included as two separate legs, whereas the coupon data describe the origins and destinations of itineraries.

SCTG code	Commodity Description
21	Pharmaceutical products
22	Fertilizers
23	Chemical products and preparations, nec
24	Plastics and rubber
26	Wood products
27	Pulp, newsprint, paper, and paperboard
28	Paper or paperboard articles
29	Printed products
30	Textiles, leather, and articles of textiles or leather
31	Nonmetallic mineral products
32	Base metal in primary or semifinished forms and in finished basic shapes
33	Articles of base metal
34	Machinery
35	Electronic and other electrical equipment and components and office equipment
36	Motorized and other vehicles (including parts)
37	Transportation equipment, nec
38	Precision instruments and apparatus
39	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs
40	Miscellaneous manufactured products

Table 14: SCTG industries classified as manufacturing.

The test of the relationship between air connections and manufacturing trade on pairs of metropolitan areas involves fitting the following equation for the (log) value of manufacturing shipments in 2007, v_{mn}, where m denotes the origin and n the destination:

$$v_{mn} = \gamma_m^O + \gamma_n^D + \beta_a a_{mn} + \beta_d d_{mn} + \varepsilon_{mn} \tag{24}$$

In equation (24), γ_m^O and γ_n^D are origin and destination fixed effects, a_{mn} is the (log) amount of air traffic between m and n in 2007, d_{mn} is the (log) distance between m and n, and ε_{mn} is an error term. The fixed effects capture all origin- and destination-level factors, including the overall level of exports from the metropolitan area. The measures of air traffic used for a_{mn} are the number of flights and the number of passengers. As the effect of distance may be highly nonlinear, some higher powers of the (log) distance are also included in the regressions. The results from the estimation of (24) are displayed in Table 15.

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS
ln(*departures* $_{2007}$) (segment)	-0.044^a (0.017)	-0.010 (0.018)	-0.010 (0.018)						
ln(*passengers* $_{2007}$) (segment)				-0.036^b (0.016)	-0.007 (0.017)	-0.007 (0.017)			
ln(*passengers* $_{2007}$) (coupon)							-0.031 (0.019)	-0.004 (0.020)	-0.004 (0.020)
ln(*distance*)	-1.547^a (0.050)	-4.343^a (0.479)	23.234 (28.687)	-1.531^a (0.048)	-4.375^a (0.474)	23.200 (28.654)	-1.524^a (0.049)	-4.409^a (0.467)	23.062 (28.600)
ln(*distance*)^2		0.229^a (0.039)	-6.346 (7.301)		0.232^a (0.039)	-6.344 (7.293)		0.235^a (0.038)	-6.319 (7.281)
ln(*distance*)^3			0.686 (0.816)			0.686 (0.815)			0.684 (0.814)
ln(*distance*)^4			-0.026 (0.034)			-0.026 (0.034)			-0.026 (0.034)
R^2	0.671	0.676	0.676	0.670	0.676	0.676	0.670	0.676	0.676

Note: 2,054 observations for each regression; robust standard errors in parentheses; *a* , *b* , *c* denote significance at 1%, 5%, 10%

Table 15: Coefficients for the effect of air traffic on manufacturing shipments between a given pair of CFSPs, controlling for distance and using CFSP-level fixed effects.

The results displayed in Table 15 indicate no significant relationship between air connections and manufacturing shipments on pairs of CFSPs. The coefficients on the numbers of flights and passengers by both segment and coupon are negative, but none of the measures is significantly different from zero when second- or higher-order powers of distance are included. Therefore, it is not possible to reject the null hypothesis that manufacturing shipments are unrelated to air connections. This result supports the notion that air connections are unrelated to the size of the local manufacturing sector.