Technical Appendix 1: Multi-Factor Productivity

ACRP 03-28: The Role of U.S. Airports in the National Economy

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1 Background and Approach

1.1 Introduction

In the 1980s and 1990s, the Federal Highway Administration sponsored a large number of research projects that explored the relationship between highway infrastructure investment and economic growth (Gillen, 1996). This literature also examined broader definitions of public capital, beyond transportation infrastructure, to understand how different types of public capital contributed to productivity improvements and economic growth. The literature also investigated how public capital was a complement or substitute to other factor inputs including labor, private capital and energy among others (Gillen, 1996).

A smaller subset of literature has sought to identify the linkages between the investment in highway infrastructure and changes in productivity or cost efficiency. Keller and Ying (1988), for example, measure how the U.S. interstate highway system led to significant improvements in the productivity growth in trucking. Shirley and Winston (2004) examined how highway investments led to changes in firms' inventory policies and estimate inventory savings in the amount of $400 Million.

More recently there have been papers that have investigated the linkages between agglomeration and productivity (Graham, 2007) and the catalytic effects of aviation (IATA, 2007, InterVISTAS, 2006). Agglomeration effects are similar in spirit to what we are trying to measure in this research. Agglomeration economies are externalities that can result in a shift in firm's cost functions due to increased specialization and higher skills. Such shifts can occur because of the concentration of spatial activity, which leads to more efficient transportation connectivity between these concentrations and markets; both for receiving goods and services needed for production and for sales to end users.

As an example, the sizes—and even the existence—of cities are considered in the urban economics literature to be determined by scale economies, as are the sizes of firms. However, agglomeration economies can provide an explanation of both size and existence even under conditions of constant returns to scale. That is, firms can be seen as low cost: not due to size, but due to the relationship (agglomeration economies) with other firms. Graham (2007) reports some examples of the elasticity of productivity with respect to agglomeration for several industry groupings—for example, transportation, storage and communication (0.223), banking, finance and insurance (0.237) and business services (0.224). Thus for business services, a 10-percent increase in the agglomeration measure would increase industry productivity by 2.24 percent.

The literature on catalytic effects of aviation explores how connectivity can lead to improvements in other markets through externalities. The changes in connectivity can result from a number of differing actions or investments. For example, a country could change its approach to negotiating air service bilaterals so each new bilateral is an 'open skies' arrangement that leads to more capacity, more airlines and more competitive fares between countries.

This research investigated how the change in air connectivity affects productivity; in our case multifactor productivity, and how the change in productivity increases real GDP which is the measure or metric of value. Increased connectivity could also result from investments in aviation infrastructure including airport capacity through additional runways, larger terminals and more carriers or by modernizing air traffic control to reduce congestion. Understanding these linkages makes it possible to measure the value of an investment in new airport infrastructure beyond the traditional standard impact model (which is a static measurement) and determine the return on investment in aviation networks and connectivity.

Measuring Multi-factor Productivity

Definition

As defined by the U.S. Bureau of Labor Statistics, multi-factor productivity (MFP) relates output (or outcomes) to two or more inputs, depending on the definition of the particular multi-factor productivity measure. By comparison, labor productivity measures relates output to the single input of labor ignoring any other inputs also used. Comparisons among MFP measures must be made with an understanding of the underlying definitions used in constructing each measure.

For ACRP 03-28, the Research Team adapted MFP to measure the growth in GDP in reaction to changes in aviation services provided at U.S. airports. Specifically, using a sample of 26 airports in 20 metropolitan areas, MFP is used to estimate growth in net value added in GDP from: (1) strengthening non-stop connectivity among airports; and (2) increased use of air cargo by industries.

Adapting Established Techniques

There are two approaches to measuring MFP. In the growth accounting methodology (Solow, 1957), MFP is typically estimated as a growth rate. In the second approach, the Tornqvist methodology, MFP is calculated as an index number (level), which is obtained by dividing the output index by a combined input index (Hulten 2001). These two approaches can be computed as follows:[1]

[1] See, Apostolides, Anthony (2008), *A Primer on Multifactor Productivity: Description, Benefits and Uses* (U.S. Department of Transportation, Bureau of Transportation Statistics)

Growth Accounting Method

$$\frac{\Delta T}{T} = \frac{\Delta Q}{Q} - \left[\alpha\left(\frac{\Delta L}{L}\right) + \beta\left(\frac{\Delta K}{K}\right) + \gamma\left(\frac{\Delta other\, inputs}{other\, inputs}\right)\right]$$

where T is MFP, Q is output, L is labor, K is capital and other inputs are intermediate inputs. α, β and γ are cost shares of labor, capital and other inputs respectively.

Tornqvist Method

In the second approach, MFP is computed as the ratio of the output index to a weighted average of the input indexes. A Tornqvist formula expresses the change in multifactor productivity as the difference between the rate of change in output and the weighted average of the rates of change in the inputs.

Let:

Ln = the natural logarithm of a variable

A = multifactor productivity

Q = output

I = combined input

K = capital input

L = labor input

M = intermediate input

Wk = the average share of capital cost in total cost in two adjacent periods

Wl = the average share of labor cost in total cost in two adjacent periods

Wm = the average share of intermediate input cost in total cost in two adjacent periods,

$$\Delta LnA = Ln\left(\frac{A_t}{A_{t-1}}\right) = Ln\left(\frac{Q_t}{Q_{t-1}}\right) - \left[W_k\left(Ln\frac{K_t}{K_{t-1}}\right) + \left[W_l\left(Ln\frac{L_t}{L_{t-1}}\right) + \left[W_m\left(Ln\frac{M_t}{M_{t-1}}\right) + \right]\right]\right]$$

MFP is a more comprehensive measure of productivity than a simple single factor productivity measure such as labor productivity. The outputs and inputs can be measured in quantity terms or in constant dollars (or real value added).

Value added of an industry, as well as inputs, may change in quality over time. This quality change must be considered in any measurement. If the measures are expressed in constant dollar units, it is possible to adjust for quality change by incorporating it into the price index used for the deflation.

As illustrated in the second approach above, the inputs in the MFP estimate are weighted. The weight of each input is the share of the input in the total cost of the production for the economic unit being considered. The weights indicate the relative importance of each input in production. They are used to estimate the contribution of each input to the change or increase in inputs.

Any change in the growth of output (GDP) can be a result of a number of changes on the input side including the quantity of inputs, productivity of the inputs and, potentially, due to changes in the technology of production.[2] This is the analytical framework used to estimate MFP. As noted, at any point in time MFP can be affected by the technology used by the firm, by the industry or in the economy; for example, one airline may fly jets and another propeller aircraft, or the entire airline industry may adopt the use of a particular anti-collision device, or one economy may adopt a carbon tax policy to deal with carbon emissions. Technology is the recipe or know-how used in different industries to produce a product or deliver a service. The technology utilized will affect the position of the MFP function. Theoretically, firms should be using the most efficient technology available; however, this need not necessarily be the case. Generally, but not always, a profit maximizing firm will be a cost minimizing firm. In some cases, less efficient technologies can lead to high profits due to the way in which factor inputs can be 'mixed' under the technology. This is an important point: measures of MFP are concerned with maximizing value added given the limited resources available; MFP is thus concerned with minimizing costs.

Over time MFP can be affected by any number of factors, these are generally classified as 'advances in technology'. Thus, for example, a change in a network can be viewed as a change in technology. Technological progress manifests itself in the form of higher quality (e.g., faster computers), improvements in construction technology (e.g., higher buildings), and in more efficient use of space. Rearrangements of machines on a factory floor can lead to efficiency improvements; such a rearrangement may speed work flow, resulting in higher value added. Other factors influencing MFP are changes in industry structure. Mergers, acquisitions and bankruptcies, as associated changes made within that entity, can affect the productive efficiency of the resultant firm.

Calculation Methods

The approach to measure the contribution of the use of air transportation services by businesses to changes in productivity makes use of multi-factor productivity as a metric of productivity change.

[2] Factor or input productivity can change as a result of a number of influences. Technology can change, which can allow one factor to be more productive. It can also occur that a (human) factor could develop new skills through, for example education.

Multi-factor productivity, as discussed above, is measured as the change in total outputs over the change in total inputs; $\Delta Q/\Delta I$.[3] It is able to handle cases of multiple outputs and multiple inputs. While MFP is more comprehensive than partial productivity measures it is also more difficult to measure. It requires significant data across a wide range of input values, several of which can be a challenge to measure accurately. There is also continuing debate as to how to measure capital inputs.[4]

While MFP is difficult and costly to measure, fortunately there are several countries in the world that do produce a consistent MFP series, including the United States. The Bureau of Labor Statistics (BLS) produces multi-factor productivity statistics which are available from 1987 through 2011 for the U.S. business sector, the nonfarm business sector, the manufacturing sector, and 18 NAICS 3-digit groups of manufacturing industries, 86 detailed 4-digit NAICS manufacturing industries, line-haul railroads and air transportation.[5]

Interpretation of Metric. There is a large economic literature that estimates econometric models linking the growth in MFP to various activities, investments, innovations and outcomes in the economy. It has a firm theoretical foundation in index number theory and the calculated productivity index can be used in subsequent regressions to understand how certain factors or events may have influenced TFP/MFP. For example, Gillen and Lall (2001) link the changes in measures of MFP for a sample of U.S. airports to differing noise management strategies. Broermsa and van Dijk (2008) look at how congestion and agglomeration have impacted the MFP growth in different regions of the Netherlands. In both of these examples, an econometric model is estimated that relates changes in MFP to exogenous variables in an attempt to understand how different variables have a divergent impact on the change in MFP and what their relative contributions to the growth of MFP are. The FHWA undertook a number of studies in the late 1980s and 1990s examining how investments in highway capital contributed to the productivity growth of industries in the

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[3] If referring to the automobile industry, outputs would be the number of cars and trucks produced in a given time period (*e.g*. year) and inputs would refer to how much labor (person-hours) of each type, how much capital measured as dollars of capital used or how many machine hours, how much intermediate materials such as steel, plastic, wiring, glass etc. and how much energy to run the machines and heat and cool the plants. An airport would produce outputs of air traffic movements and number of passengers served. The inputs would be person hours of labor, the dollar value of runway, terminal and groundside capital, the amount of intermediate materials and contracted services and the amount of energy of each type used.

[4] Economists and accountants differ significantly in how they measure the amount of capital used as an input. Accountants adopt a depreciation policy and record interest payments and capital rentals. Economists believe that this under-represents the amount of capital actually used by a firm or by an economy. The accounting measure may reflect the level of depreciation across the asset life, but not accurately reflect the actual amount of depreciation at a point in time. Accountants also do not measure the cost of equity capital or how taxation can affect the cost of capital.

[5] See http://www.bls.gov/bls/productivity.htm http://www.bls.gov/mfp/tables.htm and http://www.bls.gov/mfp/mprdload.htm. K (Capital), L (Labor), E (Energy), M (Materials) and S (Services).

U.S. economy.[6] This literature recognizes that the value of transportation is more than direct impacts of income, employment and tax revenues that are yielded by traditional impact studies; studies that use expenditures on inputs and outputs as the metric of value. Rather the productivity work measures how the economy's ability to increase real value added and real incomes has changed.

[6] See for example the extensive discussion at http://ops.fhwa.dot.gov/freight/freight_analysis/improve_econ/

2 RELATING CHANGES IN AIR TRANSPORTATION TO CHANGES IN U.S. GDP

In order to examine how changes in the aviation system affect MFP, it is necessary to have a way to measure the relevant changes in that system, so that they can be used as explanatory variables for changes in value added (together with other, non-aviation, factors). The value of the airport network or the aviation system to the U.S. economy can be measured in part by observing how changes in the size, structure and configuration of the network affect changes in measures of MFP. To determine the contribution of the air transport network for the continental U.S. in national productivity the research team uses the BLS's national MFP measures. This data set disaggregates the aggregate MFP into specific 3- or 4-digit industries. Knowing how these industries are distributed across the United States allows us to see the distributional impact of changes in the air transport network. Currently, the distribution of industries can be determined through County Business Patterns data available annually from 1964 and the U.S. Bureau of Economic Analysis has data available from 1990.[7]

2.1 Defining Connectivity and Network Characteristics

In order to relate changes in the air transport network to changes in productivity, it is necessary to define metrics for the network connectivity and other relevant characteristics. The air transport network can be defined in different ways; although, it is generally defined operationally. Connecting "n" cities as a point-to-point network needs n(n-1) direct connections. As a hub and spoke system it would have 2(n-1) direct connections. The average traffic density per connection in the point-to-point network is Q/(n(n-1)) where Q is total passengers. In a hub-and-spoke system the average traffic density per connection is approximately 2Q/(2(n-1)). There are two types of hubbing indices: concentration measures (generally applied to time series data) and topological measures (used for cross-sectional data). These metrics permit answers to questions regarding how networks differ across airlines, how networks changed over time and whether there are differences in regional networks.

[7] An example of such a relationship can be developed using a connectivity index. The Research Team began with examples of how MFP has been used in past studies of the economic role of aviation, particularly in regards to developing and using connectivity indices. One such example is a study undertaken for the International Air Transport Association (IATA) that used a connectivity indicator developed by IATA that is based on the number of seats and flight frequency between an origin and destination.

2.2 Aviation, Connectivity and Productivity

The empirical model developed for ACRP 03-28 examines how air service provides connectivity and improves productivity. The specification is:

$$MFP_j = f\left(CN', Z'\right)$$

This means multifactor productivity in industry sector j is a function of a vector of connectivity measures and a vector of other economic factors, Z. The data selected for exploring the relationship was to select a sample of cities in the U.S. and a sample of international hubs that link the U.S. economy to the rest of the world (see Table 1) and a sample of industry sectors for the years 1995, 2000, 2005 and 2010 (Table 2); this was done to keep the data collection manageable.

Table 1. Airports Selected for the Analysis

Code	Airport/region	Multi-airport regions
SF Bay	*San Francisco Bay Area*	OAK, SFO, SJC
Chicago	*Chicago metropolitan region*	ORD, MDW
ATL	Hartsfield-Jackson Atlanta International Airport	
CVG	Cincinnati/Northern Kentucky International Airport	
STL	Lambert-St. Louis International Airport	
PIT	Pittsburgh International Airport	
RDU	Raleigh-Durham International Airport	
DEN	Denver International Airport	
Phoenix	*Phoenix metropolitan region*	
SLC	Salt Lake City International Airport	
Boston	*Boston metropolitan region*	BOS, PVD, MHT
PHL	Philadelphia International Airport	
DTW	Detroit Metropolitan Wayne County Airport	
SAN	San Diego International Airport	
PDX	Portland International Airport	
TPA	Tampa International Airport	
MCI	Kansas City International Airport	
TUL	Tulsa International Airport	
SAT	San Antonio International Airport	
BNA	Nashville International Airport	
SFO	San Francisco International Airport	
OAK	Oakland International Airport	
SJC	Mineta San Jose International Airport	
ORD	Chicago O'Hare International Airport	
MDW	Chicago Midway Airport	
PHX	Phoenix Sky Harbor International Airport	
AZA	Phoenix-Mesa Gateway Airport	
BOS	Boston Logan International Airport	
PVD	Theodore Francis Green State Airport (Providence)	
MHT	Manchester-Boston Regional Airport	

These airports were selected because we wanted to include a variety of types of airports; gateway airports, large hub airports, medium hub airports, small hub airports, non-hub airports and airports that had been de-hubbed. We also wanted a geographic spread to represent the entire domestic U.S. as closely as possible.

The international airports also included are: Amsterdam, London, Frankfurt, Munich, Paris, Madrid, Hong Kong, Singapore, Shanghai, Beijing, Dubai, Seoul, Tokyo, Copenhagen and Rome.

Table 2. Eleven industry Groups Included in the Model

NAICS	Sector	Model	Other	Sectors to Include
11	Agriculture, Forestry, Fishing and Hunting		X	
21	Mining, Quarrying, and Oil and Gas Extraction		X	1
22	Utilities		X	
23	Construction		X	
31-33	Manufacturing	X		2
42	Wholesale Trade	X		
44-45	Retail Trade		X	3
48-49	Transportation and Warehousing		X	
51	Information	X		4
52	Finance and Insurance	X		
53	Real Estate and Rental and Leasing		X	5
54	Professional, Scientific, and Technical Services	X		6
55	Management of Companies and Enterprises	X		
56	Administrative and Support and Waste Management and Remediation Services		X	7
61	Educational services		X	
62	Health Care and Social Assistance		X	
71	Arts, Entertainment, and Recreation	X		8
72	Accommodation and Food Services	X		9
81	Other Services (except Public Administration)		X	10
92	Public Administration		X	

2.3 Translating National MFP for Regions

The U.S. Bureau of Labor Statistics (BLS) provides multi-factor productivity measures (MFP) numbers by industry over time at the national level. The issue is how to translate the national measures to be meaningful at the MSA level. We chose to use measures of labor productivity since these can be calculated for a metropolitan statistical area (MSA) for measurement of labor productivity for a specific industry for a specific MSA. Our transformation was undertaken in the following way.

Define MFP_i^N as the multi-factor productivity measure for industry i at the national level and, define $\hat{L}_i = Q_i/L_i$ as a measure of labor productivity for industry i where Q is a measure of value added and L is some measure of labor input (hours or numbers of employees). Further define $\hat{L}_i^k$ as the labor productivity measure of industry i in MSA k.

We reasonably assume labor productivity is a significant component in the MFP measure. Therefore, one could do the needed translation simply as:

$$\hat{L}_i^k \cdot MFP_i^N \qquad (1)$$

However, we need to take account of the national labor productivity for industry i.

Consider the following relationship which states national MFP for industry i at the national level is a function of labor productivity plus some other factors that we have no information about that would be captured in a constant α and an error term, ε.:

$$MFP_i^N = \alpha + \beta \cdot \hat{L}_i^N + \epsilon \qquad (2)$$

For simplicity, and due to lack of information, rewrite (2) as:

$$MFP_i^N = \beta \cdot \hat{L}_i^N \qquad (3)$$

which can be re-written as:

$$\beta^N = MFP_i^N / \hat{L}_i^N \qquad (4)$$

where we expect $\beta^N > 1$. We could also, in principle, reproduce (3) and (4) for MFP and labor productivity for a MSA, as

$$\beta^k = MFP_i^k / \hat{L}_i^k \qquad (5)$$

The relationship between β^N and β^k is unclear, but if we assume they are similar, then making an assumption, set:

$$\beta^k = \beta^N = MFP_i^N / \hat{L}_i^N = MFP_i^k / \hat{L}_i^k \qquad (6)$$

set MFP_i^k = X, the unknown in these equations. Manipulating (6) find X as

$$X = \left(L_i^k / L_i^N \right) \cdot MFP_i^N \qquad (7)$$

Equation 7 states that a measure of MFP for MSA k for industry i can be calculated by taking the ratio of labor productivity in industry i in MSA k to the productivity of labor at the national level for the same industry i and multiply this by the MFP for industry i at the national level. Essentially what we have done is to weight the labor productivity at the MSA level by the labor productivityof the industry at the national level; L_i^k may be ≤ or ≥ than L_i^N. Productivity at a regional (MSA) level may exceed or be lower than productivity at a national level for a given industry. It may be, for example, that industry i in location k has been significantly influenced by aviation whereas for the nation as a whole it has not, thus L_i^k would be > L_i^N. We expect the MFP_i^k within an industry will vary across MSAs. This variation in calculated MFP measures across industries will be linked to the variation in airport connectivity to discover the relative contribution of airport connectivity to the change in MFP for the MSA.

The organization of the data, including industry, MSA and year is illustrated in Table 3. There are 11 industries and there were 11 separate regressions relating aviation variables to MFP. The economic data includes, for each of the 20 MSAs in the sample.

Table 4 shows the economic data is measured for each of the 20 MSAs that comprise the data set. The variables are designed to be included with the airport access/connectivity variables in the productivity regressions to control for “other than airport” factors affecting productivity.

The variables collected for each of the 20 airports is contained in Table 5. The data are designed to measure connectivity in different ways and to distinguish domestic and international connectivity. The airport data are segmented into domestic and international.

Table 3. Organization of Industry, MSA and Year

Industry 1	City A	1995	
Indsutry 1	City B	1995	
.	.	.	
.	.	.	
Industry 1	City Z	1995	
Industry 1	City A	2000	
Indsutry 1	City B	2000	
.	.	.	
.	.	.	This will form one regression and will have a total of 80 observations; 20 cities and 4 years of data
Industry 1	City Z	2000	
Industry 1	City A	2005	
Indsutry 1	City B	2005	
.	.	.	
.	.	.	
Industry 1	City Z	2005	
Industry 1	City A	2010	
Indsutry 1	City B	2010	
.	.	.	
.	.	.	
Industry 1	City Z	2010	
Industry 2	City A	1995	
Industry 2	City B	1995	
.	.	.	
.	.	.	
Industry 2	City Z	1995	
Industry 2	City A	2000	
Industry 2	City B	2000	
.	.	.	
.	.	.	This will form a second regression and will have a total of 80 observations; 20 cities and 4 years of data
Industry 2	City Z	2000	
Industry 2	City A	2005	
Industry 2	City B	2005	
.	.	.	
.	.	.	
Industry 2	City Z	2005	
Industry 2	City A	2010	
Industry 2	City B	2010	
.	.	.	
.	.	.	
Industry 2	City Z	2010	

Table 4. Economic Data

	Description	Unit
City	20 Cities including Cincinnati, St. Louis, Pittsburgh, Raleigh, Denver, Phoenix, Salt Lake City, Boston, Philadelphia, Detroit, San Diego, Portland, Tampa, Kansas City, Tulsa, San Antonio, and Nashville.	
Year	1995, 2000, 2005, 2010	
MSA Employment	MSA Employment, thousand; seasonally adjusted by NAICS	thousand
MSA Wage	MSA Wage and salary disbursements, million $ (nominal) by NAICS	million $ (nominal)
MSA Gross Product	MSA Gross Product, million $ (nominal) by NAICS	million $ (nominal)
NAICS	NAICS codes (31-33, 42, 51, 52, 53, 54, 55, 56, 71, 72 and other)	
Geography	Detail description of the city	
MSA Population	MSA Population of each city (Number of people) (not by NAICS)	Number
industry	11 industries	
National Output (B) Dollars	National value of production, billions of current dollars by NAICS (from Dataset for MFP Project Jul 11 2013.xlsx)	Billions $ (nominal)
National MFP Index	National MFP Index by NAICS (from Dataset for MFP Project Jul 11 2013.xlsx)	
National Output per Hour Index	National Labor Productivity (from Dataset for MFP Project Jul 11 2013.xlsx)	
CPI	CPI by city and year (but not by NAICS)	
MSA Real Gross Product	MSA Real Gross Product (calculated as (MSAGrossProduct*1000000)/(CPI/100)), in $ (real) (Not in million $)	$ (real)
MSA Labor Productivity	MSA Labor Productivity (calculated as ((MSAGrossProduct*1000000)/(CPI/100)) /(MSAEmployment*1000))	$ (real)
MSA Wage Per Employment	MSA Wage Per Employment (calculated as MSAWagePerEmployment=MSAWage/MSAEmployment*1000)	$ (nominal)
MSA Labor Productivity Index	MSA Labor Productivity Index (calculated as MSALaborProductivity/MSALaborProductivity at base year 2005*100)	
MSA MFP Index	MSA MFP Index (calculated as MSALaborProductivityIndex/ NationalOutputperHourIndex* NationalMFPIndex)	
MSA Real Wage Per Employment	MSA Real Wage Per Employment (calculated as MSAWagePerEmployment/CPI*100)	$ (real)
ACQI2010	Source:	
lnMSA Real Wage Per Employment	Natural log of MSA Real Wage Per Employment (i.e. ln(MSARealWagePerEmployment))	
lnMSA Employment Rate	Natural log of Employment Rate(i.e. ln(MSAEmployment/ MSAPopulation)) (Note: MSAEmployment is by NAICS)	
lnMSA Real Gross Product	Natural log of MSA Real Gross Product (i.e. ln(MSARealGrossProduct))	
lnMSA Real Gross Product Per Emp	Natural log of MSA Real Gross Product per Employment (i.e. ln(MSARealGrossProduct/MSAEmployment*1000))	
lnMSA Real Gross Product Per Pop	Natural log of MSA Real Gross Product per Population (i.e. ln(MSARealGrossProduct/MSAPopulation))	

Table 5. Airport Data

Measurement	Variables
Number of Airlines	Number of Airlines
Flights by dominant carrier	Flights by dominant carrier
Total nonstop departures	
Domestic	Domestic Nonstop Departures
International	International Nonstop Departures
Airline hubs served (domestic)	Airline Hubs Served_Domestic
Nonstop destinations	
Domestic	Domestic Nonstop Destinations
International	International Nonstop Destinations
Percent world GDP served by	
Non-stop flights	Percent World's GDP served by Nonstop Flights
At least daily non-stops	Percent World's GDP served by At Least Daily Nonstop Flights
2 or more daily non-stops	Percent World's GDP served by Two or More Daily Nonstop Flights
International hubs served	
At least daily non-stops	International Hubs Served by At Least Daily Nonstop Flights
3 or more daily non-stops	International Hubs Served by At Three or More Daily Nonstop Flights
Total passengers	
Domestic*	Total Passengers_Domestic
Transborder*	Total Passengers_Transborder

Notes: 1. Aviation data only for scheduled service.
2. Scheduled service is in a market for a carrier for at minimum 50 flights annually.
3. Regional affiliates are considered to be part of mainline carrier.
4. Variables 2 and 4 apply only to domestic flights, Canada is separated from International.

2.4 MFP Calculations for Improved Airport Connectivity

Table 7 provides summary statistics—means and standard deviations—for the airport variables used in the regressions. Table 8 and * Bolded coefficients significant at least at 90 percent level
**Other includes NAICS 11,21,22,23

list the results of the regressions for the sample of 11 industries across the 20 MSAs in the sample. The economic variables listed in Table 4 are not included in the table simply for ease of presentation. Coefficients in bold are statistically significant at least at the 90 percent confidence level; adjusted Rsquare (R^2) and log-likelihood values are contained in the bottom rows. The degree of explanatory power ranges from a low of 64 percent for "Arts, Entertainment and Recreation" to a high of 92 percent for "Information" industry.

The non-airport/aviation network variables included are the population to have a sense of how market size may affect MFP and the yearly dummy variables. The regressions were estimated as a log-linear specification.

In all cases, the coefficients on the MSA population variable are positive and generally significant meaning market size has an impact on multi-factor productivity. The time dummy variables are, except in two cases, positive and significant. The value for 2010 is not always larger than for 2000 and 2005 showing productivity growth has varied across industries as well as over time.

The set of variables of most interest are those that capture the degree of connectivity. There are several categories of variables that sought to capture domestic and international connectivity. Included were: measures of departures; whether flights were non-stop; how frequently flights occurred; and the level that MSAs in the sample are connected to the world's economy.

The coefficients can be read as elasticities, and thus are interpreted as the percentage change in MFP of industry k with respect to a percentage change in the selected airport variable. As shown in Table 8, column 1, which lists the results for 'Manufacturing', a one-percent increase in the number of airlines serving an MSA would lead to a 0.04 percent increase in MFP for Manufacturing, a one-percent increase in the number of non-stop flights departures would increase Manufacturing MFP by 0.02 percent and a one-percent increase in the number of non-stop destinations served will increase Manufacturing MFP by 0.06 percent.

Table 9 presents the elasticity values for each of the connectivity variables. Values in bold are those that were statistically significant, and therefore are the important connectivity measures for their respective industry. This table shows that frequent service and a large number of departures are important for most industries examined, number of airline hubs serves are important for 4 industries, and number of airlines is important for only two industries. A central result to be recognized in this table is that aviation networks connect individual industries in different ways and the relative importance of these different ways to provide connectivity varies across industries as well. For example, increasing the number of non-stop destinations is three times more important for manufacturing as it is wholesale trade; 0.034 versus 0.015.

Table 6, shows a simple average for each statistically significant connectivity measure across industries for each of the airport variables included in the model.[8] On average, considering only values that were statistically significant, having two or more daily non-stop flights is the most important connectivity variable in affecting productivity. Second most important is the number of non-stop destinations and third is having daily flights to destinations that maximize access the world's GDP. The results for these last three variables makes a point that simply adding flights or destinations is important, but the importance of adding flights and destinations will rise with increasing access to larger shares of the world's economy as measured by GDP.

The column of Table 6 marked 'normalized' illustrates the relative impact of each variable; normalized is calculated by taking the elasticity values in column 1 and dividing by the value of the most important variable – routes having two or more daily non-stop domestic flights. Each variable is compared to the most important variable, which is having *two or more daily non-stop flights per day*. In considering the second most important variable which is the *number of international non-stop destinations*, this latter variable would have to increase 2.5 times from its current mean value to have the same impact on multi-factor productivity as a unit change in the number of destinations having two or more daily non-stops. Following these two variables, the connectivity variables fall into two categories, those with elasticities of about 0.03 and those around 0.02. The former group would include routes that serve a high percent of the world GDP daily, 5 or more domestic daily non-stops, the number of domestic destinations served and the number of domestic hubs served. Each of these has about 30 percent of the impact of a change in having daily flights to a significant portion of the world's GDP. These results also imply that destinations and departures provide about the same amount of connectivity and that frequency is important. The remaining variables have about 20 percent of the impact of the most important variable, having two or more non-stop domestic flights.

Table 6. Average Values of Elasticities Across Industries

Connectivity Variable	Elasticity (average)	Rank	Normalized
Number of Airlines	0.0160	11	0.17
Domestic Non-Stop Departures	0.0164	9	0.18
Airline Hubs Served-Domestic	0.0254	6	0.28
Domestic Non-Stop Destinations	0.0284	5	0.31
Two or More Daily Non-stop Domestic Flights	0.0915	1	1.00
Five or More Daily Non-stop Domestic Flights	0.0258	4	0.28
International Non-Stop Departures	0.0182	7	0.20
International Non-Stop Destinations	0.0375	2	0.41
Percent of World GDP Served Non-Stop	0.0169	8	0.18

[8] One might consider a weighted average where the weight would be the proportion of domestic GDP for which an industry accounts.

Percent of the World GDP Served Daily	0.0259	3	0.28
Percent of the World GDP Served Two or More Daily	0.0161	10	0.18

Using the average values displayed in Table 6 is worthwhile to gauge the overall effects of each connectivity variable used. However, they can be misleading for any particular industry and assessing which variables matter and their relative importance for an industry should be based on the elasticity values in Table 9.

Table 10 illustrates how these elasticities can be used to measure the impact on value added. Based on the data for the 11 industries (aggregated across the 20 MSAs), the increase in each industry's value added is calculated for those connectivity variables that were statistically significant for that industry. The last row in the table reports the change for the aggregate economy (across all 11 industries) of a change in a connectivity variable.

Note the relative differences in what were considered the key connectivity variables, measured by their elasticity value and the change in value added by each variable as indicated in the bottom row of Table 10. For example, two or more daily departures, International non-stop destinations and the percent of the world GDP accessed were estimated to have the highest elasticity and the number of airlines was ranked second to last.

The point to recognize is that it is important to identify which connectivity variable is important for different industries. In the table, the number of airlines is ranked 11th in importance based on elasticity values but this variable is important to the manufacturing sector, which is a large proportion of total GDP. Thus if the number of domestic non-stop departures in the economy (represented in this work by the sample of 11 MSAs and their airports) were to increase by one-percent the economic impact would be $201 Million.

2.5 Summary of Relating Value Added/GDP Outcomes to Connectivity Improvements Using MFP

The objective of the MFP research was to measure how network accessibility could be integrated into benefit-cost modeling. The approach used here was to define a set of variables that captured the differing aspects of connectivity, which is what a network provides. These connectivity variables were linked to changes in MFP and change in real economic or income growth. The approach has generated a useful start and identified the relative importance of the different connectivity variables and also showed how their importance will differ across industries. However, the sample used was limited to 20 MSAs and to 11 industries, therefore, the estimated elasticities should not be seen as holding across all industries. This is a first step and these are the first estimates and more work is needed using a larger set of data to test the robustness of the results.

Table 7. Summary Statistics for Airport Variables used in Regression

	1995		2000		2005		2010	
Aviation Variable	**Mean**	**St Dev**	**Mean**	**St Dev**	**Mean**	**St Dev**	**Mean**	**St Dev**
Number of Airlines	18.25	12.79	19.20	14.79	19.50	14.77	17.45	13.48
Flights by dominant carrier(%)	0.52	0.21	0.52	0.22	0.49	0.22	0.44	0.20
Total nonstop departures								
Domestic	138,992.05	105,285.01	159,328.90	117,204.33	180,434.70	129,055.61	154,895.10	129,024.05
International	4,245.05	4,992.95	7,271.55	9,813.93	7,880.20	8,239.48	9,404.70	12,533.41
Airline hubs served (domestic)	24.95	9.49	28.50	11.63	28.55	11.43	28.95	10.66
Nonstop destinations								
Domestic	69.50	37.81	74.30	41.55	88.55	47.24	82.85	50.39
International	10.20	9.81	12.20	14.21	14.05	15.36	15.80	19.94
Pct world GDP served by								
Non-stop flights	0.22	0.24	0.26	0.25	0.24	0.23	0.22	0.22
At least daily non-stops	0.16	0.21	0.21	0.22	0.20	0.22	0.17	0.20
2 or more daily non-stops	0.07	0.13	0.10	0.16	0.11	0.15	0.09	0.13
Total airfreight (M of metric tons)								
Enplaned Domestic	26,200.33	28,763.66	24,715.20	25,690.82	116,503.02	113,612.52	92,383.97	75,868.67
Enplaned International	31,595.09	64,290.66	42,161.29	82,884.56	42,569.14	92,838.46	43,423.94	95,478.17
Deplaned Domestic	26,103.43	25,926.89	25,694.70	26,193.93	124,665.02	108,816.02	98,510.37	73,128.86
Deplaned International	28,120.09	60,630.04	54,226.56	113,479.68	60,216.87	136,591.41	55,383.73	131,683.49
International hubs served								
At least daily non-stops	1.35	2.03	2.25	3.21	2.45	3.62	2.60	3.94
3 or more daily non-stops	0.35	0.81	0.55	1.23	0.55	1.23	0.50	1.10
Total passengers(Million)								
Domestic	20,499.49	16,495.41	25,433.51	19,606.57	26,386.99	21,609.33	24,744.37	21,394.70
International	1,191.44	1,628.85	2,069.34	2,986.69	2,071.89	2,755.35	2,273.01	3,352.39
Domestic non-stop destinations								
2 or more daily non-stops	53.20	32.16	60.70	37.05	70.15	41.47	60.10	41.38
5 or more daily non-stops	25.50	21.52	29.55	22.31	35.15	27.10	29.10	26.38

Table 8. Regression Results for Business Productivity Regressions: Aviation Networks and Industrial Multifactor Productivity

Ln MFP for MSA	NAICS 31-33	NAICS 42	NAICS 51	NAICS 52	NAICS 53	NAICS 54
Independent Variable (in Ln)	Manufacturing	Wholesale Trade	Information	Finance & Insurance	Real Estate, Rental & Leasing	Professional Scientific & Technical Services
Constant	**-1.0913**	**6.4783**	**9.1860**	**0.5697**	**9.0946**	4.5121
Year 2000	-0.0546	0.0395	-0.0004	**0.0601**	**0.0223**	**0.0689**
Year 2005	0.0608	**0.0657**	**0.2552**	**0.1264**	**0.6151**	0.0151
Year 2010	**0.2107**	**0.2486**	**0.3492**	**0.2622**	**0.4221**	0.0115
Ln MSA Population	**0.0037**	**0.0015**	0.0013	**0.0433**	**0.0252**	0.0447
Ln Number of Airlines	**0.0439**	**0.0215**	0.0596	0.0048	0.0797	0.0435
Ln Domestic Non-Stop Departures	**0.0237**	**0.0257**	0.0192	**0.0479**	**0.0213**	**0.0182**
Ln Airline Hubs Served-Domestic	0.0423	0.6624	**0.0151**	**0.0716**	0.0316	**0.0361**
Ln Domestic Non-Stop Destinations	**0.0344**	**0.0152**	0.0074	0.0711	**0.0397**	0.0504
Ln Two or More Daily Non-stop Domestic Flights	**0.0991**	0.0607	**0.0121**	**0.0312**	**0.0406**	0.0112
Ln Five or More Daily Non-stop Domestic Flights	0.0531	**0.0318**	0.0192	0.0697	0.0256	0.0096
Ln International Non-Stop Departures	0.0163	0.0003	**0.0244**	**0.0132**	0.0039	**0.0262**
Ln International Non-Stop Destinations	**0.0479**	**0.0191**	**0.0144**	0.0375	**0.0532**	0.0275
Ln Percent of World GDP Served Non-Stop	0.0174	0.0117	0.0147	0.0911	0.0246	0.0107
Ln Percent of the World GDP Served Daily	0.0263	**0.0214**	**0.0257**	**0.0107**	0.0612	**0.0491**
Ln Percent of the World GDP Served Two or More Daily	**0.0157**	0.0032	0.0201	0.0072	0.0079	0.0205
No Observations	80	80	80	80	80	80
Adjusted Rsquare	0.74	0.79	0.92	0.89	0.84	0.81
Log-Likelihood	633.25	449.62	345.76	318.98	329.87	366.77

** Bolded coefficients significant at least at 90 percent level*
***Other includes NAICS 11,21,22,23*

Table 8. Regression Results for Business Productivity Regressions: Aviation Networks and Industrial Multifactor Productivity (cont'd)

Ln MFP for MSA	NAICS 55	NAICS 56	NAICS 71	NAICS 72	NAICS Other
Independent Variable (in Ln)	Management of Companies & Enterprises	Administration & Support Waste Management Services	Art, Entertainment & Recreation	Accommodation & Food Services	Other**
Constant	**1.9440**	**3.9618**	**3.9720**	**5.8501**	**1.2294**
Year 2000	**0.0318**	**0.0983**	0.0416	0.0163	**0.8700**
Year 2005	0.1104	**0.0130**	**0.0263**	0.0541	**0.0812**
Year 2010	0.0287	**0.0112**	**0.0693**	0.1218	**0.5798**
Ln MSA Population	**0.0185**	**0.0004**	**0.0113**	**0.0529**	0.0981
Ln Number of Airlines	0.0152	0.0519	0.0562	0.0161	0.1004
Ln Domestic Non-Stop Departures	0.0843	**0.0104**	0.0817	**0.0001**	**0.0004**
Ln Airline Hubs Served-Domestic	**0.0106**	0.0226	**0.0093**	0.0456	0.0285
Ln Domestic Non-Stop Destinations	**0.0321**	**0.0301**	**0.0132**	**0.0229**	**0.0371**
Ln Two or More Daily Non-stop Domestic Flights	0.0151	0.0269	0.0191	0.0153	0.0227
Ln Five or More Daily Non-stop Domestic Flights	0.0749	0.0074	**0.0197**	0.0885	0.0452
Ln International Non-Stop Departures	**0.0091**	**0.0211**	0.0217	0.0691	0.0142
Ln International Non-Stop Destinations	**0.0227**	**0.0877**	0.0215	0.0526	**0.0136**
Ln Percent of World GDP Served Non-Stop	**0.0203**	**0.0472**	0.0576	0.0231	0.0946
Ln Percent of the World GDP Served Daily	0.0579	0.0357	**0.0399**	**0.0222**	**0.0129**
Ln Percent of the World GDP Served Two or More Daily	**0.0779**	0.0176	0.0291	0.0883	0.0907
No Observations	80	80	80	80	80
Adjusted Rsquare	0.85	0.71	0.64	0.74	0.62
Log-Likelihood	352.81	444.81	338.91	282.95	227.13

** Bolded coefficients significant at least at 90 percent level*
***Other includes NAICS 11,21,22,23*

Table 9. Elasticity Values for Airport Connectivity Variables across Industries

Ln MFP for MSA	NAICS 31-33	NAICS 42	NAICS 51	NAICS 52	NAICS 53	NAICS 54
Independent Variable (in Ln)	Manufacturing	Wholesale Trade	Information	Finance & Insurance	Real Estate, Rental & Leasing	Professional Scientific & Technical Services
Ln Number of Airlines	**0.0439**	**0.0215**	0.0596	0.0048	0.0797	0.0435
Ln Domestic Non-Stop Departures	**0.0237**	**0.0257**	0.0192	**0.0479**	**0.0213**	**0.0182**
Ln Airline Hubs Served-Domestic	0.0423	0.6624	**0.0151**	**0.0716**	0.0316	**0.0361**
Ln Domestic Non-Stop Destinations	**0.0344**	**0.0152**	0.0074	0.0711	**0.0397**	0.0504
Ln Two or More Daily Non-stop Domestic Flights	**0.0991**	0.0607	**0.0121**	**0.0312**	**0.0406**	0.0112
Ln Five or More Daily Non-stop Domestic Flights	0.0531	**0.0318**	0.0192	0.0697	0.0256	0.0096
Ln International Non-Stop Departures	0.0163	0.0003	**0.0244**	**0.0132**	0.0039	**0.0262**
Ln International Non-Stop Destinations	**0.0479**	**0.0191**	**0.0144**	0.0375	**0.0532**	0.0275
Ln Percent of World GDP Served Non-Stop	0.0174	0.0117	0.0147	0.0911	0.0246	0.0107
Ln Percent of the World GDP Served Daily	0.0263	**0.0214**	**0.0257**	**0.0107**	0.0612	**0.0491**
Ln Percent of the World GDP Served Two or More Daily	**0.0157**	0.0032	0.0201	0.0072	0.0079	0.0205

Ln MFP for MSA	NAICS 55	NAICS 56	NAICS 71	NAICS 72	NAICS Other
Independent Variable (in Ln)	Management of Companies & Enterprises	Administration & Support Waste Management Services	Art, Entertainment & Recreation	Accommodation & Food Services	Other**
Ln Number of Airlines	0.0152	0.0519	0.0562	0.0161	0.1004
Ln Domestic Non-Stop Departures	0.0843	**0.0104**	0.0817	**0.0001**	**0.0004**
Ln Airline Hubs Served-Domestic	**0.0106**	0.0226	**0.0093**	0.0456	0.0285
Ln Domestic Non-Stop Destinations	**0.0321**	**0.0301**	**0.0132**	**0.0229**	**0.0371**
Ln Two or More Daily Non-stop Domestic Flights	0.0151	0.0269	0.0191	0.0153	0.0227
Ln Five or More Daily Non-stop Domestic Flights	0.0749	0.0074	**0.0197**	0.0885	0.0452
Ln International Non-Stop Departures	**0.0091**	**0.0211**	0.0217	0.0691	0.0142
Ln International Non-Stop Destinations	**0.0227**	**0.0877**	0.0215	0.0526	**0.0136**
Ln Percent of World GDP Served Non-Stop	**0.0203**	**0.0472**	0.0576	0.0231	0.0946
Ln Percent of the World GDP Served Daily	0.0579	0.0357	**0.0399**	**0.0222**	**0.0129**
Ln Percent of the World GDP Served Two or More Daily	**0.0179**	0.0176	0.0291	0.0883	0.0907

Table 10. Impact of 1% Changes in Different Connectivity Measures on Industry Value Added – Aggregated Across all 20 Regions (2010 $Ms)

Industry	GRP over 20 MSAs *(3)*	Number of Airlines	Domestic Non-Stop Departures	Airline Hubs Served-Domestic	Domestic Non-Stop Destinations	Two or More Daily Non-stop Domestic Flights
Manufacturing	$358,857.91	$157.54	$85.05		$123.45	$355.63
Wholesale Trade	$199,956.26	$42.99	$51.39		$30.39	
Information	$158,156.77			$23.88		$19.14
Finance & Insurance	$315,875.87		$151.30	$226.17		$98.55
Real Estate, Rental & Leasing	$444,512.52		$94.68		$176.47	$180.47
Professional Scientific & Technical Services	$311,416.85		$56.68	$112.42		
Management of Companies & Enterprises	$80,042.52			$8.48	$25.69	
Administration & Support Waste Management Services	$108,779.27		$11.31		$32.74	
Art, Entertainment & Recreation	$34,213.83			$3.18	$4.45	
Accommodation & Food Services	$87,114.85		$0.09		$19.95	
Other**	$734,242.98		$2.94		$272.40	
Total	**$2,833,169.64**	**$200.53**	**$453.44**	**$374.14**	**$685.55**	**$653.79**
Industry	**Five or More Daily Non-stop Domestic Flights**	**International Non-Stop Departures**	**International Non-Stop Destinations**	**Percent of World GDP Served Non-Stop**	**Percent of the World GDP Served Daily**	**Percent of the World GDP Served with Two or More Daily Flights**
Manufacturing			$171.89			$56.34
Wholesale Trade	$63.59		$38.19		$6.40	
Information		$38.59	$22.77		$40.65	
Finance & Insurance		$41.70			$33.80	
Real Estate, Rental & Leasing	$48.90		$236.48			
Professional Scientific & Technical Services		$81.59			$152.91	
Management of Companies & Enterprises		$7.28	$18.17	$16.25		$14.33
Administration & Support Waste Management Services		$22.95	$95.40	$51.34		
Art, Entertainment & Recreation	$6.74				$13.65	
Accommodation & Food Services					$19.34	
Other**			$99.86		$94.72	
Total	**$119.22**	**$192.11**	**$682.77**	**$67.59**	**$361.46**	**$70.67**

3 AIR CARGO & INDUSTRY PRODUCTIVITY

3.1 Introduction

The modeling of air cargo deviates from the relationship between aviation networks and business productivity (as described above), as there is much less data describing domestic air cargo activity than on either passengers or the supply of passenger capacity. Air cargo moves on both scheduled and non-scheduled flights. There are multiple routings, and a mix of air and truck is used. Moreover, integrated carriers, such as FedEx and UPS, dominate domestic airfreight.[9] Some dedicated cargo carriers provide air cargo service themselves but also wet lease aircraft to other airlines to transport air cargo being handled by those airlines, and freight also moves in the belly hold of passenger aircraft. In addition, when air cargo enters the U.S., it is not tracked when it moves to its final destination in the U.S> from its point of entry. Finally, data for air cargo are sparse in comparison to the detailed information we have on passenger movements, routing and pricing. Air cargo data tend to be reported by airport, but it is not clear where the cargo came from (unless it was an international flight), where it is going and how or what price was paid.[10] As a result, it would be impossible to replicate, for air cargo, the type of analysis that is undertaken for passenger traffic. In sum, the richness of the data that is available for studying air passenger markets is not available for air cargo.

The airlines report cargo traffic by segment and market on the T-100 schedules, in the same way as passenger traffic. In addition they generally report enplaned and deplaned cargo at each airport to the airport authority, which typically publishes this in the monthly airport activity statistics. So while the data are not collected on air cargo activity on a regular basis, domestic air cargo shipments, analogous to the 10 percent O&D survey for passengers, is not collected on an ongoing basis. Data on the true origin and destination of international air cargo is collected by the U.S. Customs and Border Protection from the customs documentation for each shipment and made available through other Federal government agencies, such as the Census Bureau and the International Trade Administration of the U.S. Department of Commerce.

For passenger travel, we measure air service in terms of the destinations served by non-stop flights, the number of daily flights in a market, and similar metrics. But unlike passengers, a pound of cargo does not care how many times it transfers between flights or

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[9] Both Federal Express and UPS have large truck fleets that move air cargo that can be trucked for 3-4 day delivery. This cargo moves on air waybills despite being moved over land.

[10] There are some O&D data for domestic air cargo in the Federal Highway Administration (FHWA) Freight Analysis Framework (FAF). See www.ops.fhwa.dot.gov/freight/freight_analysis/faf/ for details.

how long it spends at an airport waiting for a flight or what routing it takes. What matters to the shipper is when the cargo is delivered to the destination.

There is little value in asking whether geographic differences in air cargo air service could explain regional differences in productivity in a given industry sector, as we are attempting to do for passenger travel. There have of course been changes in air cargo air service over time, particularly the rise of the integrated carriers and changes in price,

The air cargo industry, including the integrated carriers, have developed a sophisticated logistics system that can get almost all shipments from anywhere in the U.S. to anywhere else in the U.S. overnight if required, or by the second or third day for a lower price. Furthermore, the integrated carriers have a standard pricing structure that does not vary by location, at least for large metropolitan regions.[11] So it can be argued that unlike passenger travel, the air cargo industry provides a ubiquitous and highly standardized level of air service throughout the country.

3.2 Approach

The research question was to determine how the amount of air cargo activity correlates with the productivity growth of a metropolitan area? The unit of analysis becomes the 20 MSAs. We also have determined the MFP for each of 11 industries in each of these MSAs for each of four years (1995, 2000, 2005 and 2010). For each MSA we have assembled data for enplaned and deplaned air cargo for the 26 airports in the MSAs. Finally we have GDP and other economic data for each of the MSAs in each of the four years.

Let:

$Q_{j,t}^{k}$ be the output (or GDP) for industry j, in time t at location k

Y_{t}^{k} is the output (or GDP) of MSA k in time t

$MFP_{j,t}^{k}$ is the MFP of industry j, at time t in location k

eR_{t}^{k} is enplaned air cargo at time t in location k (metric tons)

dR_{t}^{k} is the deplaned air cargo at time t in location k (metric tons)

[11] There is also the issue that a significant proportion of air cargo moves at contracted rates rather than posted (or sticker) prices. This pricing information is impossible to obtain on any systematic basis.

$\overline{MFP_t^k} = \sum_j \left(Q_{j,t}^k / Y_t^k \right) MFP_{j,t}^k$ is a weighted average of MFP for a location at time t, where the weights are the value added of industry j relative to the total value added of the 11 industries included in the analysis for the MSA, with j=1, 11, t=1, 4 and k=1, 20

If we had a time series data set over say 20 years we could undertake a Granger Causality test between Y_t^k and $\overline{MFP_t^k}$ and between $\overline{MFP_t^k}$ and a measure of air cargo activity at the airport in the MSA. The Granger causality test is determining the direction of causality between two variables, or what drives what; is GDP higher because productivity is higher or is productivity higher because GDP is higher? Unfortunately we have only 4 discrete years of data at 5-year intervals.

To explore the research question we have formally modeled the relationship between $\overline{MFP_t^k}$ and air cargo activity at the airport in the MSA. The regressions provide a statistical test of whether and how much productivity is affected by a set of variables including air cargo activity, for example one specification would be:

$$\overline{MFP_t^k} = \alpha + \beta_1 eR_t^k + \beta_2 dR_t^k + \sum \gamma_i z_i + \varepsilon$$

where the z_i's are other variables such as dummy variables for year, the type of airport (hub, non-hub) etc.. The data set is organized as a panel stacked in the following way.

$\overline{MFP_t^k}$	k=1, 20	1995
$\overline{MFP_t^k}$	k=1, 20	2000
$\overline{MFP_t^k}$	k=1, 20	2005
$\overline{MFP_t^k}$	k=1, 20	2010
total observations = 80		

The regression results are reported in Table 11. The impact on an MSA's GDP in dollars is reported in Table 12.

Approach to Regression Analysis. The regressions are a fixed effects model where each MSA is considered as having a separate individual impact on the productivity measure; said differently, we take into consideration that San Francisco may be different, for any number of reasons, than Tulsa so we control for these possible effects using the technique called a fixed effects model. We have 20 MSAs thus we have 20 groups. The fixed effects modeling technique takes account of variations across groups that are unrelated to the right-hand-side (independent) variables that are specified in the regression. This minimizes any bias on the estimated coefficients of the right-hand-side variables.

The results are reported for the log-linear specification of the regression. In all cases the dependent variable is the Ln (natural log) of the measure of multi-factor productivity (MFP) for a MSA. We began with the weighted average MFP across industries constructed in the manner described above. However, the results were not encouraging so we estimated the air cargo model for separate industries. The industries included in the table were those for which the regression coefficients were statistically significant.[12]

The coefficients listed can be interpreted (except for dummy variables such as 'Hub') as an elasticity, meaning a percentage change over a percentage change. For example, under NAICS 31-33 the coefficient for air cargo domestic enplaned is 0.031 and this can be interpreted as a 1 percent increase in domestic enplaned air cargo (from its current mean level) would lead to a .03 percent increase in the MFP of the manufacturing industries in each of the MSAs in our sample. The calculations of impact are contained in Table 12 and are discussed below.

3.3 Regression Results.

The results of the air cargo regressions illustrate what is discussed above; specifically that air cargo is well developed in the US, as are the interstate road systems. Thus, a small impact is seen for air cargo activity on MFP. Part of the explanation may lie in the fact we used the same industry set for examining the impact of the connectivity of the airport network on business productivity from passenger activity. The set of industrial sectors that would use aviation as a business tool for linking business personnel may not be the same ones that would use air cargo to move their products to markets; e.g. fresh seafood and fresh cut flowers are dependent on air cargo connectivity.

Not all the variables used in the analysis will be discussed but there are some important relationships. First, the year dummies show that air cargo activity turned down (there is a negative sign on the coefficient) in 2000 and 2005 for most industries, NAICS 54 and 62 (Professional, Scientific and Technical Services, and Health Care and Social Assistance, respectively) being exceptions. Second, the hub dummy was not significant except in one case, NAICS 31-33 – manufacturing. This shows that being connected as a hub does not provide an added impetus to air cargo over and above the market size effect since large

[12] Statistical significance is considered in terms of confidence levels. A coefficient is considered to be significant if it exceeds the 90 percent confidence level.

hubs are generally in large cities. Third, the adjusted R2 that indicate the proportion of variation explained by the regression are respectable.

The table also shows there is no consistent pattern to the impact of air cargo activity on productivity, at least for the industries in our sample and for the years selected. When the aggregate data set (meaning all industries in the data set are aggregated) is used (column 2) there is no statistically significant effect. Most likely this is because a large number of industries were not affected and this swamped the small effects on industries that were affected. We therefore disaggregated the data to individual industries or a few industries added together. For manufacturing (column 3) only the amount of domestic enplaned air cargo has an impact for wholesale trade (column 4) international enplaned air cargo has an impact. However, for Professional, Scientific and Technical Services (column 5) both enplaned domestic air cargo and international enplaned air cargo are significant and, for Accommodation and Food Services (column 6) international enplaned air cargo activity has an impact. Finally, for the NAICS aggregate (Other) domestic enplaned air cargo is significant in affecting MFP.

Table 11. Summary Regression Results for Air Cargo (by Industry-NAICS Code)

Ln MFP for MSA	All Industries	NAICS 31-33	NAICS 42
Independent Variable (in Ln)		**Manufacturing**	**Wholesale Trade**
Constant	**97.99**	**110.71**	**102.30**
Year 2000	**-8.72**	**-6.17**	**3.20**
Year 2005	**-11.92**	**-11.32**	**-4.49**
Year 2010	-5.47	12.11	**-9.27**
Hub Dummy	-44.73	**-84.65**	-5.91
MSA Employment Rate	0.04	0.01	0.12
MSA Real Gross Product	1.73	0.65	0.17
Air cargo-Domestic Enplaned	-5.15	**0.031**	0.07
Air Cargo-Domestic Deplaned	6.63	-0.046	-0.03
Air Cargo-International Enplaned	-1.01	-0.059	0.01
Air Cargo-International Deplaned	0.88	0.078	**0.04**
No Observations	80	80	80
Adjusted R^2	0.34	0.41	0.71
Log-Likelihood	710.59	734.05	354.29

Notes: Air cargo is measured in metric tons
** Bolded coefficients significant at least at 90 percent level*

In order to translate the results of Table 11 into more meaningful numbers we used the coefficients to calculate how much of a change in Real GDP would occur in each MSA for manufacturing and wholesale trade. Table 12 provides the real value added in the sample of data.

In Table 12, the first column (marked All Industries) is the total real value added of manufacturing and wholesale industry sectors of the MSAs considered in the sample; it is not the total GDP of the MSA, which would be substantially higher.

If one assumes a one percent increase in air cargo activity, the impact on each industry in each MSA can be calculated by multiplying the GDP of the left side of Table 12 (columns two and three) by the estimated (and statistically significant) coefficients from the bottom row of Table 12 (columns two and three) and by .01, which is the one percent assumed growth in air cargo. The results are provided in columns four and five of Table 12.

3.4 Cargo Summary

The analysis of air cargo has provided an order of magnitude measures of how increased cargo activity can affect a local economy. Our results show that relatively few of the industries contained in our sample were affected. Subsequent research needs to focus on industries that are currently or emerging air cargo users and on a longer time period to establish causality.

Table 12. GDP Data for Industries by MSA for 2010 and Increase GDP in 2010 Resulting from a 1 Percent Increase in Air Cargo Enplanement or Deplanement (in $Millions)

MSA	GDP for Industries			Increase Value Added Given a 1% Increase in Air Cargo	
	NAICS 31-33 Manufacturing	NAICS 42 Wholesale Trade		NAICS 31-33 Manufacturing	NAICS 42 Wholesale Trade
Atlanta	$17,318	$20,357		$5.37	$8.14
Boston	$26,972	$13,539		$8.36	$5.42
Chicago	$54,883	$31,340		$17.01	$12.54
Cincinnati	$11,781	$6,661		$3.65	$2.66
Denver	$8,099	$7,857		$2.51	$3.14
Detroit	$19,964	$10,562		$6.19	$4.22
Kansas City	$7,662	$5,680		$2.38	$2.27
Nashville	$6,673	$4,324		$2.07	$1.73
Philadelphia	$21,903	$17,013		$6.79	$6.81
Phoenix	$13,999	$10,243		$4.34	$4.10
Pittsburg	$9,617	$5,930		$2.98	$2.37
Portland	$35,911	$6,712		$11.13	$2.68
Raleigh-Durham	$5,564	$2,407		$1.72	$0.96
Salt Lake City	$7,101	$3,126		$2.20	$1.25
San Antonio	$4,938	$3,946		$1.53	$1.58
San Diego	$13,707	$6,123		$4.25	$2.45
San Francisco	$32,965	$10,123		$10.22	$4.05
St. Louis	$13,332	$7,313		$4.13	$2.93
Tampa	$6,317	$5,888		$1.96	$2.36
Tulsa	$5,369	$1,746		$1.66	$0.70
Grand Total	**$324,077**	**$180,890**		**$100.46**	**$72.36**
Elasticity Values	*0.031*	*0.04*			

4 Literature of Multi-factor Productivity and Aviation

Productivity is an important measure of the state of the economy, at different levels: firm, industry, sector and broad macroeconomy. Productivity refers to the efficiency with which output(s) are produced with a variety of inputs. Output can refer to goods such as cars or services such as medical services. Inputs would include all the different types and skills of labor, private and public capital of different vintages (old and new machines, for example), the sum of all the different types of energy used such as coal, natural gas, oil or nuclear and the materials used such as basic raw materials (*e.g.* iron ore) or semi-manufactured goods like wiring harnesses in cars. It should also include land. Also considered is the technology used and whether the technology is factor augmenting or factor neutral.[13] Productivity can be expressed in terms of a single factor, labor productivity or in terms of many or multiple factors, termed multifactor productivity (MFP).

A number of studies have examined the contribution of investments in the transportation system or other changes to the transportation system to increases in productivity, either productivity within the transportation sector (see references at end of this section).

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[13] Factor neutral technical change means that any change in technology affects each factor of production or each input in the same way so relative input facto productivities do not change. Factor augmenting technical change means that one or more factors have their productivity effects more than other inputs so relative input factor productive will change.

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5 NOTES TO CONSTRUCTION OF INDUSTRY DATA

The following are the steps taken to construct data:

1) Start with the tabs MSA Employment, MSA Value Added, MSA Income, and Population of the file "USA and MSA Employment and Wage Data.xls". The variables of these spreadsheets include geography, description of the industry, employment, gross product, and income.
2) Merge the tabs MSA Employment, MSA Value Added and MSA Income by city, by description of the industry, and by year.
3) Merge the population by city, and by year into the database.
4) CPI by City and by year is then merged. I can find the CPI (All Urban Consumers) of all cities except Raleigh, Salt Lake City, San Antonio, Nashville, and Tulsa from BLS. The CPI of these states are also not reported. These cities are included in the "South-Urban" and I use the CPI of "South-Urban" for the 5 cities.
5) The CPI of Phoenix has not been reported since early 2002 and CPI of the state, Arizona is not reported either. The city is included in "West Urban" so the CPI of "West Urban" is used as the CPI of Phoenix.
6) Merge the National GDP in Dollars, National MFP Index and National Output per Hours Index.
7) Calculate all variables required for the analysis (such as MSA Labor Productivity Index, SAM Real Wage per Employment etc.).

Table 13. Cargo Data by MSA

Variable	Description	Unit
City	20 Cities including Cincinnati, St. Louis, Pittsburgh, Raleigh, Denver, Phoenix, Salt Lake City, Boston, Philadelphia, Detroit, San Diego, Portland, Tampa, Kansas City, Tulsa, San Antonio, and Nashville.	
Year	1995, 2000, 2005, 2010	
MSA MFPIndex	MSA MFP Index (calculated as MSALaborProductivityIndex/ NationalOutputperHourIndex* NationalMFPIndex)	
Industry	5 Industries including Industry 1 (NAICS 31-33), 2 (NAICS 42), 6 (NAICS 54), 10 (NAICS 72), and 11 (Other)	
Enplaned Domestic	Total air freight enplaned at domestic airport (destination airport) and deplaned at the selected city	metric tons
Enplaned Transborder	Total air freight enplaned at transborder airport (destination airport) and deplaned at the selected city	metric tons
Enplaned International	Total air freight enplaned at international airport (destination airport) and deplaned at the selected city	metric tons
Deplaned Domestic	Total air freight deplaned at domestic airport (origin airport) and enplaned at the selected city	metric tons
Deplaned Transborder	Total air freight deplaned at transborder airport (origin airport) and enplaned at the selected city	metric tons
Deplaned International	Total air freight deplaned at international airport (origin airport) and enplaned at the selected city	metric tons
Hub	San Francisco, Chicago, Atlanta, Cincinnati, St. Louis, Pittsburgh (1995 and 2000 only), Raleigh (1995), Denver, Phoenix, Salt Lake City, Philadelphia, Detroit, and Nashville (1995) are cities where airlines use their airports as hubs.	

Note: San Francisco includes Airports SFO, SJC, and OAK
Chicago includes Airports ORD, and MDW
Boston includes Airports BOS, MHT, and PVD

Table 14. Productivity Measures

Variable name	Description
City	20 Cities including Cincinnati, St. Louis, Pittsburgh, Raleigh, Denver, Phoenix, Salt Lake City, Boston, Philadelphia, Detroit, San Diego, Portland, Tampa, Kansas City, Tulsa, San Antonio, and Nashville.
Year	1995, 2000, 2005, 2010
Employment	Employment, thousand; seasonally adjusted
Wage	Wage and salary disbursements, million $ (nominal)
Gross Product	Gross Product, million $
NAICS	NAICS codes (31-33, 42, 51, 52, 53, 54, 55, 56, 71, 72 and other)
Geography	Detail description of the city
Population	Population of each city
Industry	11 industries
National Output (B) Dollars	National value of production, billions of current dollars by NAICS (from Dataset for MFP Project Jul 11 2013.xlsx)
National MFP Index	National MFP Index by NAICS (from Dataset for MFP Project Jul 11 2013.xlsx)
National Output per Hour Index	National Labor Productivity (from Dataset for MFP Project Jul 11 2013.xlsx)
CPI	CPI by city and year (but not by NAICS)
MSA Labor Productivity	MSA Labor Productivity (calculated as GrossProduct/Employment*1000)
MSA Wage Per Employment	MSA Wage Per Employment (calculated as MSAWagePerEmployment=Wage/Employment*1000)
MSA Labor Productivity Index	MSA Labor Productivity Index (calculated as MSALaborProductivity/MSALaborProductivity at base year 2005*100)
MSA MFP Index	MSA MFP Index (calculated as MSALaborProductivityIndex/ NationalOutputperHourIndex* NationalMFPIndex)
MSA Real Wage Per Employment	MSA Real Wage Per Employment (calculated as MSAWagePerEmployment/CPI*100)