The effect of air transport on the production of goods and services

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Abstract

This paper estimates the effect of air travel connections on local production in the manufacturing and service sectors, using data from the United States. These effects are relevant to policies that aim to develop an airport or to otherwise attract airlines to operate to and from the airport. To solve the endogeneity problem that results from airlines expanding operations in response to increased demand, the 1944 National Airport Plan of the Civil Aeronautics Administration is used to instrument for the current distribution of airports. Better air connections are found to have a positive effect on the size of the local service sector, with an elasticity of approximately 0.1, and a negative effect on manufacturing. There is no measurable effect on the production of non-tradable services.

Keywords: air transport; services trade; infrastructure

JEL classification: F14, H54, R41

1. Introduction

This paper estimates the effect of increased accessibility via air travel on employment in the manufacturing and service sectors within a metropolitan area. The measurement of these effects is important for the design of policies related to airport construction and improvement as well as to efforts to induce airlines to expand local operations. It also contributes to a broader question about the effects of infrastructure improvements. The analysis is conducted for metropolitan areas in the United States of America (henceforth the “US”) using an instrumental variables approach to address the obvious endogeneity problem arising from increases in air traffic potentially being driven by demand resulting from increased activity in...
the relevant sectors. Increased air connectedness is found to have a positive effect on employment in tradable services and possibly a negative effect on employment in manufacturing. The negative effect on manufacturing would be interpreted as being due to a substitution of factors to the tradable service sector. There is no measurable effect on employment in non-tradable services.

Evaluation of the effects of infrastructure improvements is central to the design of public policy. The example of airport improvements is relevant both in a general sense, as it adds to our understanding of the effects of increased accessibility and connectedness, and in a specific sense, as it is important to understand the effects of policies that involve airport improvements. Airports are often established and expanded as an initiative of or with the participation of local and national governments. In North America, public ownership of commercial airports is the norm. Though the demand for air travel can induce airport construction as a private enterprise, the participation of governments is suggestive of concern about the effects on the broader economy. The goal of improving accessibility is also evident in efforts to persuade airlines to operate to or from a city, particularly as a hub of operations. To evaluate the effects of such initiatives, it is necessary to understand the effects than an airport has on its local economy.

Airport improvements normally aim to increase capacity or to make travel more convenient for users of the airport. Often these aims coincide, as higher-capacity airports usually host more frequent flights to a wider range of destinations, provide non-stop flights to more distant destinations, have better transport links with nearby communities, and offer more associated services. These aims are therefore well reflected in the level of traffic, which is used here as the measure of airport size. An alternative specification uses the number of destinations, which emphasises the convenience of travel. The actual policy action may be to expand the physical size of the airport, but due to the costs of acquiring land and constructing runways and terminals this normally implies the loosening of a constraint on capacity, with the predictable result of an increase in traffic.

3 As an example, a new international airport was constructed from scratch in Denver, Colorado in the early 1990s and the old airport was closed down, as an initiative of the City of Denver. The project used land acquired from the county and cost $4.8 billion to complete, $4.4 billion of which came from public funds (General Accounting Office, 1995).
To estimate the effects of improved air transport links on local employment it is necessary to address the endogeneity problem that results from air traffic increasing in response to demand. The approach used here is to instrument for the current sizes of airports using the 1944 National Airport Plan of the Civil Aeronautics Administration, the first national plan for the US airport network to come into effect. The Plan explains a significant amount of the variation in the present-day distribution of airports across metropolitan areas but is exogenous to other determinants of the distribution of industry-level employment. The Plan greatly influenced the subsequent development of airports as inclusion in the most recent plan was a prerequisite for federal funding. The persistence of sites developed decades ago was ensured by the high costs of acquiring land to expand present airports or to construct alternative sites. Though later airport development naturally depended on demand from individuals and firms, the 1944 Plan had a lasting effect, and its distribution of airports is otherwise not correlated with the current distribution of industrial sectors.

The analysis in this paper is conducted using data from metropolitan areas in the contiguous mainland of the US (the District of Columbia and all states excluding Alaska and Hawaii). The use of data from the US has several distinct advantages over other potential candidates. Firstly, it is a single political entity with relatively homogenous institutions and culture, rather than a collection of small, independent states. Secondly, the US has several national airlines with a high degree of overlap in their geographical coverage, notwithstanding a number of ‘fortress’ hubs that are dominated by single airlines, and there is competition on all major internal routes. Thirdly, the availability of alternative modes of transport is relatively homogenous over the land mass. Although locations near the coasts and the Great Lakes have particular access to sea transport, a national highway network and secondary roads connect settlements in different regions to a relatively similar degree and few metropolitan areas are separated by bodies of water. And fourthly, it is a large economy with many metropolitan areas, providing more data points than other areas that are comparable in terms of the first three factors.

The effects of air connections on employment are estimated for three broadly-defined industries: tradable services, manufacturing, and non-tradable services. Tradable services are generally able to be ‘shipped’ from one location to another, in the sense that they may be

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4 A list of the NAICS 2-digit industries included in these categories is given in appendix 1.
consumed in different locations from where they are produced: a process that sometimes involves the producers of these services travelling by air. Manufacturing involves the production of goods that are also often shipped some distance to the final consumer, though these goods are predominantly delivered by some mode of surface transportation rather than by air. Non-tradable services involve tasks such as hairdressing for which the producer and consumer of the task must be in the same location.

The estimated effects on employment shares are as follows: an increase in air traffic to or from a metropolitan area has a positive and significant effect on tradable services, a negative and significant (though smaller) effect on manufacturing, and no measurable effect on non-tradable services. The effect of a 10% increase in the level of air traffic is to increase the proportion of the population employed in tradable services by around 0.30% (an elasticity of 0.10) and to decrease the proportion of the population employed in manufacturing by around 0.23% (an elasticity of -0.25). The negative effect on manufacturing appears not to be a direct effect, as a larger airport is unlikely to be an obstacle to manufacturing. The explanation offered here is that it reflects substitution of employment to tradable services, the production of which is aided by the air connection. An analysis of the relationship between air traffic and manufacturing shipments on metropolitan-area pairs supports this explanation. As non-tradable services must be consumed in place, it is intuitive that their production be unrelated to air connections.

The findings presented in this paper are specific to air travel but contribute to a broader literature about the importance of transportation infrastructure. Research on this topic is subject to an endogeneity problem, as infrastructure development usually reflects past or anticipated growth in demand. Recent studies on the effects of roads by Baum-Snow (2007), Michaels (2008), Duranton and Turner (2011; 2012), and Duranton, Morrow, and Turner (2011) use historical data including the 1947 federal highway plan to instrument for the current provision of roads, an approach similar to that employed in this paper. Of these, the exercise most closely related to the current paper is that by Duranton, Morrow, and Turner (2011), who estimate the effect of metropolitan-area highways on trade. They find a positive effect of highways on the weight but not value of exports from a city and that cities with

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5 Each of these papers instruments using the 1947 federal highway plan except for Michaels (2008), who uses the 1944 federal highway plan. Duranton and Turner (2011; 2012) and Duranton, Morrow, and Turner (2011) additionally use 1898 railways and 1528 to 1850 exploration routes as instruments.

More specifically, this paper contributes to the small literature on the effects of air transport infrastructure. Brueckner (2003) estimates the effect of airports on overall and industry-specific employment growth in US metropolitan areas, using the “hub” status of an airport and geographical “centrality” to instrument for air traffic levels. Consistent with the current paper, he finds a positive effect of airport size on service employment. However, these instruments may not in fact be exogenous: the “hub” status of an airport results from an endogenous decision by an airline that reflects demand, while the “centrality” measure is intended to reflect the suitability of a city as a connection point but may well be correlated with other factors, such as proximity to the coast, that influence the quality of a location for an exporter.6 Green (2007) tests the effect of airports on growth, also using an instrumental variables approach, though the use of current airport size and industry-level employment measures as instruments for air traffic puts the validity of the approach into question.

The current paper contributes to this literature in a number of ways. Firstly, it uses an original type of historical data as a more reliable source of exogenous variation in the allocation of airports. Secondly, the instrument is more directly related to current airport size and is therefore potentially stronger than prior alternatives. Thirdly, it uses data from a far larger number of metropolitan areas and thus represents a more comprehensive assessment of the underlying mechanisms. Fourthly, it analyses the relationship between air travel and trade on specific routes, rather than being limited to the metropolitan-area level.

The remainder of the paper is arranged as follows: the model for the relationship between air travel and industry sizes is described in section 2; the data are described in section 3; the empirical analysis of the effect of airport size on local employment is presented in section 4; and concluding remarks are presented in section 5. The appendices contain some definitions,

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6 Indeed, many of the largest US airports are near the periphery of the mainland and, depending on the criteria for including metropolitan areas in the sample, the “centrality” measure can be a negative factor in air traffic.
the first-stage results, and an analysis of air traffic and manufacturing shipments by pair of metropolitan areas.

2. Model
The empirical tests of the effect of airport provision on industry shares are conducted by estimating a system of two equations. The first identifies the variation in the level of air traffic in 2007 that is explained by planned 1944 airports. The second takes the estimated 2007 level of air traffic from the first step and relates this to employment shares. The first-stage equation is specified as follows:

\[ a_{m,2007} = \alpha + \beta_A A_{m,1944} + \beta_X X_m + \varepsilon_{1,m} \]  

And the second-stage equation is:

\[ E_{i,m} = \alpha' + \beta_d a_{m,2007} + \beta_X' X_m + \varepsilon_{2,m} \]  

In equation (1), \( a_{m,2007} \) is the (log) level of air traffic in metropolitan area \( m \) in 2007, \( A_{m,1944} \) is the number of class 4 and 5 airports in metropolitan area \( m \) according to the 1944 National Airport Plan, \( X_m \) is a set of geographic and pre-1944 demographic controls, and \( \varepsilon_{1,m} \) is an error term.

In equation (2), \( E_{i,m} \) is the share of workers in metropolitan area \( m \) who are employed in industry \( i \), \( a_{m,2007} \) is the (log) level of air traffic in metropolitan area \( m \) in 2007 estimated in (1), \( X_m \) is the same set of controls as in (1), and \( \varepsilon_{2,m} \) is an error term. As the industry employment shares are given as proportions while the airport sizes are in natural logs, a 1% increase in the size of the airport leads to a \( \beta_d \) % change in the employment share. This specification has the advantage of making the magnitudes of the effects comparable across industries.

For the effect of air travel on employment to be identified by the system of equations (1) and (2), the following conditions must be satisfied:

\[ \beta_A \neq 0 \]  

\[ Corr(A_{m,1944}, \varepsilon_{2,m}) = 0 \]
The first of these is the relevance condition (3), 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 tested for below by running weak identification tests. The second condition is the exogeneity condition or exclusion restriction (4), which requires that the number of planned airports effect employment only through airport size. Though it is not feasible to test for this condition statistically, there are several reasons why the condition is likely to be satisfied, as explained below.

3. Data

The empirical analysis in this paper uses a dataset constructed from several sources and aggregated by Core Based Statistical Area (CBSA). The CBSAs are defined by the Office of Management and Budget as sets of counties. According to the definition, each CBSA represents an urban core and surrounding areas with which it is highly integrated. The November 2007 definitions are used and only those CBSAs in the continental US are included. In total, 290 CBSAs are included in the sample. A summary of the main variables in the data is given in Table 1.

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<th>Mean</th>
<th>Std. dev.</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>1940 population</td>
<td>286,934</td>
<td>861,417</td>
<td>4,745</td>
<td>11,950,188</td>
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<td>2010 population</td>
<td>801,264</td>
<td>1,761,394</td>
<td>17,398</td>
<td>18,897,084</td>
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<td>Number of existing class 4-5 airports in 1944</td>
<td>1.5</td>
<td>1.9</td>
<td>0</td>
<td>14</td>
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<tr>
<td>Number of proposed class 4-5 airports in 1944</td>
<td>1.8</td>
<td>2.3</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Number of commercial airports in 2007</td>
<td>1.9</td>
<td>1.7</td>
<td>1</td>
<td>16</td>
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<tr>
<td>Number of departing flights in 2007</td>
<td>33,319</td>
<td>81,968</td>
<td>1,003</td>
<td>633,633</td>
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<td>Number of departing passengers in 2007</td>
<td>2,568,941</td>
<td>7,299,818</td>
<td>1,898</td>
<td>56,404,489</td>
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<tr>
<td>Number of CBSAs flown to at least daily in 2007</td>
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<td>43.8</td>
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<td>200</td>
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<td>Manufacturing (31-33) employment</td>
<td>30,931</td>
<td>64,175</td>
<td>60</td>
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<td>Services (51-56) employment</td>
<td>93,971</td>
<td>243,150</td>
<td>548</td>
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<td>Information services (51) employment</td>
<td>10,283</td>
<td>29,296</td>
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<td>322,194</td>
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<td>Finance and insurance services (52) employment</td>
<td>19,435</td>
<td>52,072</td>
<td>134</td>
<td>633,580</td>
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<td>Real estate services (53) employment</td>
<td>6,557</td>
<td>16,991</td>
<td>60</td>
<td>183,952</td>
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<td>Professional-scientific-technical services (54) employment</td>
<td>24,498</td>
<td>68,841</td>
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<td>680,488</td>
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<td>Management of companies and enterprises (55) employment</td>
<td>9,698</td>
<td>26,358</td>
<td>0</td>
<td>281,068</td>
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<tr>
<td>Administrative and support services (56) employment</td>
<td>23,300</td>
<td>55,356</td>
<td>45</td>
<td>514,641</td>
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<tr>
<td>Other services (81) employment</td>
<td>15,288</td>
<td>34,371</td>
<td>191</td>
<td>364,122</td>
</tr>
<tr>
<td>Total employment</td>
<td>324,889</td>
<td>733,184</td>
<td>4,643</td>
<td>7,671,171</td>
</tr>
</tbody>
</table>

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

Table 1. Summary of the main variables in the dataset by CBSA.

The data are from several sources. The population statistics are from the decennial census conducted by the United States Census Bureau for each of the relevant years. The locations and sizes of existing and proposed airports in 1944 are from the National Airport Plan of that
year authored by the Civil Aeronautics Administration. The traffic levels at each airport in 2007 are from the T-100 segment data made available by the US Bureau of Transportation Statistics. The employment figures are from the 2007 County Business Patterns. The trade flows of manufactured goods are from the 2007 Commodity Flow Survey.

The employment data include CBSA-level figures for total employment and for employment in a selection of 2-digit North American Industry Classification System (NAICS) industries. These industries are henceforth grouped and referred to as manufacturing (31-33), tradable services (51-56), and non-tradable services (81). The industries classified as ‘tradable’ services include functions such as publishing, insurance, computer programming, and management – services that can be delivered to locations remote from where they are produced. In contrast, the ‘non-tradable’ services include hairdressing and beauty salons, parking lots, auto repair, and cleaners – services that are impossible or excessively costly to deliver to other locations. A list of the original descriptions of these 2-digit NAICS industries is given in appendix 1.

The remaining data are from a variety of sources. The location of a CBSA adjacent to the Pacific Ocean, the Atlantic Ocean, or one of the Great Lakes is read from the November 2007 map of CBSAs from the United States Census Bureau. The elevation data, used to calculate the ‘elevation’ and ‘ruggedness’ variables, are from the Global Positioning System. The elevation variable is measured at the 2010-population-weighted midpoint of the CBSA. 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 centred on the midpoint: one with a radius of three miles and the other with a radius of ten miles. The annual heating and cooling degree days and the average wind speed for each CBSA are from the National Oceanic and Atmospheric Administration.

The sample is restricted to CBSAs for which the relevant variables are defined, so each must have a commercial airport and employment data in the County Business Patterns. The sample is further restricted to CBSAs that host at least 1,000 annual departures, which excludes some smaller communities that are likely both to be serviced by better airports outside of the CBSA boundaries. These CBSAs also have fewer residents and therefore noisier figures for employment shares. This leaves 290 CBSAs.
A map of the 290 CBSAs included in the sample as well as the proposed airports in the 1944 National Airport Plan is shown in Figure 1. It can be seen from the map that the sample includes populated areas from all across the country. Indeed, the 290 CBSAs include parts of all 48 of the contiguous states and the District of Columbia. Given the mean 2010 population of around 800,000 for the 290 CBSAs in the sample, the sample includes approximately three quarters of the US population. Employment in the sectors included in the sample represents roughly 43% of total employment: 9% in manufacturing (sectors 31-33), 29% in tradable services (sectors 51-56), and 5% in non-tradable services (sector 81).

Figure 1. Map of the 290 CBSAs included in the sample (shaded) and the proposed class 4 and 5 airports in the 1944 National Airport Plan (marked with crosses, the larger being the class 5 airports).

3.1. 1944 National Airport Plan

The empirical strategy used in this paper involves instrumenting for airport sizes and locations using the 1944 National Airport Plan of the Civil Aeronautics Administration (CAA). This was an updated version of the original plan devised by the CAA after the passing of the Civil Aeronautics Act in 1938. This bill removed the existing ban on the federal government providing funding for the construction and improvement of airports, established the CAA, and directed this new authority to propose a plan for the national air

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7 The agency founded in 1938 with the passing of the Civil Aeronautics Act was named the “Civil Aeronautics Authority”. In 1940 the responsibilities of this agency were split between the newly-formed Civil Aeronautics Administration (CAA) and Civil Aeronautics Board (CAB) (Bilstein, 2001).
In order to receive federal funding, an airport was required to be in the most recently approved version of the plan, a condition that remains in effect to this day. The first National Airport Plan, submitted to Congress in 1939, failed to gain approval for apparently political reasons. However, as a compromise motivated by the exigencies of the war effort, a more limited program was then approved to develop a small number of facilities for military needs. The 1944 National Airport Plan was a revised version of the original plan and became the first to gain approval by Congress, being passed along with the Federal Airport Act in 1946. Indeed the 1944 plan greatly influenced the provisions in the Federal Airport Act, which defined how federal funds would be applied to airports in the subsequent decades through the Federal Aid Airport Program (Blaine, 1954; Wilson, 1979).

The 1944 National Airport Plan lists the 6,305 existing and proposed airports in the 48 states and the District of Columbia. Of these, 2,950 were existing airports, 491 of which were to be improved and 72 downgraded, and 3,355 were to be new airports. The location of each airport is given by the name of the nearest town or city and in some cases by identifying the actual facility. These locations are converted into latitude and longitude figures that are used to identify which CBSA, if any, the airport would be located within. The current and proposed sizes of the facilities are given by their class on a scale of 1 to 5. The smallest were the class 1 and 2 airports, which were appropriate for privately-owned aircraft and some small transport aircraft. Class 3 airports were large enough to handle contemporary twin-engined transport aircraft. The class 4 and 5 airports were substantial facilities with capacity for the largest aircraft then in operation as well as those anticipated to begin operating in the coming years. Of the 6,305 airports in the Plan, 856 are class 4 or 5. The class 4 and 5 airports were to have substantially larger land areas, more terminal facilities, longer and wider runways, and more stringent requirements for the clearing of potential obstacles along

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8 The ban on federal funding of airports was instituted by the Air Commerce Act of 1926 (Wilson, 1979).

9 The 1939 plan was based on a survey conducted in 1938 and 1939 and proposed the development of 4,000 facilities. A bill approving $80 million for the 1939 plan passed the House of Representatives and seemed set to pass the Senate, but after details were leaked from the House Appropriations Committee the Senate committee received a large amount of mail from constituents requesting funds for their local areas and the Senate reacted by refusing to approve any funds. After President Roosevelt argued that the funding was important for military purposes, a compromise was reached in which $40 million for 250 airports was approved under the program named Development of Landing Areas for National Defense (DLAND) (Wilson, 1979).
approach paths.\textsuperscript{10} As these larger facilities are the most likely to remain useful and permit expansion in later years, the number of class 4 and 5 airports in each CBSA, as a ratio of the 1940 population, is used to instrument for the number of departures in (2).

To be a relevant instrument, the 1944 National Airport Plan must explain a significant amount of the variation in 2007 air traffic levels. This condition is represented by (3). This seems reasonable due to the importance of the Plan in determining which airports would be developed and to the persistence in airport locations. All existing airports in 1944 were included, even if a few were recommended to be downgraded, so the Plan reflects the airfield development that occurred during the Second World War. When the War ended, the special programs to develop airports for military needs were wound up. Since then, an airport has had to be in the most recently-approved version of the plan to receive federal funding, as specified in the Civil Aeronautics Act. Though the plan was updated regularly and the approval of funds in principle did not always lead to improvements being carried out, much of the airport development in the decades following the Second World War was conducted according to the 1944 Plan. This was a period of rapid growth for the US air network, which added more than 5% airfields annually during the decade following 1945.\textsuperscript{11} Under the Federal Airport Act, the federal government was funding up to half of the costs of all but the very largest projects, for which local governments took a larger share (Wilson, 1979).

For the 1944 National Airport Plan to explain the current allocation of airports through its influence on historical airport construction it is necessary that the locations and sizes of airports be persistent. This appears also to be true. Due to the large fixed investment involved in establishing a new airport, in particular for the acquisition of a substantial area of ever-scarcer land, historical construction is related to the current locations of airports (Redding, Sturm, and Wolf, 2011). Indeed, with few exceptions, the sites of what would become the nation’s major airports had already been established as airfields by the late 1940s (Daley Bednarek, 2001). The $F$-statistics from the weak instrument tests are large enough to suggest that the instrument comfortably satisfies the relevance condition (3). The coefficients

\textsuperscript{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).

\textsuperscript{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).
for the instrument from the first-stage estimation of (1), given in appendix 2, support this result.

The exogeneity condition (4) requires that the instrument affect industry shares only through the allocation of airports, conditional on the control variables. The 1944 National Airport Plan credibly satisfies this condition for a number of reasons. Firstly, the stated criteria for the selection of sites are not related to sectoral composition or factors that could influence the future growth of particular sectors. The Plan was explicitly designed to connect civilians to the budding air network, the main criterion being population distribution, and to meet potential military needs. Additional criteria included the function of a potential airport in the national air travel network and proximity to trained military aviators who could be employed as commercial pilots. Secondly, the Plan was drawn up after only preliminary consultation with state and local governments about the locations and sizes of airports, minimising the possibilities for local politicians and businesses to influence the distribution of airports to suit local industries (Wilson, 1979). Thirdly, the Plan was made in an era when air travel was at an early stage of development and the extent, manner, and cost of air travel were vastly different from today, limiting the potential for the decisions made in the 1940s about the allocation of airports to be correlated with present-day factors (Bilstein, 2001).

Perhaps the most serious threat to the exogeneity of the instrument would be a relationship between the allocation of airports in the 1944 Plan and the contemporary size of either the manufacturing or the service sector. Areas with large shares of a given industry in the 1940s are likely to have large shares today, because of persistence and unobserved factors that make the location suitable for the given industry. Were more airports located in areas with more service firms in the 1940s, it could be that the same areas remain centres of service production today, so the error term $\varepsilon_{2,m}^i$ in (2) would be correlated with the number of planned airports $A_{m,1944}$ and the exogeneity condition (4) would be violated. However, it is possible to test for this possibility. Table 2 displays the results of regressions of the proposed class 4 and 5 airports in the 1944 Plan on the employment shares of the service and

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12 The promotion of local businesses is in fact mentioned in the plan as a minor motivation, but these businesses are limited to aircraft sales, flight schools, and services such as restaurants that would be located at the airport, suggesting that the effect on industries not related to air travel were not being considered. Presumably other, larger industries would have been mentioned had the effects on those industries been considered.
manufacturing industries in 1940 and 1950, for the 56 Standard Metropolitan Areas included in the 1950 Census of Population. No significant relationship between proposed airports and industry shares emerges, suggesting that airports were not allocated according to the location of these industries.

Table 2. Proposed airports in the 1944 National Airport Plan and contemporary industry shares.

4. Results

4.1. OLS results

The results from the ordinary least squares (OLS) estimation of (2) for each of the three industries are displayed in Table 3. 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. These results are included to give an impression of the overall relationship between air traffic and the industry shares in the data.

The coefficients for the three industries are shown in separate panels in Table 3. The columns represent separate regressions with a range of different control variables. 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 devised. The second column introduces limited geographical controls: the area of each CBSA and location adjacent to the Atlantic or Pacific coast or the shore of one of the Great Lakes. The third column introduces further geographical controls: elevation, ruggedness, and average wind speed. To control for potential regional differences, the fourth column introduces census division fixed effects. Further controls for potential regional variation are included in the fifth and sixth columns, in the form of annual numbers of heating and cooling days. To account for possible variation due to recent development, the sixth column includes population figures from the decennial censuses from 1900 to 1930. The seventh and eighth columns limit the sample to CBSAs above 2010 population thresholds of 50,000 and 100,000, respectively.
A negative relationship between air traffic and manufacturing employment is evident from Table 3. With the share of manufacturing employment as the dependent variable, for all specifications the coefficient of air traffic is negative and strongly significant. Conversely, there is a strong positive relationship between air traffic and the concentration of tradable services employment for all specifications. That is, those CBSAs that host more traffic in 2007 had higher concentrations of tradable service production. There appears to be no relationship between the number of departures from a metropolitan area and the employment share of non-tradable services.

4.2. IV results

The results from the instrumental variables (IV) estimation of (2) are displayed in Table 4. The instrument used in each regression is the count of proposed class 4 and 5 airports in the CBSA according to the 1944 National Airport Plan, as a ratio of the 1940 population. These
regressions use the same sets of controls and minimum 2010 populations as in the OLS estimates presented in Table 3.

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**Panel A.** Dependent variable: Manufacturing employment share in 2007

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<td>-0.023***</td>
<td>-0.021*</td>
<td>-0.026*</td>
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<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.014)</td>
<td>(0.020)</td>
<td>(0.010)</td>
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<td>0.026***</td>
<td>0.026***</td>
<td>0.024**</td>
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<td>0.023***</td>
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<td>(0.010)</td>
<td>(0.012)</td>
<td>(0.014)</td>
<td>(0.050)</td>
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<td>(0.006)</td>
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**Panel B.** Dependent variable: Tradable services employment share in 2007

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<td>ln(departures2007)</td>
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<td>0.031***</td>
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<td>(0.013)</td>
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<td>ln(pop1940)</td>
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**Panel C.** Dependent variable: Non-tradable services employment share in 2007

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<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.002)</td>
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<td>ln(pop1940)</td>
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<td>N</td>
</tr>
<tr>
<td>ln(pop1940)</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Minimum 2010 population</td>
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<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
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<td>290</td>
<td>290</td>
<td>290</td>
<td>290</td>
<td>263</td>
<td>229</td>
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</tbody>
</table>

Note: robust standard errors in parentheses; * significant at 10% level, ** significant at 5% level, *** significant at 1% level

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

The estimates of the effect of air travel on the share of manufacturing employment are presented in Panel A of Table 4. For each of the specifications the coefficient is negative in sign and in most cases it is significant. The only case in which the coefficient is not significant is the specification that introduces 1900 to 1930 population, which controls for development in the period preceding the 1944 Plan. In this case, the first-stage statistic is also lower, so apparently some of the variation in airports in the Plan is captured by the population figures. As the controls also apply in the second stage, this would tend to absorb the variation explained by the instrumented variable and therefore to reduce its significance. With the exception of the first specification that does not include any geographical controls, the magnitude of the coefficient is consistent at around -0.023, so that a 10% increase in the level of air traffic is associated with a 0.23% reduction in the share of manufacturing employment. This corresponds to an elasticity of approximately -0.25.
The negative effect of air traffic on the share of manufacturing employment demands some explanation, as air travel should not represent any direct obstacle to manufacturing. Indeed, 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). The explanation offered here is of the substitution of factors towards the expanded service sector. The possible explanations are explored in more detail through the analysis of air traffic and manufacturing shipments between pairs of metropolitan areas in appendix 3.

The coefficients for the effect of air travel on the employment share of tradable services are displayed in Panel B of Table 4. The coefficient on air traffic is significant and positive in each of the specifications, indicating that air traffic has a positive effect on employment in tradable services. The size of the coefficient is around 0.030 for each of the specifications excepting the case with no geographical controls and that with the minimum 2010 population of 100,000, which are slightly lower. The effect of a 10% increase in air traffic is therefore to increase the employment share of the service sector by 0.30%. The corresponding elasticity is approximately 0.10.

Panel C of Table 4 displays the coefficients for the effect of air travel on the employment share of non-tradable services. The coefficients are small in magnitude and statistically insignificant in each of the specifications, indicating that there is no measurable effect of air travel on the size of the non-tradable-service sector. This is reasonable as the services in this category are largely either impractical or impossible to transmit between locations, so the distribution of their production must closely match that of their consumption. Unless there are systematic differences in the rates of consumption between metropolitan areas that result from variation in air traffic, there would not be any apparent effect on non-tradable services.

The results from the weak identification tests for the instrument are reported at the bottom of Table 4. The $F$-statistics for all specifications are above a reasonable threshold to reject the hypothesis of the instruments being weak. The statistics are large enough to pass comfortably in all specifications excepting that in which the 1900 to 1930 population figures are included, which appear to be somewhat correlated with the instrument and therefore to absorb some of the variation represented by existing and planned new airports in 1944.
5. Conclusion

This paper estimates the effects of air travel accessibility on local production in the manufacturing and service sectors. The main difficulty in estimating these effects is the endogeneity of air services, which are likely to increase in response to demand from industries that use air travel. This problem is addressed by instrumenting for current airports using the 1944 National Airport Plan, which explains a substantial amount of the variation in the current distribution of airports but appears to be otherwise unrelated to present sectoral concentrations.

The findings are that a metropolitan area that has better air connections because of an exogenous historical allocation of airports specialises less in the production of manufactured goods and more in the production of tradable services. A 10% increase in the frequency of flights from a metropolitan area is found to decrease the local employment share of manufacturing by 0.23% (an elasticity of -0.25), to increase the local employment share of tradable services by 0.30% (an elasticity of 0.10). There is no measurable effect on employment in non-tradable services.

The interpretation of these results is that tradable services, which can be delivered to another location partly by use of air travel by employees, are produced in the most accessible metropolitan area and exported to other locations. As non-tradable services must be consumed in close proximity to where they are produced, their employment share is relatively static and is not affected by air travel. Manufacturing is decreasing in the size of the airport but this is unlikely to be due to any direct effect; rather, a larger service sector employs workers, land, and other factors that may otherwise have been used in manufacturing. This interpretation is supported by the analysis of trade flows of manufactures presented in appendix 3, which shows no correlation between air services to a metropolitan area and the level of exports to the same area.

The findings of this paper are informative about the effects of infrastructure improvements and have implications for the evaluation of policy. Airport construction and expansion are often justified on the basis of the improved accessibility being a positive factor in employment. The results presented above support this justification, as the sectors that most obviously make use of air travel expand when air connections are improved. However, there is evidence of a less obvious effect on other sectors, which may suffer from the reduced availability of factors of land, workers, and other factors of production. Though it may not
seem necessary to consider the effects of airport improvements on sectors that do not use air travel, these should be taken into account in the evaluation of airport development projects.

References


**Appendix 1**

Table 5 displays a list of the 2-digit NAICS industries that are included in the samples. For the purposes of this paper industries 31-33 are classified as manufacturing, industries 51-56 are classified as tradable services, and industry 81 is classified as non-tradable services.

<table>
<thead>
<tr>
<th>NAICS code</th>
<th>Industry description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-33</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>51</td>
<td>Information</td>
</tr>
<tr>
<td>52</td>
<td>Finance and Insurance</td>
</tr>
<tr>
<td>53</td>
<td>Real Estate Rental and Leasing</td>
</tr>
<tr>
<td>54</td>
<td>Professional, Scientific, and Technical Services</td>
</tr>
<tr>
<td>55</td>
<td>Management of Companies and Enterprises</td>
</tr>
<tr>
<td>56</td>
<td>Administrative and Support and Waste Management and Remediation Services</td>
</tr>
<tr>
<td>81</td>
<td>Other Services (except Public Administration)</td>
</tr>
</tbody>
</table>

Table 5. NAICS titles for the 2-digit industries included in the samples of manufacturing (31-33), tradable services (51-56), and non-tradable services (81).

**Appendix 2**

Table 6 displays the results from the estimation of (1), the first-stage relationship between number of class 4 and 5 airports per capita in the 1944 National Airport Plan and the (log) number of departures in 2007. The same sets of controls and minimum CBSA sizes as in Table 3 and Table 4 are used in the regressions represented by Table 6.
The coefficients displayed in Table 6 reflect that for each of the specifications, the number of planned airports is a strong factor in the level of air traffic in 2007. Figure 2 plots the actual versus predicted numbers of departures obtained from the estimation of (1) using only log 1940 population, the geographical variables, and census divisions as controls. Figure 2 therefore corresponds to the results displayed in the fourth column of Table 6.

Figure 2. Actual versus predicted numbers of departures from the first-stage estimation.

Appendix 3
The result that an enlarged airport leads to a reduction in the size of the local manufacturing industry can be explored in more detail. The explanation proposed in this paper is of the substitution of factors to an expanded tradable service sector. The alternative would be of a
direct relationship: either an effect of the air connection on manufacturing shipments, or of both being influenced by some unobserved factor. These explanations would imply a negative correlation between air traffic and manufacturing shipments on specific routes, not only at the nodes of the network. A simple way to test whether there may be a direct relationship between air connections and manufacturing trade is therefore to test for this relationship on metropolitan area pairs, controlling for origin- and destination-level factors. This appendix describes such a test and presents the results from it.

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, controlling for distance, all destinations are equally costly to operate flights to from any given metropolitan area, given the costliness of operating flights from the same origin to any destination and the costliness of operating flights from anywhere to the same destination. If manufacturing trade is directly related to air travel, then air traffic patterns should readily adjust in response to demand from the manufacturing industry, or vice versa. A relationship between the two could reflect an external factor that affects both air traffic and manufacturing, that is to say an indirect effect. The absence of a relationship would suggest there not to be a direct relationship between the two.

The analysis of air connections and manufacturing shipments by metropolitan-area pairs 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 as manufacturing is included in Table 7. The CFS data are used along with information on air traffic from the T-100 segment data published by the US Bureau of Transportation Statistics, aggregated by CFSP.
Table 7. 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:

$$V_{mn} = \gamma_m^O + \gamma_n^D + \beta_D D_{mn} + \beta_A A_{mn} + \epsilon_{mn}$$  \hspace{1cm} (5)

In equation (5), $\gamma_m^O$ and $\gamma_n^D$ are origin and destination fixed effects, $D_{mn}$ is the (log) distance between $m$ and $n$ (with coefficient $\beta_D$), $A_{mn}$ is the (log) amount of air traffic between $m$ and $n$ in 2007 (with coefficient $\beta_A$), and $\epsilon_{mn}$ is an error term. The fixed effects capture all origin- and destination-level factors, including the overall level of exports from the metropolitan area and so on. As the effect of distance may be highly nonlinear, some higher powers of the (log) distance are also included in the regressions. The measures of air traffic used for $A_{mn}$ are the number of flights and the number of passengers, both of which reflect the quality of the air connection. The results from the estimation of (5) are displayed in Table 8.
The results displayed in Table 8 indicate that there is no significant relationship between air connections and manufacturing shipments on pairs of CFSPs. The coefficient on the number of passengers is negative in the most basic specification, but neither measure of air traffic is significantly different from zero when second- or higher-order powers of distance are included. Therefore, it is not possible to reject the null that manufacturing shipments are unrelated to air connections. This result favours the explanation for the apparently negative effect of air connections on the size of the local manufacturing sector as being due to substitution towards the expanded service sector, rather than to a direct effect.