Economic Development RESEARCH GROUP

Appendix 5: Literature Review

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

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1 INTRODUCTION

This Appendix is the literature review that was completed at the start of this effort and formed the basis for subsequent research. Subject matter includes:

- Definitions of components of economic impacts of airports
- Model packages that are used to calculate the full economic impacts of airports
- Readily available national economic data sets
- National level airport economic impact studies, as well as a sample of economic impact studies of single airport and airport systems
- Aggregation of methodologies used for economic impact studies of airports by NPIAS classification (These are a compilation of studies developed or used by the research team and do not reflect libraries on web sites, such as those provided by Airports Council International – North America or the National Association of State Aviation Officials.)
- The role of air cargo in the national economy
- An overview of literature that explores linkages between aviation and productivity. This review explores the role of aviation in leveraging improved productivity by: (a) improving intermodal connectivity and (b) strengthening supply chains. These are critical links that frame the economic importance of the role played by airports by defining how aviation extends the national transportation system to enable long distance and international passenger travel, as well as the shipment and delivery of goods.
- The initial list of variables needed to develop "bottom-up" economic impacts studies, as gleaned from literature, studies and data sources reviewed above.

Although this research project involved multiple factors that explain and quantify economic impacts of airports, the scope of the research effort emphasizes analysis of national impacts without ignoring local/regional/state impacts that are not national. In reviewing economic studies, it is important to recognize that values can differ significantly depending on context. The reasoning is that different types of studies focus on the perspectives of: (1) on/off airport spending of passengers; (2) airlines; (3) GA aircraft owners and operations, (4) civil aviation industries, such as aircraft manufacturing and sales; (5) off airport customers of air services transportation users and (6) the role of aviation in the national transportation system. These different perspectives can be important because by distinguishing among perspectives the Research Team and Panel are able to explore and explain the differences of how airports contribute to the U.S. economy and economies on state, regional and local scales.

2 DEFINITIONS OF TYPES OF IMPACTS AND MEASURES

Economic impact studies of airports differ in defining direct, indirect and induced economic impacts based on: (1) guidance developed by the Federal Aviation Administration (FAA) in the late 1980s and early 1990s that are centered on what occurs on-airports and then account for airport related impacts that occur off-airport; and (2) economic definitions that are centered on initial economic shocks to regional or national economies and resulting multiplier impacts. This lack of consistency between definitions of impacts creates a challenge in comparing findings across studies.

2.1 Guidance of the Federal Aviation Administration

Guidance issued by the Federal Aviation Administration, "Estimating the Regional Economic Significance of Airports" (1986 and 1992), as well as the 2011 FAA study, "The Economic Impact of Civil Aviation on the U.S. Economy" provides definitions for the key categories of economic impacts generated by airports. These impacts are:

- ***Direct impacts:***[1] The direct impacts of airports occur as a result of operations carried out by airport management, airport tenants, and supporting and complementary businesses. Typically, airport economic impact studies use surveys to estimate the economic activity directly attributable to the airport, after which, economic multipliers are applied to simulate the indirect and induced effects of spending in the economy. Direct economic impacts are created through on- airport activities measured by the employment, payroll and output.
- ***Indirect impacts:*** Indirect impacts result from the expenditures of air passengers, excluding airfares and associated charges paid directly to airlines or travel arrangers. Visitor expenditures translate into sales, payroll and employment for the following industries:
  - Traveler accommodations (hotel, motel, etc.)
  - Food and beverage providers (restaurants, bars, fast-food outlets and stores)
  - Arts, entertainment and recreation (museums, theaters, amusement parks)
  - Visitor travel services (sightseeing and other tourist services, travel agencies)
  - Ground transportation (to and from airports)
  - Other on- and off- airport purchases of goods and services (souvenirs)

[1] The 2011 FAA study reviewed "civil aviation", which includes "aircraft and components manufacturing". This sector is not listed below because it is not an airport impact other than establishments in the sector that might be airport tenants.

- ***Induced Impacts:*** Induced impacts result from expenditures made by industries identified in the measurement of direct and indirect impacts above (also referred to as primary impacts) to supporting businesses and entities, as well as the spending by direct and indirect employees. Induced impacts capture the secondary impacts to the economy as direct/indirect sales, and the circulation of payroll impacts to supporting industries.

2.2 Regional Economic Definitions

Economists use alternate definitions for direct, indirect and induced impacts, which are imbedded in regional economic models like REMI, RIMS, and IMPLAN. (The packages are discussed in Section 3, below.) The differences arise because the FAA looks at how airports are affected, while the economists look at the initiation of economic activities as direct impacts, subsequent supplier sales as indirect economic impacts, while induced impacts are derived from disposable income earned by workers in these direct and indirect activities and spent on consumer activities.

The jargon of “indirect” and “induced” become particularly muddled when considering visitor spending. By the economic definition, visitor spending derived from airport passenger traffic is considered a direct shock to a local, regional or state economy[2], which accordingly are considered to be direct spending impacts that are attributable to one or more airports. Studies that consider visitor spending to be a direct impact assume that all expenditures by businesses at the airport to source goods and services from their suppliers elsewhere in the region are indirect impacts. In this approach, induced impacts are limited to the re-spending of additional personal income by employees. Thus, the definitions of impact categories found in economic impact studies often differ from those in the FAA guidance. Table 1 summarizes the differences of the two ways that economic impacts of airports are depicted.

[2] In addition, by this definition, spending by international visitors is considered a shock to the national economy.

Table 1. Contrasting Definitions

Impact category	FAA Guidance (1986, 1992, 2011)	Regional Economic Definitions
Direct impact	On-airport activity and activity	Initial economic activities or initial shock) for all economic activities *related to the airport*, including visitor spending at the airport and elsewhere in the region, and activities by airport-reliant businesses.
Indirect impact	Expenditures by visitors/air passengers at businesses located in the airport and elsewhere in the region	Expenditures made by businesses located at the airport to their suppliers for sourcing goods and services, and other supporting entities.
Induced impact	Expenditures by airport-related businesses to suppliers and other supporting entities, as well as the re-spending by employees. (*In the regional economics parlance, this includes "indirect" and "induced" impacts*)	Re-spending of additional employee income (supported by airport-based activities, visitor spending, air-dependent businesses, and suppliers of goods and services).

2.3 Common Measures of Economic Impact

The commonly used measures of economic impact are defined below. These are the standard measures used across all studies reviewed.

- ***Output*[3]*:*** The current dollar production of goods or services by a production unit and measured by total sales or receipts of that unit, plus other operating income, commodity taxes (sales and excise taxes) and changes in inventories. Note that while taxes are included in this definition, many studies separately quantify the federal, state, and local taxes and fees generated by the airport and its allied businesses. Care must be taken to not double count these when estimating economic impacts.
- ***Wages or Personal Income:*** These include the earnings in the form of wages and salaries, other labor income, benefits, and proprietors' income paid to all employed persons who deliver final demand output and services.
- ***Jobs:*** The number of people employed in the industry that provide civil-aviation services, manufacture aircraft and aircraft engines, or work in other industries that are indirectly affected by activity in the civil air transportation sector. This is measured differently across studies as full-time equivalents or headcounts of full-time and part-time employees.

[3] Note that "output" is sometimes described in economic impact studies as "business sales", "business review" and other terms, so the concept can be more intuitively understood by readers.

3 Review of Prevalent Economic Impact Models

Alternative models/approaches are available to gauge the economic impacts from airports' direct economic activities and other initial off airport impacts, such as visitor spending. We present a summary of capabilities below as relates to the context of estimating national-level impacts of airports for three modeling systems, IMPLAN, REMI Policy Insight, and the LIFT model available through INFORUM and one data product, RIMSII available through US BEA (see Table 2).

Several caveats should be stated immediately:

- The choice of model (method) depends upon the breadth of airport-emanating influences the impact system will need to account for, since some methods are limited in their set of economic responses.
    - It is safe to say that all four alternatives <u>can</u> deliver a *multiplier analysis* based on an airport's (or an entire airport system) direct annual activity stated in terms of key economic metrics (e.g. jobs, payroll, purchases, business or leisure traveler spending net of the airfare expense), but two (REMI Policy Insight, and LIFT) of the four choices would be '*over-kill'* in terms of budgetary resources if the focus was just on the air transportation facility.
    - Similarly, if the objective was to capture instances across the U.S. public-use airport system where an airport confers regional productivity gains to industries which use the airport's services (for business travel and/or cargo shipments), then two (IMPLAN and RIMSII data) of the four methods will not suffice.
- If multi-regional U.S. impacts are relevant, then one method of the four is eliminated since it (the LIFT model) is only available as a U.S. macro-impact model; and only the REMI Policy Insight and IMPLAN models are structured to handle multi-regional analysis.

Capabilities of Alternative Economic Impact Methods

	National-level Economic Impact Analysis Products			
	RIMSII multiplier data	**IMPLAN model**	**REMI Policy Insight (PI+) model**	**LIFT model**
	Bureau of Economic Analysis - US Dept. of Commerce	MIG, Stillwater, MN	Regional Economic Models, Inc. Amherst, MA	INFORUM, Univesity of Maryland, College Park
	purchase	purchase	software lease (6 or 12-month)	subcontract to be run by INFORUM staff
	static input-output	static input-output	Dynamic computible general equilibrium	Dynamic computible general equilibrium
ns	NO	YES	YES	YES - somewhat
	406 detailed; 62- aggregate	440 (can be aggregated)	23 or 70	51 value-added industries; 97 commodities
	NONE	NONE	Annual impact forecasting through 2055	Annual impact forecasting through 2040
	NO	NO	YES	YES
	NO	NO	YES	YES
	industry-specific & aggregate economy			
	Jobs, Labor-income, Gross Domestic Product, Output			
	$275	$640	**6-Month lease** $14,500 23-sector, $18,000 70-sector; **12-Month lease** $17,500 for 23-sector, $23,000 for 70-sector	must obtain quote

3.1 Overview of Vendor Products

IMPLAN Model

MIG, Inc. (Formerly "Minnesota IMPLAN Group, Inc.") produces the IMPLAN (**IM**pact analysis for **PLAN**ning) data and software (Version 3.0).[4] The current system is driven off of historical data for 2010. The IMPLAN framework is based on input-output (I-O) economic transactions (using the social accounting matrices) that lead to industry-specific "output multipliers" meaning their interpretation is based on an increment in local production (as opposed to an increment in local final demand as will be discussed in Section 3.2, underpins the RIMSII data products). The multipliers available in the IMPLAN analysis system allow the analyst to identify

- **Total** number of jobs or: dollars of value-added, dollars of sales, or dollars of labor income, across an economy that can be expected to emerge from an initial (direct) job change (or change in dollars of value-added, dollars of sales, or dollars of labor income) in a specific industry (or set of industries).
- **Indirect** number of jobs or: dollars of value-added, dollars of sales, or dollars of labor income, across an economy that can be expected to emerge from an initial (direct) job change (or change in dollars of value-added, dollars of sales, or dollars of labor income) in a specific industry (or set of industries). This indirect stage of impact change is attributed to multiple rounds of supplier transactions between industries as triggered by the policy investigation.
- **Induced** number of jobs or: dollars of value-added, dollars of sales, or dollars of labor income across an economy, that can be expected to emerge from an initial (direct) job change (or change in dollars of value-added, dollars of sales, or dollars of labor income) in a specific industry (or set of industries). This induced stage of impact change is attributed to household spending changes for consumer goods through the multiple rounds of wage creation/elimination as triggered by the policy investigation.

Analyses can be structured in the model using the complete industry-detail of 440-sectors if necessary, or custom industry aggregations can be performed in advance of calculating the internal multipliers. As with all methods that are solely based on I-O fundamentals (including RIMSII data), there are certain assumptions invoked, including no constraint in the labor or input markets; industries each face a fixed relationship in their deploying of en labor, capital and other inputs to production, and the default assumption is that local firms will procure local inputs before purchasing imports that limit the application of such

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[4] www.implan.com

methods to answering only certain questions about economic impacts – namely those related to changes in the level of production. This framework is 'time neutral' therefore the interpretation of the phasing of the resulting total economic impacts is left to analyst to be consistent with the scale of direct impact fed into the model. Resulting job impacts reflect a mix of full and part-time positions.

RIMSII Data

A set of regionally-calibrated multiplier vectors can be purchased from the Bureau of Economic Analysis based upon 2010 historical data and the 2002 U.S. benchmark table.[5] Regional input-output multipliers such as the RIMS II multipliers attempt to estimate how much a one-time or sustained increase in final demand activity in a particular region will be supplied by industries located in the region. RIMSII offers Type I (indirect effects) and Type II (inclusive of the household spending effects) multipliers. Each set of multipliers includes six types of multipliers—four final-demand multipliers (jobs, value-added, sales, and labor income) and two direct-effect multipliers. The final-demand multipliers are all "per-output" multipliers. To use these multipliers, an analyst must first estimate the value of local output purchased by the final user (also known as the final-demand change.) The final-demand multipliers times the final-demand change valued in "producer prices" will provide an estimate of total gross output, total earnings, total jobs, and total value added, depending on the final-demand multiplier that you use.

Jobs impacts estimated using the final-demand and direct-effect employment multipliers include both part-time and full-time employees. Similar to IMPLAN, this framework is 'time neutral' therefore the interpretation of the phasing of the resulting total economic impacts is left to analysts to be consistent with the scale of direct impact fed into the model.

REMI Policy Insight (PI+)

The REMI model (developed in 1986 by Regional Economic Models, Inc.[6]) is an advanced economic model that combines an input-output model at its core with an additional ability to forecast shifts (through 2055) in prices, competitiveness factors and business attraction over time. This latter feature makes the system dynamic and allows the model to "forecast" an economic trajectory under a set of conditions. These conditions can describe a *reference case* (sometimes called *business-as-usual*), or a proposed policy event that has economic implications. Annual impacts are identified when comparing alternative trajectory to the reference case values. The Policy Insight model comes in three levels of industry detail (23-sector, 70-sector, and 169-sectors) with cost escalating for more detail (Table 2 addresses the first two levels of detail on the basis that either of these would be sufficient). The single-area national model is capable of examining U.S. export share impacts for industries

[5] https://www.bea.gov/regional/rims/rimsii/

[6] See: http://www.remi.com/

achieving cost efficiencies from a number of improved contexts. The results from this model are much more complex than derived from either of two prior I-O methods, both on reporting industry-specific metrics, and national indicators. The National model will not predict a change in U.S. population under any scenario since such changes would be determined by changes in immigration policy which is not part of the model's equation structure.

LIFT Model

The *LIFT* model (Long-term Interindustry Forecasting Tool) is a national macroeconomic impact system that was initially developed in 1967 by the University of Maryland, Department of Economics staff, which continues to maintain the model. In the class of computable, general equilibrium (CGE) models, it is responsive to domestic & global competitiveness effects (to 2040).[7] The system is specified for 97 tradable Commodity sectors with 800 macro variables that can be "shocked" within a bottom-up solution algorithm.

The level of disaggregation facilitates the modeling of prices by industry, and examination of the causes and effects of relative price changes. While *LIFT can* be linked to the University's suite of inter-industry forecasting tools (INFORUM), including INFORUM's system of bi-lateral trade models (BTM), it can also cost-effectively embed commodity-specific *export* and *import* price elasticities from the BTM - as exogenous parameters for specific country Origin-Destination pairs. Countries include NAFTA nations, Japan, China, South Korea, and all major European countries. The LIFT model will report industry-specific impacts for jobs, value-added, output, and labor income along with changes in nation-level indicators (GDP by demand sources – consumption, investment, exports, imports, Inflation, Employment, Unemployment rate, Labor productivity, real wages). The National model will not predict a change in U.S. population under any scenario since such changes would be determined by changes in immigration policy which is not part of the model's equation structure.

Review of Economic Impact Methods

Karlsson, et. al.[8], reviews the use of RIMSII, IMPLAN and REMI in the ACRP synthesis of methodologies in developing economic impacts of airports. In this case, the models are assessed as input/out tools for calculation of indirect and induced impacts. Karlsson outlines the main comparative advantages and disadvantages of the three tools. The main advantage of the RIMS II model is the accessibility and detail of the main data source provided by the Bureau of Economic Analysis. RIMS II is also relatively simple to understand

[7] http://inforumweb.umd.edu/services/models/lift.html

8 Karlsson, Ludders, Wilde, Mochrie, & Seymour. "ACRP Synthesis 7: Airport Economic Impact Methods and Models. A synthesis of airport practice." Transportation Research Board. 2008.

and the most inexpensive. In addition, data in RIMS II can easily be inflated or deflated depending on the desired year of analysis.

IMPLAN and REMI are computer-based software-based models that allow for easy modification of variables. Although REMI and IMPLAN are both fairly easy to use, IMPLAN has the advantages of easier data entry analysis.

In terms of disadvantages, RIMS II is a spreadsheet-based model where the user is responsible for setting up the multiplier worksheet. Each time a new variable is added the worksheet must be physically changed. Data used in IMPLAN and REMI must be inflated or deflated before being entered. Also, the costs of the three tools vary significantly.

- RIMS II: The RIMS II model is based on an input– output table that shows the industrial distribution of inputs purchased and outputs sold for any individual industry sector. Created by the U.S. Department of Commerce, this model is generally considered to be the most inexpensive ($2,000 to $5,000) and is widely used in public, private, and military applications.
- IMPLAN: The IMPLAN model is a more complex (as compared with RIMS II) and somewhat more expensive ($5,000 to $15,000) application of the input–output approach in its dynamic application of multipliers. The primary source of data used in IMPLAN is provided by the U.S. Census Bureau and the BEA.
- REMI: The REMI model is generally considered to be the most expensive ($20,000 to $100,000) and complex of the three models. The detailed structure of the REMI model requires a large array of data including BEA employment, wage, and personal income data; the Quarterly Census of Employment and Wages (ES-202) business establishment, employment and wage data; and U.S. Census Bureau County Business Plan data.

4 Applicable National Economic Data Sets

In this section, the Research Team reviews national data sets that will be useful when the Top-down approach is developed in Task 5 and implemented in Task 7. Data sets reviewed are summarized in Table 3 , and then listed by government agency/vendor starting in Section 4.1.

Table 3. Overview of Applicable National Data Sets

Source	Data Series	Data Measured						Highest NAICS Levels	Update Frequency
		Population	Jobs	Income	Firms	Sales/ Output	GDP/GRP/ Value Added		
Census	Decennial Census and American Community Survey	x	x	x				6	Varies[C]
Census	Economic Census		x	x	x	x		6	5 Years
Census	Foreign Trade Division							6	Monthly
Census	County Business Patterns		x	x	x			6	Annual
BLS	Quarterly Census of Employment and Wages		x	x	x			6	Quarter
BLS	Current Employment Statistics Survey		x	x				6	Monthly
BLS	Occupation Employment Statistics Survey		x	x				5[A]	Annual
BLS	National Compensation Survey			x				2[A]	Varies[C]
BEA	U.S. Economic Accounts		x	x			x	4	Varies[C]
IRS	Statistics of Income (SOI)	x		x				6	Annual
Nielsen Claritas	Business-Facts database		x		x	x		6	Monthly
MIG, Inc.[D]	Aggregation of National data sets	x	x	x		x	x	5[B]	Annual

Notes: A - Employment data are reported for detailed occupations, not industry; B - Data are in 2-5 digit NAICS; C - Update frequency varies by program or data product; D - Formerly Minnesota IMPLAN Group, Inc.

4.1 Bureau of Labor Statistics

Current Employment Statistics Survey: The Current Employment Statistics (CES) survey, an establishment payroll survey, is based on data collected from 141,000 businesses and government agencies representing approximately 486,000 worksites throughout the United States. This survey publishes national statistics on employment, average weekly hours, average hourly and weekly earnings and payroll from non-farm establishments; diffusion indexes of employment change are also provided. Data series produced through the CES includes information on all employees, production or nonsupervisory employees (as determined by industry), and women employees. Data on employment excludes proprietors, the self employed, unpaid family or volunteer workers, farm workers, and domestic workers; government employment excludes uniformed members of the armed services. Persons on the payroll of more than one establishment are counted in each establishment. The business establishments included in the survey are classified into industries based on their principal production activity based in accordance with the 2012 North American Industry Classification System (NAICS). NAICS classifications can vary up to six-digit detail depending on the industry and data of interest (air transportation and supporting industries vary from 3-5 digit NAICS in level of detail). Whether the data is seasonally or not seasonally adjusted may vary by data type.

In addition to generating national data, the CES generates statistics for States, the District of Columbia, Puerto Rico, the Virgin Islands, and about 400 metropolitan areas and divisions. Data is collected monthly and statistics are made available in the Employment Situation news release and in Employment and Earnings Online; data can also be retrieved from various databases available on the CES website. Preliminary national estimates generated by this survey are released in conjunction with national estimates from the Current Population Survey (CPS), a Census survey which provides data on the labor force, employment, unemployment, persons not in the labor force, hours of work, earnings, and other demographic and characteristics. Those who are self-employed, unpaid family workers, agricultural workers, and private household workers are covered in the CPS.

National Compensation Survey. The National Compensation Survey (NCS) provides national statistics on (and regional and local) occupational earnings. Data on average hourly wages are available for over 800 occupations. Wage estimates produced through the survey, which cover the civilian, private, and State and local government sectors, are provided for various different employment characteristics, including by industry, occupational group, full-time and part-time status, union and non-union status, establishment size, time and incentive status, and job level. (Federal Government, military, agricultural, and household workers are excluded). Occupations covered in the survey are determined through probability selection and are classified using the 2000 Standard Occupational Classification system. The NCS also provides: a) quarterly changes in employer costs (using the Employment Cost Index); b) quarterly employer cost levels (using the

Employer Costs for Employee Compensation [ECEC] survey) and c) incidence and provisions of employee benefits in private establishments. National data is published on an annual basis, with data collection occurring over an approximately 13 month period; data is also available for broad regions and metropolitan and selected non-metropolitan localities. Summary information and downloadable data are available on the NCS website.

Occupation Employment Statistics. The Occupational Employment Statistics (OES) program produces National estimates of the number of people employed in certain occupations and the wages paid to them for over 800 occupations, which are classified using the Standard Occupational Classification System. (National occupational estimates for specific industries are also available). The OES defines occupations as "set of activities or tasks that employees are paid to perform". "Employees" in the OES survey include all part-time and full-time workers who are paid a wage or salary, and exclude the self-employed, owners and partners in unincorporated firms, household workers, and unpaid family workers. Industry classifications are available to the 4-digit NAICS level for occupations pertinent to airports and air transportation, and range between the 3-digit and 5-digit NAICS levels for other industries. Occupation employment and wage estimates are available for over 450 industry classification at the national level.

While both the OES and the NCS (see above) programs provide information on wages and salaries by occupation, only OES has information on employment for detailed occupations and includes U.S. Postal Service and some Federal executive branch employment. Benefits information is excluded from wage and salary estimates, however. The OES program releases estimates annually (though data are collected in a series of semi-annual panels), with the May 2011 occupation and wage data being the latest available. In addition to producing national estimates, the OEW produces estimates for States and for 585 metropolitan and nonmetropolitan areas. OES data for 1997 onward are available online in several formats, although not all formats are available for each year Summary tables, tools for creating customized maps and tables, and downloadable data are available on the OES and BLS websites.

Quarterly Census of Employment and Wages. The Quarterly Census of Employment and Wages (QCEW) tabulates employment and wage information for workers covered by State unemployment insurance (UI) laws and or the Unemployment Compensation for Federal Employees (UCFE) programs, which collectively represent about 99.7% of all wage and salary civilian employment in the country . Data are derived from the quarterly tax reports that employers submit to state workforce agencies and are then aggregated to annual levels, higher industry levels, and higher geographic levels. Data includes information on numbers of establishments, employees, total wages, and average weekly wages and annual pay, and can be classified by geographic area, industry, establishment type or ownership type (private or government classifications). Data is available at the national level for nearly every NAICS industry , with 6-digit NAICS classifications for air transportation and supporting industries, and at State and area levels down to the 6-digit NAICS Industry level (if disclosure restrictions are met).Employment data excludes the armed forces, the self-employed, proprietors, domestic workers, unpaid family workers, and railroads workers covered by the railroad unemployment insurance system, among others, although BLS states that partial information on agricultural industries and employees in private households is available . Wage data incorporates paid leave, bonuses, stock options, tips, the cash value of meals and lodging, and in some States, contributions to deferred compensation plans (such as 401(k) plans) . The BLS publishes QCEW data quarterly in a variety of formats, along with the annual bulletin *Employment and Wages, Annual Averages,* and Most State workforce agencies have QCEW employment and wage data for both the private and government sectors by county and for major labor market areas.

4.2 Internal Revenue Service

Statistics of Income (SOI) Tax Stats. The IRS's Tax Statistics program produces a range of datasets containing information on income, deductions, tax, credits and other items; these include sets for corporations, individuals, international and foreign corporations, tax-exempt organizations, and estates, gifts, and trusts. Three particularly relevant bodies of data include the Corporation Tax Statistics, the Integrated Business Data (IBD), and the County Income data. Corporation Tax Statistics include information on the number of returns, total assets, total receipts, net income (less deficit), income subject to tax, total income tax before credits, and total income tax after credits. Summary tables are provided in the Corporation Complete Report for tax years as recent as 2009, and in downloadable Excel Files, with 2008 being the most recent tax year available. Available NAICS classifications vary by industry, (for example, corporate statistics are available for air transportation code 481, but air transportation support activities are organized into a larger group); for some industries 6-digit codes are available.

The Integrated Business Data (IBD) combines data on corporations with data on partnerships and non-farm sole proprietorships. Data available on businesses includes the number of tax returns, total receipts, business receipts, Net Income, Deficit, and Net Income (net deficit) through 2008, with data available on Total Business Deductions, Cost of Goods Sold, Salaries and Wages, Taxes Paid, Interest Paid, and depreciation through 2003. Classifications by sector, form of business, and tax year (among other parameters) are possible.

The SOI County Income dataset provides data at the county level based on addresses shown on the population of returns from the IRS Individual Master Files System. County Income Data are available for the entire United States, are updated annually, and include the number of tax returns (approximating number of households), number of personal exemptions (approximating the population), adjusted gross income, wages and salaries, dividends before exclusion and interest received. These data (including state totals), are available for Tax Years 1989 through 2006 and can be purchased from the IRS Statistical Information Service Office. (General Reference: http://www.irs.gov/uac/SOI-Tax-Stats---County-Income-Data). The Tax Stats Table Wizard makes it possible to create customized tables showing relevant income data.

4.3 U.S. Census

Decennial Census and American Community Survey. The U.S. Decennial Census, last conducted in 2010, provides a count of the population in all 50 states, the District of Columbia, Puerto Rico, and the U.S. Island Areas. The Census can be used to obtain counts of the U.S. population at a variety of geographic levels, along with information about their basic characteristics (including sex, age, race, Hispanic origin, and homeowner status). A component of the Decennial Census program, the American Community Survey (ACS), releases new estimates at one, three, and five year intervals; estimates areas with populations in excess of 65,000 are released annually, while those for areas with populations in excess of 20,000 and areas as small as census tracts and block groups are released every three and five years, respectively. As of the 2010 Decennial Census, the ACS collects data previously collected on the Census long form , and provides data on a variety of demographic and housing characteristics, including data on employment status and worker class (including classifications by industry and occupation), and income and earnings. Industry information for air transportation and services incidental to transportation are limited to 3-digit NAICS classifications, although 6-digit NAICS classifications are available for aircraft and aerospace manufacturing and other industrial classifications. The U.S. Census Bureau states that generally, data from the American Community Survey can be compared with 2000 and 2010 Census Data and provides guidance on the U.S. Census Bureau website. Generally, the most recent data from the American Community Survey is available for 2011. Decennial Census and ACS data can be researched and downloaded using the American Factfinder application on the U.S. Census Bureau Website.

Economic Census. The economic Census provides statistics on employment, numbers of establishments and firms, payroll, and measures of output (such as sales, receipts, revenue, value of shipments or value of construction work done). The availability of additional data items for the national level, such as certain business expenses, varies by economic sector. Data is collected every five years, and requires several years subsequent to collection for processing and release; results from the 2007 Economic Census began to be released in 2009. All domestic non-farm business establishments, besides those operated by governments, are included in the results, although most reports are confined to businesses with paid employees. The most detailed statistics and classifications are available for the national level, although information is also provided for States, Metropolitan Areas, Counties, Places and ZIP codes (a separate economic census is conducted for Puerto Rico and other U.S. island areas). Related U.S. Census economic statistical programs include the County Business Patterns, Non-employer Statistics, Statistics of U.S. Businesses, the Vehicle Inventory and Use Survey, and the Business Expenses Survey programs.

County Business Patterns. The County Business Patterns (CBP) annual data services provides national statistics on establishments, paid employment, and first quarter and annual payroll for businesses in the U.S., Puerto Rico, Guam, American Samoa, the

Commonwealth of the North Mariana Island, and the U.S. Virgin Islands. Basic Data items included in the CBP are extracted from a number of U.S. Census maintained data sources, including the Business Register (BR), the Company Organization Survey (COS), and the Economic Census, among others, along with administrative record sources. Data is available to the 6-digit NAICS industry code (including for air transportation and supporting activities) and by State, County, Metropolitan area and ZIP code levels, with data for Puerto Rico and the Island areas available at the state and county equivalent levels. Data are collected annually in March, which facilitate year to year comparisons, but also negate seasonal variations of industries.

CBP data excludes information on crop and animal production, rail transportation, the National Postal Service, pension, health, welfare, and vacation funds, trusts, estate, and agency accounts, private households; and public administration. The CNP also excludes most establishments reporting government employees and indicates that establishments for smaller companies may be missed along with establishments for companies not responding to the Economic Census or the COS. The U.S. Census makes County Business Patterns statistics available approximately 18 months after a given reference year, with data available for download and in the American FactFinder .

Foreign Trade Division. The Foreign Trade Division of the U.S. Census produces detailed statistics on the goods and estimates of services shipped between the U.S. and foreign countries. Export statistics are based on goods valued at more than $2500 per commodity shipped by individuals and organizations (which include freight forwarders, exporters, and carriers) to other countries, while import statistics are for goods valued at more than $2,000 per commodity shipped by individuals and organizations (including customs brokers and importers) being brought into the U.S. Data for both air imports and air exports are compiled in terms of quantities, values, commodity classification, shipping weights, method of transportation (air or vessel), customs districts and ports. Additional data on exports includes state of (movement) origin, countries of destination, and whether contents are domestic goods or re-exports, while other import statistics include duties collected, unit prices and market share, country of origin, and import charges and duties. Statistics for both imports and exports account for 240 U.S. trading partners, 400 U.S. ports, and 45 districts and are reported monthly and on a year to date basis. A series of data products can be purchased from the Foreign Trade Division, including subscriptions to the USA Trade Online service, which enables users to access current and cumulative U.S. export and import data for all 18,000 export and import commodities. USA Trade Online offers import and export data by for states at the 3 and 4-digit NAICS levels for commodity classification purposes, and up to the 6-digit NAICS level for NAICS import and export District data. The Foreign Trade Division also maintains the Exporter Database and issues related annual reports, although this database is generally unavailable to the public. Private vendors, including WiserTrade (www.wisertrade.org), aggregate data is easy to process time series and cross tabulations by transportation mode, commodity or industry, weight and value (current value, which needs to be standardized for time series analyses).

4.4 Bureau of Economic Analysis

U.S. Economic Accounts. The Bureau of Economic Analysis (BEA) provides economic data according to the following major sets of accounts: national, international, and regional, and industry. Data for the four economic account sets can be viewed and downloaded using interactive tables based on the BEA website.

The National Income and Product Accounts (NIPAs) produce data on gross domestic product (GDP) and GDP measured as incomes earned in production (GDI), sources and distribution of income among private enterprises, sources and uses of income received by individuals, transactions of federal, state, and local governments, receipts and payments associated with foreign trade. GDP and corporate income data is made available quarterly, while personal income and outlay data is available monthly. The International Economic Accounts provide statistics on transactions between the U.S. and foreign residents, which include imports and exports of goods and services, and on the value of U.S.-owned assets abroad and foreign-owned assets in the United States, among other data.

Through its Industry Economic Accounts, BEA publishes GDP by industry, including components of value-added by industry -including compensation of employees, gross operating surplus, and taxes on production and imports, less subsidies - on an annual basis. This is available down to the 3-digit NAICS level for air transportation and transportation support activities, although 4-digit NAICS level information is available for some industries. Also included in the Industry Economic Accounts are annual and benchmark input-output tables and several satellite accounts. Among these are the U.S. Travel and Tourism Satellite Accounts, which are available quarterly and present estimates of expenditures by tourists, or visitors on 24 types of goods and services (9) Also included are the Transportation Satellite Accounts, which were jointly developed by the BEA, the Bureau of Transportation Statistics and the U.S. Department of Commerce and present estimates of both in-house and for-hire transportation services, although these were last updated in 1997.

4.5 Private Data

IMPLAN Data. The IMPLAN dataset draws on an aggregation of federal sources, including BEA, the Census of Employment and Wages from the Bureau of Labor Statistics, and the County Business Patterns from the U.S. Census Bureau, and data is controlled using the NIPA from the BEA. IMPLAN data files include six major components: employment, value added (factors), output (which varies by industry), final (institutional) demand, and inter-institutional transfers, along with national structural matrices. Additional data types available within this overall structure include foreign exports and state and local government sales. Employment data in IMPLAN refers to annual average full-time/part-time jobs (including both wage and salary and self-employed workers). IMPLAN Data files include information for industries at the 2 to 5 NAICS code level. The most recent IMPLAN data currently available for purchase is for 2010, and can be purchased at the national, state, county and congressional district levels or in combinations of these.

Nielsen Claritas Business Facts Database. Nielsen Claritas Business Point Service, a business-to-business (B2B) marketing system, draws data from the Nielsen Business-Facts database, which covers over 13 million U.S. business establishments. The Business-Facts database uses the infoUSA data file, which in turn draws from a broad series of public and private data and record sources, including the Yellow and White Pages, company annual reports, and *The Wall Street Journal*, among others. Basic data include business names, locations and contact information, industry size indicators, franchise/branch/chain information, employment, and sales volume data, among other items. Claritas undertakes various modeling efforts once the data is received; some results include the production of sales volume records for nearly all business records (excluding government) having an estimated sales volume, and approximately 80% and the generation of actual employment data or "most likely" employment estimates from U.S. businesses . Both NAICS (6-digit level) and Standard Industrial Classification (SIC) groupings are available for the BusinessFacts data. Updates to the Business-Facts database are made monthly. Geographic analyses are possible at National, State County, Zip Code, Census Tract and Block Group geographic boundaries, among others , but national level dataset would require the purchase of all state-level data packages, which is costly. The Business Point Service also makes it possible for users to analyze markets in a specified (polygon) area around a designated area, but repeating this process for airports throughout the U.S. airport system might be too labor intensive compared to the information yielded.

References for Section 4:

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http://www.bts.gov
IMPLAN V3 Reference Manual
http://implan.com/V4
http://www.claritas.com

5 AIRPORT ECONOMIC IMPACT STUDIES

The large majority of airport economic impact studies use data on airport operations, combined with survey data of on-airport and off-airport businesses and visitors. Some studies however, have used regression models of the type envisioned for the bottom-up approach proposed for the ACRP 03-28 projects. These studies offer insights into the data and regression variables that help explain the economic impact of airports.

Section 5 focuses on the data collected and calculation methods that are used in looking at economic impacts of airports. Three types of studies were reviewed: Section 5.1 includes studies of economic impacts of airports based on regression modeling, which are primarily from academic sources; Section 5.2 is a review of national level studies that do not employ regression; and Section 5.3 looks at a sample of the many economic impact studies of airports and airport systems that use input-output analysis. Lastly, to conclude Section 5, Section 5.4 presents a summary of airport and system studies that were reviewed by the Research Team.

5.1 Academic/Consulting Studies Based on Regression Modeling

Benell, D.W. and Prentice, B.E. (1993), "A Regression Model for Predicting the Impacts of Canadian Airports," Logistics and Transportation Review, 292: 139–158.

The study aims at estimating the relationship between sets of readily available indicators of airport activity and the economic impacts of Canadian airports. The result is an economic model that provides elasticities of airport employment and revenue and can be used to update economic impacts in the future. These elasticities can be used to predict the effects on an airport's direct economic impacts of changes in variables such as passenger volumes and local economic conditions. The study used data from 38 airport economic impact studies to estimate a regression model. The study found that employment and revenue impacts of airports do not always decline with decrease in passenger movements and they are not correlated with each other either, so other factors must be responsible for these impacts apart from passenger traffic.

The key indicators of airport activity used as regression variables in this study included:

- **Passenger traffic:** Economic impact is expected to increase with higher passenger traffic. International and domestic passenger movements have different impacts on airport economic activity. The correlation between passenger traffic and direct revenue and employment is likely to be positive, but not necessarily linearly because passenger traffic would include some passengers who are in transit and do not contribute significantly to the economy.

- **Aircraft movement statistics, by size/weight of aircraft**: Aircraft movements were segregated into weight groups based on gross take-off weights, as small, medium, and large aircraft.
- **City's income or commercial activity:** Changes in commercial activity and employment relate to economic activity overall and may be correlated with economic activity at the local airport. GDP statistics, if available, can be used, or average residential home prices can be used as a proxy for commercial activity because average home prices should rise or fall with economic conditions in the region.
- **Facilities such as carrier/airline maintenance bases, airport towers, and flight service stations (FSS):** The presence of these facilities usually indicates a certain level of airport activity and these were represented as dummy variables in the regression.

The dependent variables in the two regression equations were employment and revenue and the coefficients in the equations can be interpreted as long run elasticities of employment and revenue. The variables for small and medium aircraft movements, FSS, and towers were omitted from the final regression because they were either not significant indicators of economic activity or they were excessively correlated with other explanatory variables (showed multicollinearity), such that the remaining variables sufficiently account for the effects of the omitted variables.

The regression results from a cross-sectional analysis of the economic impacts of 38 Canadian airports showed that 97% of the variation in direct airport-related employment and 95% of the variation in direct airport-related revenues was explained by the variables in the models above – passenger traffic, city's income, large aircraft movements, and presence of an air carrier maintenance base. The comparison of actual and predicted values for employment and revenues shows a high degree of accuracy across big and small airports; therefore, the results were independent of airport size. However, employment shows greater accuracy because it is more consistently measured across studies, whereas revenues are not often consistently measured because different categories of airport economic activity may be included in different studies. Employment figures are not likely to be double-counted, whereas revenues can be; therefore, with measuring revenues, it is not possible to be 100% certain that all double-counting has been avoided after netting out revenues and expenditures. For example, sales of airline meals constitute revenue for the caterer and expenditure for the airline, and may be double counted.

The study also showed that with a 1% increase in passenger traffic, an increase in direct employment of 0.75% and an increase in direct revenue of 0.49% can be expected. These elasticities can be used for planning purposes. For example, the local airport authority could use the 0.75% measure to estimate the potential gain in employment of attracting a new airline connection. Also, the 0.49% measure provides an estimate of the returns to the community that local politicians may translate into tax revenues.

Such regression equations can allow cities to update the analysis of economic impacts of airports without undertaking expensive new surveys, simply basing the estimates on revised values of variables included in the regression model. The equations also help in clarifying relationships important for planning and promoting airports. To the authors' knowledge, this was the first time that revenue or labor elasticities were derived for commercial airports.

Green, R. (2007), "Airports and Economic Development," Real Estate Economics, v35, 1: pp. 91-112.

This paper uses regression equations to test whether the activity at a metropolitan area's airport helps predict population and employment growth. The study uses various measures of airport activity, including boardings, originations, hub status, and cargo volume. It also includes additional explanatory variables for airport activity, including proximity to a city with a large or medium hub, per capita income, and industrial structure.

Because airports may be a function of, as well as a cause of, growth, the article uses an instrument variable approach to account for this endogeity. The study shows that, under a variety of specifications, passenger activity is a powerful predictor of growth, but cargo activity is not. This result is also supported by another study by Brueckner (2003).

Specific measures of airport activity used in the study are:

- **Boardings and passenger originations per capita in each metro area from FAA data** (http://www.transdata.bts.gov) – if there was more than one airport in a metropolitan area, boardings were combined to get a total for the MSA. Boardings primarily impact the number of jobs created at the airport. On the other hand, passenger originations indicate how many people from outside the region are contributing to economic activity in the region. Both measures predict economic activity strongly.
- **Presence of an airport that is a hub for a major carrier**
- **Cargo activity –** cargo tonnage per capita is the variable used here, analogous to boardings per capita for passengers. While the boardings per capita measure captures the impact of airports arising from business and tourist development, the cargo measure captures the impact of airports arising from the distribution of goods.

This study's strength is that unlike some other analyses based on regression models, this one used a wide range of economic and demographic factors as control variables because these factors can also affect economic development in the region. Some of the factors considered were property, corporate and income tax rates; heating and cooling degree days; the share of the population over the age of 25 with high school diplomas; the share with college degrees; the share of employment in the finance, insurance and real estate (FIRE) sector; the share of employment in the manufacturing sector; the population in 1990; whether the state is a right-to-work state (has unions or not) and average commuting time in the region. All variables were from 1990, and the data was primarily obtained from the 1990 census of population and housing.

The reasons for including these variables are mentioned in the study. For example, tax rates and education levels of the residents are known to have an impact on regional economic development. The shares of employment in the fast-growing FIRE sectors and relatively slow-growing manufacturing sectors also have an impact. Warmer, milder weather in the southern and western regions of the country and right to work laws impact the location of employment and workers and hence, the growth of employment in these regions. Commuting time was also included because it can affect economic growth in large cities if it is high enough to reflect congestion and negative externalities.

The results of this analysis indicate that passenger boardings per capita and passenger originations per capita in the nation's largest metropolitan areas are powerful predictors of population growth and employment growth.

The study found that one standard deviation increase in boardings per capita produces an 8.0% increase in employment growth. Hub cities saw employment grow between 8.4% and 13.2% faster than in non-hub cities. However, there was no impact on cargo activity.

The author uses the example of two large cargo hubs, Memphis (the home of Federal Express) and Louisville (the home of UPS), neither which are fast-growing MSAs, to explain that while business travelers serve high value "knowledge based businesses," those that ship cargo contribute to lower value economic activity. While anecdotal evidence shows that companies have located warehouses near Memphis and Louisville, warehouses have become increasingly automated and warehouse and distribution jobs are not high-wage jobs. Therefore, the author concludes that it is not surprising that cargo has little predictive power for economic development.

Button, K. and Yuan, J. (2012), "Air Freight Transport and Economic Development: An Examination of Causality," Urban Studies, 1-12.

The paper examines the potential role that air freight transport in the U.S. can play in stimulating local and regional economic development. The analysis examines trends in employment and income for metropolitan statistical areas that make use of air freight services. The focus is on causality, and not on simple correlation, and uses econometric analysis rather than simpler economic multiplier approaches. By conducting statistical causality tests on panel data covering the top 35 airports (based on cargo volume) and 32 MSAs in the U.S. from 1990 to 2009, it was found that air freight transport was a positive driver for local economic development. A recent analysis of U.S. multipliers at the national level, where leakages are very much smaller than for states, indicates a range of 0.8 to 1.5 (quoted in the study). Variables used in the econometric analysis were:

- Employment
- Personal income
- Per capita personal income
- Air cargo volume for each MSA

Some of the key findings were that construction causes short-term primary economic impacts and employment/income multiplier effects in the region, but if specialized labor or equipment is imported for construction, the size of the multiplier is reduced.

Secondary effects relate to running and operating the airport, such as security, handling and customs. As more technology is introduced into airport operations for activities such as electronic tagging and tracking of cargo, the scale of the secondary effect is likely to decline in the future relative to the initial expenditures involved.

Tertiary effects stem from stimulus to the regional economy from firms and people having access to air transport services. These differ for hub and spoke cities. Hubs offer direct flights for business travelers but this is less important for cargo, where just-on-time delivery is more important than routing. Yet the hub also benefits those on the spokes because without a hub-and-spoke structure many would find it difficult to travel long distances at all. Moreover, with regard to modal share of merchandise in American trade, air transport carried over 25 per cent in 2010 in terms of value, but only 0.4 per cent in terms of weight. The source for air cargo data used here is the TranStats database of the Research and Innovation Technology Administration of United States Department of Transportation.

CDM Smith (2012), "The Economic Impact of Commercial Airports in 2010," prepared for Airports Council International – North America.

This economic impact study summarizes the contribution that the 490 commercial airports in the U.S. make to the national economy, based on a regression analysis of data from more than 75 state and individual airport economic impact studies. Initially, the study defines the scope of analysis to include all economic impacts associated with commercial airports in the U.S. Commercial airports were defined as any airport listed in the National Plan of Integrated Airport Systems (NPIAS) designated by the FAA. NPIAS also classifies commercial service airports as large, medium or small hubs, or non-hubs.

Two groups are broadly responsible for generating economic impacts at commercial airports. One group consists of businesses and organizations engaged in airport activities at commercial airports, and the other consists of visitors traveling via commercial airlines to and from commercial airports that spend money during their visit.[9]

Direct impacts were identified as those tied to the initial point of economic activity at commercial airports, which included 1) purchase of aviation goods and services on the airport, 2) on-airport construction, and 3) spending by airline passengers passing through the region. Visitor spending was classified as “non-local passengers” which is interpreted to mean “foreign visitors” since any U.S. passenger spending would be considered only to have a re-distributive effect. Output for each category was obtained by existing studies or estimated through regression analysis.

Multiplier impacts were calculated and defined as (1) Indirect impacts: businesses spending on expenses from suppliers and 2) Induced impacts: employees of direct and indirect businesses who spend part of their earnings on goods and services. Both types of impacts re-circulate until they leak out of the U.S.

Direct impact data were found for only 272 out of the 490 commercial airports. This data was reviewed and any results that were not suitable because the underlying assumptions were incompatible with this study were discarded. Payroll and output results from studies dated prior to 2010 were adjusted for inflation using standard Consumer Price Index inflation rates from the Bureau of Labor Statistics. Direct impact data for the other airports and for any discarded data was estimated using regression analysis.

The independent variables obtained for each airport included:

- Passenger enplanements, from FAA NPIAS data
- Various types of aircraft operations from FAA ATADS data
- Population, employment, and total income tied to each airport’s associated city.

Strong correlations were found as follows (see table 15 in the study). Using these correlations, linear relationships were established after removal of outliers to estimate dependent variables where needed. In the correlations below, the first variable is the dependent variable and the second is the key independent variable with which it was most strongly correlated.

- On-airport employment was very strongly correlated with air carrier and air taxi operations data (correlation coefficient=0.96); and moderately correlated with city-level employment (0.59)
- On-airport payroll was very strongly correlated with enplanements (0.93)

[9] To ensure consistency, general aviation visitor impacts were deleted from the analysis when it was possible to separate them from commercial aviation.

- On-airport output was very strongly correlated with air carrier operations (0.96)
- Visitor expenditures were very strongly correlated with total passengers (0.93)
- Capital improvement expenditures were very strongly correlated with airport employment (0.93)

Once direct impact data was available for all five dependent variables, the data was entered into an economic model (IMPLAN) to estimate multiplier impacts. The IMPLAN model was used to quantify the nationwide multiplier effects of all the 490 commercial airports. The study analysis found that the 490 commercial airports in the U.S. have the following impacts:

- Support 10.5 million jobs
- Create an annual payroll of $365 billion
- Produce an annual output of $1.2 trillion

Tharp, W., Frieson, S., and Green, A. (2008), "An Analysis of the Economic Impact of the Chattanooga Metropolitan Airport: A Report to the Board of Directors of the Chattanooga Metropolitan Airport Authority," prepared by Community Research Council (CRC).

CRC conducted a multiple regression analysis of the relationship between air service and economic growth in mid-size cities to determine how increases (or decreases) in air services are related to changes in population, firm growth, income and employment in the selected comparison regions. Economic impact measures used were employment, income, and output.

Airport employment depends on the volume of aviation activity at an airport, which is determined not only by the population of the region it serves, but also by the airport's air service function. The number of commercial flights and the mix of locations served by them defines whether the airport functions as an: (1)intercontinental gateway, (2) international (same continent) gateway, (3) regional transfer hub, (4) local origin/destination point, (5) specialized air cargo distribution center, or (6) overnight parcel hub.

Empirical studies reviewed Tharp, et. al., confirm that higher air traffic results in economic effects of higher magnitude. Brueckner (2003) found that a 10 percent increase in passenger enplanements in a metro area results in a 1 percent increase in service employment, controlling for reverse causality. Button's (1999) study of 300 metropolitan areas similarly confirmed a positive relationship between the level of high-technology employment and airport size. Brueckner's finding applied only to service related employment, with no impact on goods-related employment. Consistent with Brueckner (2003), Green (2007) found that an increase in boarding per capita of 1 standard deviation resulted in increased employment growth of 8 percent. Like Brueckner (2003), Green found no link between air traffic and economic development in regards to goods-related (manufacturing) employment.[10]

The data gathered included the number of visitors and visitor spending – the impact of visitor spending was studied by using data from the DB1B DOT/FAA Database, which is a 10% sample of all flight itineraries of passengers within the U.S. With this data, it is possible to determine the percentage of passengers boarding flights at Chattanooga Metropolitan Airport who began their journey there or at some other city. This method was employed to determine the number of annual visitors to the Chattanooga area that uses the airport services.

The 2006 DB1B data for Chattanooga Metropolitan Airports indicates that 73.5% of passengers boarding planes in Chattanooga were "round-trippers", meaning they started and ended their trips in Chattanooga (i.e. residents). The remainder, 26.5%, either took one-way trips out of town or originated their trips elsewhere and could be considered visitors to the area. Applying this proportion to the 2006 enplanement data for Chattanooga Metropolitan Airport, the annual visitors to the Chattanooga region as a result of airport service can be estimated.

Per visitor spending rates were applied for general travelers; for business travelers federal per diem rates were applied to calculate total visitor spending. In addition, visitors arriving on general aviation aircraft were separately estimated. The Aircraft Owners and Pilots Association estimates an average of 2.5 passengers per aircraft. Applying this ratio to general aviation aircraft to the landings/deplanings at the airport provided the number of GA passengers. The assumption is that each aircraft that both landed and deplaned at CMAA had 2.5 visitors to the Chattanooga area. General Aviation traveler spending was separately estimated.

The study followed FAA guidance on the recommended based aircraft-to-employment ratio for impact estimation purposes (one full-time employee per 7.2 aircraft).

Travel time cost of driving to other airports if this airport did not exist were also calculated, but are not relevant for a national analysis.

The results of the CRC analysis of midsize regions and airports finds that there is only a limited relationship between growth in passenger enplanements and cargo at regional airports and growth in regional population, employment and wages. Passenger growth explains 10% of the change in regional population and wages and 14% of growth in regional employment. This finding is at variance with other studies that have identified a stronger

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[10] See: Brueckner, J. K. (2003), "Airline traffic and urban economic development." Urban Studies, 40(8), 1455-1469

relationship, though those studies have tended to focus on both larger airports and more populous regions.

Oxford Economics, Economic Benefits from Air Transport in the US, 2011

The Oxford Economics global forecasting and research consulting firm has produced a series of county-based economic studies to highlight the benefits of the aviation industry. Both the International Air Transport Association (IATA) and the Airports Council International (ACI) provided data on aviation and economic activity for these reports. These reports examine the following factors:

- The aviation sector's contribution to national GDP
- The jobs supported by the aviation sector (those directly supported by the aviation sector, those supported through the aviation supply chain, those supported through aviation sector/supply chain employee spending, and those supported through tourism effects).
- The productivity of air transport services employees (based on measures of Gross Value Added (GVA) per employee).
- Tax income created by the aviation sector, its supply chain, and aviation sector/supply chain employee spending.

For many reports, the aviation sector is defined as airline and ground-based infrastructure activities. Reports for some countries (including the United States, Germany, Singapore, and Canada), however, expand the definition of the aviation sector, and the benefits generated by that sector, to incorporate aerospace manufacturing activity. The structure of the national aviation sector as presented by Oxford Economics is presented in The Oxford reports, which measures consumer surplus for passengers and shippers based on: passenger numbers, freight tonnage, and related charges, estimates elasticities of demand for individual market segments, and incorporates assumptions regarding passenger and shipper willingness-to-pay for aviation services.

Across the world in its analyses, Oxford Economics offers a Connectivity Index, which is defined as "a measure of the quality of a country's air transport network that reflects both the volume of passenger traffic and the importance of the destinations served." The index incorporates information on the number of destinations a country's air network serves, the frequency of service, the number of available seats per flight, and the relative importance of the destinations served (within the global air transport network). By nation, the Index reflects a higher value by the more destinations that are served and the frequency of services. The larger the number of available seats per flight and the greater the relative importance of the destinations served. Improving air connectivity may create opportunities to access foreign markets, speed up the incorporation of new business practices (i.e. Just-in-time delivery), among others.

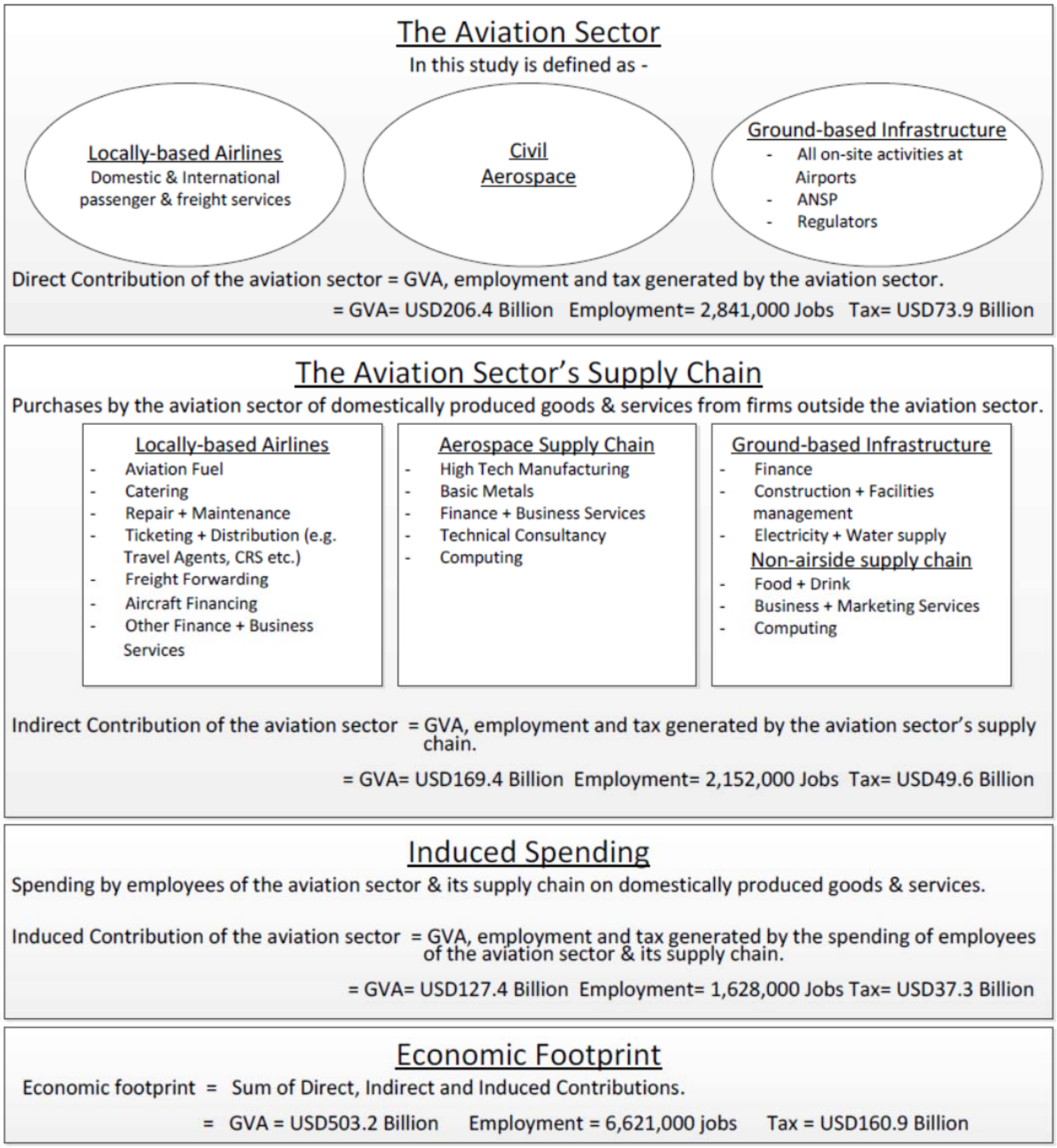
The national study for the United States depicted in Figure 1estimates economic benefits from the aviation sector and its economic footprint. The aviation sector is comprised of three distinct types of activity:

- Airlines transporting people and freight (within the U.S. and between the U.S. and an international destination)
- Ground-based infrastructure that includes the airport facilities, the services provided for passengers on-site at airports, such as baggage handling, ticketing and retail and catering services, together with essential services provided off-site, such as air navigation and air regulation.
- Aerospace manufacturing that builds and maintains aircraft systems, airframes and engines.

Direct aviation sector output is measured by Gross Value Added (GVA). GVA is measured either as the firm or industry sales revenue less purchases from other companies, or equivalently, as the sum of employee compensation and gross operating surplus, measured before the deduction of depreciation, interest charges and taxation.

The study notes that passenger and freight traffic is accounted for in different ways across the industry supply chain, depending on the focus of the operator and the purpose of analysis. For example, airlines generally count the number of passengers who board their aircraft, whereas airports often count the number of passengers arriving or departing their airport – which in some cases can lead to totals significantly larger than those reported by airlines, despite referring to the same inherent volume of passengers.

Figure 1. The U.S. Aviation Sector



Gartner, W., Tuck, B., and Erkkila, D.(2011). "Update of a Web-Based Economic Impact Calculator for Small- and Medium-Sized Airports and a Study of the Economic Impact of Minnesota Airports," Center for Transportation Studies, University of Minnesota, report number CTS 11-01, 2011.

The report describes the methodology for updating the Web-based airport economic impact calculator and the calculation of the statewide economic impact of Minnesota's public airports. The research products were: 1) a newly updated economic impact calculator containing impact coefficients that reflect current economic conditions, with added flexibility to handle large, unique airport operations 2) and an estimate of the total economic impact of Minnesota's airports in 2009.

The airport economic impact calculator prompts users to enter data on nine main types of economic activity to calculate the impact of their local airport. These include:

- public airport operations and capital investments
- fixed based operators (FBOs)
- commercial scheduled air service
- retail businesses
- general aviation
- freight operators
- private corporations with flight departments
- non-profit and government entities, and other activities.

These nine activities also contribute to the economy of Minnesota. To calculate the economic impact of the airport system in Minnesota, primary data were collected from airport mangers, FBO's, corporate flight departments and governmental units. Secondary data were obtained for some airports like Minneapolis-St. Paul International, Rochester International, and Duluth International airports to provide a comprehensive economic impact analysis for the state.

5.2 National Studies of Economic Impacts of Aviation[11]

In this section, the Research Team reviews various estimates for the national economic impact of U.S. public use airports not developed through regression modeling. Literature is reviewed on the following topics:

- Impact summary of findings – The findings are expressed in economic indicators such as jobs, gross domestic product (GDP which is also known as value added), wages (e.g. payroll), and output. These impacts will serve as a benchmark for economic impacts of national network of public use airports.
- Methodologies for estimating impacts and sources of economic activity included in direct, indirect, induced, catalytic, and related categories. Sources of data for these estimates are also reviewed.

[11] Excluding studies discussed in Section 3.1, above.

- Economic modeling – Sources of economic modeling software (e.g. REMI and IMPLAN) as well as ratios (e.g. RIMS II) are reviewed and analyzed in their approach for estimating indirect, induced, catalytic, and related impact effects. In some cases multipliers were customized using previous dataset for detailed impacts by aircraft type.

The breadth of the research presented illustrates the various methodologies utilized to calculate national impacts of the U.S. airport system, which may highlight specific aspects depending on the intended audience. Each study slightly varies in scope, categorization, and date yet all share common classifications and includes "spin-off" or "multiplier effects that occur as direct aviation impacts percolate through the economy and expanding in impact.

All of the reports identify some representative version of direct, indirect, and induced economic impact categories that are linked to the aviation industry. However differences arise in the types of industries that are included in each impact category and how they relate to "spin-off" or "multiplier" effects.

U.S. DOT, FAA. "The Economic Impact of Civil Aviation on the U.S. Economy." August, 2011.

As discussed in Section 2, the definition of direct, indirect and induced is consistent with FAA guidance published in 1986 and updated in 1992. Direct impacts include: 1) air transportation and supporting services (including GA) and 2) aircraft, aircraft engines and parts manufacturing. Indirect Impacts include travel and trip related expenditures by travelers using air transportation. Induced or secondary impacts result from expenditures made by industries identified in the direct or indirect impact category to supporting businesses/suppliers and the spending of direct and indirect employees

Data were collected from a combination of government and private sources. The 2007 U.S. Economic census was incorporated into this report. Baggage fees were also included in the analysis, as reported to the Bureau of Transportation Statistics. One data item not seen in other studies is the average number of FTE maintenance workers per network airline aircraft is 12.4 in 2009 and per passenger airline aircraft is 7.9 in 2009.

BEA RIMS II multipliers were used to estimate the Induced/Secondary impacts of direct and indirect effects. Total economic activity attributed to civil aviation-related goods and services were reported as:

- 10.2 million jobs
- $394.4 billion in payroll (earnings)
- $1.3 trillion in output

Airline passengers' expenditures on hotels, rental cars and entertainment at their destination contribute $597 billion (about 46%) of the total output, while airline operations accounts for $297 billion () and airport operations contributes $79 billion (roughly 23% and 6% of total output , respectively). Operations and aircraft manufacturing and parts (other than GA aircraft) account for $177 billion (an additional 14%). GA operations, manufacturing, and visitor expenditures contributed an additional $76.5 billion (6%). Air couriers and travel agencies together account for 5% of total output.

DRI WEFA (A Global Insight company), and Campbell-Hill Aviation Group, Inc. "The National Economic Impact of Civil Aviation." July, 2002.

The DRI study estimated the total impact of civil aviation on the national economy in 2000 as 11.2 million Jobs and $904 Billion in GDP. Direct impacts included: 1) air transport and airport expenditures, 2) aircraft and aircraft parts 2) tourism and travel arraignment, and 3) freight forwarding. These impacts covered both commercial and GA aviation. Indirect impacts were industries that were suppliers to civil aviation and related industries, and induced impacts were generated by the spending of income by employees of both direct and indirect industries.

Estimates for output and employment for aircraft and aircraft parts was based on Bureau of the Census and Bureau of Economic Analysis of U.S. Department of Commerce (BEA) data for 2001. General Aviation operations were estimated by subtracting commercial aviation data from the entire air transportation industry. Travel and tourism data was based on Travel Industry Association surveys. The split between commercial tourism and GA tourism is based on the number of GA trips that are overnight compared to all overnight trips. The "Tourism by Air" category appears to include both domestic and international visitors. Freight forwarding, travel arrangement, and flight training data are based on the 1997 Economic Census.

A DRI WEFA U.S. Macroeconomic model, based on a Cobb-Douglas production function, was used to develop the Production and Income multipliers. The Production (Indirect) multiplier is a ratio of direct and indirect impacts to direct alone [(Direct+Indirect)/(Direct)] of about 2.0. However the aviation and tourism industries are characterized by high labor costs. As such, the direct impact is high than for most industries which reduced the production multiplier for civil aviation in this study to 1.7. The) multiplier uses the same ratio calculation and was originally thought to be 2.0 but was lowered to 1.5 to account for supply-side limitations.

Allen, Blond, "General Aviation's Contribution to the U.S. Economy." Prepared for the General Aviation Manufacturers Association and the National Association of State Aviation Officials (NASAO) by Merge Global. May, 2006.

This study found that general aviation's contribution to the U.S. Economy in 2005 was 1.26 million jobs, $53.2 billion in payroll and $150.3 billion in output.

To capture the relationship between industries depend on each for materials, supplies, and services, the following categories are defined to explain the impacts of GA aviation on the national economy. New aircraft sales, aircraft usage rages, and operations and maintenance costs were provided from GAMA, the FAA, and Conklin and deDecker.

Direct impacts include operation, maintenance, or manufacture of GA aircraft Indirect impacts include purchase of goods and services by firms directly involved in the operation, maintenance, or manufacture of GA aircraft. Induced impacts include expenditures of wage-earners employed by firms that generate directly or indirectly from GA.

Merge Global used a 1997 BEA I/O model while the 2002 RIMS II update was under construction. According to the authors, MergeGlobal used detailed sub-sectors from the 1997 table to create “a slightly more robust model of the economy that tracks with the more aggregated 2004 table developed [by BEA].” This I/O framework covers 65 sectors including the important sectors for determining the impact of GA aircraft sales and operations on the economy (i.e., airframe, aircraft engines, avionics, and interiors).

Airports Council International North America (ACI-NA). “The Economic Impact of U.S. airports 2002”

This study found that total economic impacts of U.S. Airports in 2001 included 6.7 million jobs, $190.2 billion in earnings and $506.5 billion in output. Direct impacts include: 1) airlines, airport management, fixed base operators, and other aviation-related tenants, 2) aviation related goods and services, and 3) airport construction and capital improvement. Indirect/induced impacts are consequences of: 1) on-airport businesses, 2) off-airport visitor spending, and 3) the successive sounds of spending in the local community. No distinction is made if visitor spending applies only to foreign visitors.

Capital development project information was gathered from the 2001 ACI-NA General Information Survey. The report appears to only cover commercial service airports. The ACI-NA report did not indicate which economic modeling software package was used to estimate the Indirect and Induced impacts.

International Civil Aviation Organization (ICAO). “Economic Contribution of Civil Aviation.” Circular 292-AT/124. 2005.

Findings of this study are that the worldwide impacts of civil aviation in 1998 were 27.7 million Jobs and $1.36 trillion in Output. Direct impacts included in the ICAO study were: 1) airlines, other aircraft operators and affiliates, 2) airports, air navigation services providers and affiliates, and 3) aerospace and other manufacturers, other services industries, and their affiliates. Indirect impacts include transactions with numerous aviation-specific and other suppliers along the production chains. Induced impacts include the wages spent by employees of the direct and indirect industries on retail and other services. In addition, this study includes “catalytic impacts”, which are defined as off-airport expenditures of air transport users (passengers and freight forwarders). The ICAO report did not indicate which economic modeling software package was used to estimate the indirect, induced, and catalytic impacts.

5.3 Selection of Airport Economic Impact Studies Based on Survey Data and Input-Output Models

Economic Development Research Group and Mead & Hunt (2004), Lansing Capital City Airport Economic Impact Study

The study estimated economic impacts of the Capital City Airport for the three-county Lansing metropolitan area. The total economic impacts were calculated based on landside and airside on-airport employment by industry, tons of cargo shipped, takeoffs and landings, categorized by general aviation, military, and commercial airlines, scheduled airline flights per day, and enplanements. Passengers were categorized by commercial air travelers (including air carrier and commuter airline passengers) and general aviation travelers, visitors flying into the airport, categorized by those from other states, from elsewhere in Michigan, from outside U.S. and from within the tri-county region. These were additionally categorized as those citing business, leisure, military, or miscellaneous as the primary purpose of the trip.

Additional data was generated through three survey efforts. A survey of airport tenants profiled of on-airport business sales, budgets, jobs and payroll by type of business activity. Secondly, surveys of visitors (airport travelers) providing profiles of trip purpose, destinations in the Lansing area, duration of stay of non-resident business and leisure travelers, and amount of money spent by visitors in the region on various off-airport businesses, including hotels, restaurants, retail, recreation, and local travel (taxis, car rental, transit) . Lastly, major regional businesses and institutions were surveyed to determine the portion of their activities that required the Capital City Airport to transport staff, clients, or cargo. This last effort defined off-airport non-aviation businesses that relied on the airport, e.g., businesses in manufacturing, professional services, and trade industries

Data related to tax impacts were gathered on the annual revenue generated for various taxes and fees, including airport fees, fuel taxes, state income and sales tax revenues, local property tax revenue generated as a consequence of business growth supported by the airport, its users, and suppliers, and other local or state taxes and fees that increase with airport workforce, income, and business activities.

County data were used to segregate impacts by county since it was a multi-county region (this was before IMPLAN had a multi-county model function). Economic impacts were allocated to each county in the airport region based on county population, employment, residence of airport workers, the presence of hotels and other lodging, and a breakdown of business sales based on visitor spending and airport-reliant businesses and suppliers was generally consistent with employment distribution in each county.

A tri-county economic model based on IMPLAN was used to represent inter-county and intra-county flows of business sales. The total economic impacts of the airport were measured in terms of total jobs, wages, and business sales attributable to the airport, owing to the following economic activities:

- Airport-based economic activity (airport terminal related and tenants)
- Off-airport businesses serving airport travelers
- Off-airport businesses dependent on airport for staff or cargo movement
- Suppliers of goods and services to airport and air dependent businesses
- Re-spending of worker income (supported by airport based activities, visitor spending, air dependent businesses, and suppliers of goods and services)

Mead and Hunt and EDR Group, 2010 South Dakota State Aviation System Plan, Chapter 6, Economic Impact, South Dakota Department of Transportation

Data collected for this study included payroll and employment provided by airport managers, as well as names of airport tenants and other businesses that rely on the airport and have aircraft at the airport (e.g., couriers). Data on headcount of full-time and part-time employees obtained from managers was converted to FTE based on BEA ratios. County-specific and statewide income and employment data by industry was based on the federal sources as aggregated by MIG, Inc. Surveys were also used to collect average visitor spending by in-state, out-of-state visitors and for general aviation and commercial aviation categories.

Additional data collected on one type of off-airport aviation dependent business, agricultural spraying, because agriculture is one of the largest industries in South Dakota. Analysis was based on data collected from 44 in-state agricultural sprayers.

Data on aggregate annual airport-related construction expenditures obtained from the State DOT for new airport development, runway extensions/rehabilitation, taxiway construction, installation of navigational aids and airport lighting. Construction impacts were calculated based on the IMPLAN model and measured in jobs, personal income, and business sales in that sector.

ICF SH&E and EDRG (2011), "Virginia Airport Economic Impact Study, Technical Report," prepared for Virginia Department of Aviation (DOAV).

This study traced impacts of the Commonwealth of Virginia's 64 public use airports[12], including 7 commercial airports (1 medium hub, 2 small hubs and 4 non-hubs), 8 relievers and 49 GA. Each airport was assigned a catchment area of one or more counties. Three types of economic impacts were calculated for airports and for the system as a whole: on-airport generated impacts, visitor spending and air reliant industries in Virginia (other than industries that rely on Regan National or Dulles International airports). Air reliant impacts were estimated on a statewide basis only.

To determine direct impacts of on-airport tenants, surveys were conducted to count employees by airport and business sector (including state/local government and federal agencies). The survey also asked business/government establishments to provide payroll. If payroll was not provided, it was calculated on the basis of county-specific data aggregated from federal agencies using IMPLAN.

Visitor spending surveys were administered at each air-carrier airport and for GA airports (as well as through FBOs of air carrier airports to capture GA visitors arriving through those facilities). The surveys documented spending by air visitors to the Commonwealth (including transient GA operations) on lodging, food, retail (margined to capture local effects only), local transportation, and entertainment, average duration of visits, and trip purpose (business or personal). The surveys were also used to estimate the average number of passengers (including pilots) per GA transient operation by airport classification. FAA and state data were used to estimate total enplanements net of transferring passengers, and total transient GA operations.

Economic impacts of airport reliant businesses were determined by a general statewide business survey (excluding catchment areas for Reagan National and Dulles International), and a survey of business aircraft based aircraft on Virginia's public use airports. These surveys identified a baseline of airport-reliant businesses by industry, including the percent of economic activity at each business that is reliant on airport services. These survey results were not expanded to account for the state economy. Reporting was limited to actual survey results (the baseline) and then expanded to cover all businesses that were surveyed.

The IMPAN modeling system was used to calculate missing direct data based on averages by industry in each airport catchment area. The systems data includes ratios of wages to workers and output to wages and output to worker (used for visitor spending to calculate

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[12] The economic impacts of Washington Dulles International and Regan National Airports were calculated in a separate study (Metropolitan Washington Airports Authority, *Technical Report: Economic Impact Study*, prepared by the Louis Berger Group, 2010) and merged with findings of the economic impacts of the 64 airports to account for all 9 commercial airports in Virginia and all 66 of Commonwealth's public use airports.

employment). The IMPLAN system was then used to calculate indirect impacts (supplier sales) and induced impacts (respending of workers' incomes in local consumer economies) to provide a full accounting of economic impacts by airport in catchment regions and statewide.

The Hartsfield Planning Collaborative with Economic Development Research Group and CH2MHill (2009), "Hartsfield-Jackson Atlanta International Airport 2009 Economic Impact Study"

This study examines the 2009 economic impact of the Hartsfield-Jackson Atlanta International Airport (ATL) on metropolitan Atlanta, as defined by the 28-county Atlanta-Sandy Springs-Marietta, Georgia Metropolitan Statistical Area (MSA), the state of Georgia, and the Piedmont Atlantic Megaregion (PAM).

The analysis framework included a survey of airport administration and both airside and landside tenants to quantify on-airport direct employment. The IMPLAN modeling package was calibrated to the 28-county Atlanta MSA, Georgia and PAM to calculate personal income and business sales (output) based on on-the survey findings.

The study incorporated visitor survey data provided by Airport Interviewing & Research, Inc. (AIR) of New York to establish off-airport visitor spending and cross tabulations of business and personal trip purposes with U.S. and international origin. The AIR survey also established the proportion of visitors to total enplanements and percent of passengers who were connect to other flights and never leave the airport. Lastly, airport cargo data and data from the Foreign Trade Division of the U.S. Census Bureau (packaged by WISERTrade), were used to develop an analysis of the role of air cargo shipments in the economies of the metropolitan region, as well as Georgia and the nation. The IMPLAN modeling package was used to calculate indirect and induced economic impacts based on (1) on-airport employment; (2) visitor spending; and (3) the value of air cargo produced in the analyses regions and enplaned at ATL.

Karlsson, et. al, ACRP Synthesis 7, 2008. Airport Economic Impact Methods and Models. Transportation Research Board of the National Academics.

The literature review in this synthesis of practice includes 26 airport and airport system economic impact studies, which is listed below in Table 4. As can be seen, several of these studies (or updates for the same airports/systems) are presented above. Additionally, several others are summarized following the list that add different perspectives to studies summarized above.

Table 4. Economic Impact Studies Reviewed in ACRP Synthesis 7

Airport Technology and Planning Group, Inc., *The Economic Impact of Aviation in Pennsylvania,* Bureau of Aviation, Pennsylvania Department of Transportation, Harrisburg, n.d.
Analyzing the Economic Impact to the City of Fayetteville from Operations and Capital Improvements at Drake Field, Center for Business and Economic Research, Sam M. Walton College of Business, University of Arkansas, Fayetteville, 2005.
A Study of the Current Economic Impact of the Blue Grass Airport on the Lexington–Central Kentucky Area, Center for Business & Economic Research, Gatton School of Business & Economics, University of Kentucky, 2001.
Beyers, B. and S. J. Hyde, *King County International Airport/ Boeing Field: 2003 Economic Impact Study,* Airport Division, King County Department of Transportation, Seattle, 2003.
Breitenbach Weiss and Martin Associates, *The Local and Regional Economic Impacts of Milwaukee County's General Mitchell International Airport 2005,* Milwaukee County, Wis., 2005.
Bunting, D., et al., *The Economic Impact of Spokane International Airport,* The Board of Spokane International Airport, Washington, 2006.
Center for Economic Development and Business Research, *Economic Impact of Salina Municipal Airport and Salina Airport Industrial Park,* Salina Airport Authority, Salina, Kans., 2007.
Eclat Consulting, *Economic Impact Study,* Newport News/ Williamsburg International Airport, Newport News, Va., 2006
Economic Development Research Group, Inc., *Logan International Airport's Evolving Role in the New England Economy,* The New England Council, Boston, Mass., 2001.
Economic Development Research Group, and Mead and Hunt, *Economic Impact Study: Preliminary Final Report,* Capital Region Airport Authority, Lansing, Mich., 2004.
Economics Research Associates, *Economic Impacts, Costs and Benefits of Contra Costa County Airports,* Contra Costa County, Calif., 2000.
Flint Communications, *Economic Impact of Aviation in North Dakota,* North Dakota Aeronautics Commission, Bismarck, 2004.
Harrah, J., et al., *Wichita Mid-Continent Airport Economic Impact,* Wichita State University, Wichita, KS, 2003.
HNTB and Economic Research Group, Inc., *The Economic Impact of Airports in Colorado,* Division of Aeronautics, Colorado Department of Transportation, Denver, 2003.
HNTB and Economic Research Group, Inc., 2004 *Virginia Airport System Economic Impact Study: Final Technical Report,* Virginia Department of Aviation, Richmond, 2004
Kaskie, S., *Twin County Airport Economic Impact Analysis— Detailed Report,* Marinette County UW–Extension, Menominee, Mich., Mar. 2007.
Martin Associates, *The Local and Regional Economic Impacts of Hartsfield Atlanta International Airport,* Atlanta Department of Aviation, Atlanta, Ga., 1997.
PA Consulting Services, Inc., and Economic Development Research Group, *The Economic Role of Nashville International Airport,* Metropolitan Nashville Airport Authority, Nashville, Tenn., 2001.
SH&E, and Economic Research Group, Inc., *The Economic Impact of Aviation in Arizona,* Aeronautics Division, Arizona Department of Transportation, Phoenix, n.d.
Shoening, N., *Economic Impact Study: Port of Huntsville 2003,* Port of Huntsville, 2003.
Sparks Bureau of Business and Economic Research, *The Economic Impact of Memphis International Airport,* Center for Manpower Studies, University of Memphis, Memphis, Tenn., 2005.
Teterboro Airport Economic Impact Study: Greater than the Sum of its Parts, Port Authority of New York and New Jersey, New York, N.Y., 2005.
Wilbur Smith Associates, Inc., *The Economic Impact of Kansas City International Airport,* Kansas City Aviation Department, Kansas City, Kans., 2001.
Wilbur Smith Associates, Inc., *Alabama Airports: Gateway to Economic Growth,* Alabama Department of Transportation, Aeronautics Bureau, Montgomery, n.d.
Wisconsin, State of, *Economic Impact: Austin Straubel International Airport* (*GRB), Green Bay, Wis.,* Bureau of Aeronautics, Wisconsin Department of Transportation, Madison, n.d.
Wyoming, State of, *2004 Wyoming Economic Impacts of Aviation,* Aeronautics Division, Wyoming Department of Transportation, Cheyenne, 2004.

Airports Economic Impacts Study for Monterey, San Benito, and Santa Cruz Counties—Association of Monterey Bay Area Governments, California, 2003

Analysis Approach. Direct impacts included (1) spending in the local area for goods and services by airport tenants, including airport administration, FBOs, airlines, airport concessions, and a variety of non-aviation-related businesses located on airport property: and (2) spending in the local area by visitors who arrive by air. Indirect impacts were defined as the business community's perception of the airport's impact on local business operations. Only data from businesses that responded they would lose revenue, lay off workers, or relocate out of the area if the airport were closed were included in the calculation of the indirect impact for the airports. The induced impact consists of the multiplier effect that results from the respending of the direct impact.

Breitenbach Weiss and Martin Associates—The Local and Regional Economic Impacts of Milwaukee County's General Mitchell International Airport, Milwaukee County, Wisconsin, 2005

Analysis Approach. Direct impacts were defined as economic activities generated by airport operation that would not exist if vanish if aviation activity at General Mitchell were to discontinue. Indirect impacts included jobs, personal income and output generated as a result of the purchase of goods and services by firms dependent on airport activity. Third induced impacts were described as regional economic activity because individuals directly employed owing to airport activity spend their wages locally on goods and services. This study also identified "related impacts" as jobs with firms in the regional economy. These firms use the airport for air cargo shipments. Related jobs are not as directly dependent upon the airport as the direct and induced jobs, but reflect the importance of the airport as a catalyst for economic development.

5.4 Economic Impact Studies Reviewed by Research Team

In all, the Research Team reviewed 52 studies on the economic impacts of airports and statewide aviation systems, which account for 1,949 NPIAS airports, 58% of the total system-wide, as well as an additional 302 non-NPIAS airports. This is the first step towards developing a bottoms-up approach that will be developed for Task 5 and implanted in Task 7.

Table 5 shows that that the review represents 45% - 60% of each classification of NPIAS airports, and 58% overall. Moreover, this synopsis includes only the most recent available study for each airport or aviation system that was available. For example members of the Research Team worked on the 2004 and 2008 economic impact studies for the State of Colorado, and only the 2008 study was reviewed for methodology and findings.

Table 5. Break down of NPIAS Airports Analyzed

	Studied	Total in NPIAS System	%
Large Hub Airports	16	29	55%
Medium Hub Airports	23	37	62%
Small Hub Airports	42	72	58%
Commercial, Non-Hub Airports	163	365	45%
Reliever Airports	162	269	60%
GA Airports	1543	2560	60%
TOTAL NPIAS Airports	**1949**	**3332**	**58%**

In the process of this literature review, the Research Team found that nearly three-quarters of economic impact studies of airports and state systems were conducted using IMPLAN and about one-quarter of the economic impacts were calculated in RIMS II and REMI, combined, with less than 2% in using other modeling packages. Note the Team tabulated studies, as well as the airports that are part of each study, and these proportions are roughly consistent per study as well as by counts of airports. The major difference among the categories is that REMI is used disproportionately for airport systems (and therefore a larger proportion of airports than airport studies) largely due, it is assumed, to its significantly higher costs than IMPLAN or RIMSII (see Table 6).

Table 6. Economic Model Tool Used

Number and Percent		IMPLAN	RIMS II	REMI	Other	TOTALS
By Study	Number	42	6	1	3	52
	Percent	81%	12%	2%	6%	100%
By Airport	Number	1,417	249	249	34	1,949
	Percent	73%	13%	13%	2%	100%

The analyses of airports in these studies include on-airport impacts of aviation related businesses, and only few did not consider impacts from government agencies and terminal businesses.

In the case of small GA airports, there may not be terminal businesses. However, studies that consider the presence of these businesses will report zero terminal establishments and employment for these small facilities. In this discussion, airports for which terminal businesses were included in the study design, but where the count is zero, are included in Table 7, as opposed to analyses that did not include the presence (or possibility) of terminal business for economic impact analyses.

In addition, two-thirds of airports reported the direct impacts from on-airport construction efforts, and over 20% of airports reported impacts from on-airport private sector non-aviation businesses.

Table 7. Direct On-Airport Impacts Considered

	Aviation	Terminal Businesses	Construction	Government Agencies	Private Sector non-aviation
Number of Airports Studied	1949	1739	1284	1733	416
% of Airports Studied	100%	89%	66%	89%	21%

When reporting direct impacts off-airport, the majority considered Visitor Spending from commercial, reliever and GA airports, impacts from aviation businesses that are off airport and air reliant businesses located off airport. (See Table 8)

Table 8. Direct Off-Airport Impacts Reported by Airport Classification

	Visitor Spending-Commercial	Visitor Spending - GA/Reliever	Aviation Businesses off Airport	Air Reliant businesses off airport
Number of Airports Studied	216	1673	1436	1514
% of Airports Studied	89%	98%	74%	78%

Each study reported indirect and induced multiplier effects, regardless of multiplier package used, although there is different treatment of by study of how these effects were defined and assessed. About half of the studies reported indirect and induced effects separately and half combined the two in a single multiplier impact. (See Table 9) As reported in Section 1, there is considerable confusion over terminology if "indirect" and induced" and one way around that jargon is to report the two together as "spinoffs", "ripple effects", "multiplier impacts" or with other language. In these cases, however, both economic impacts from supplier sales (indirect) and spending of wages by workers who direct or indirect beneficiaries of airports (induced) are calculated before they are combined. Also, FAA guidance is to combine multiplier impacts under the heading "induced" impacts of airports.

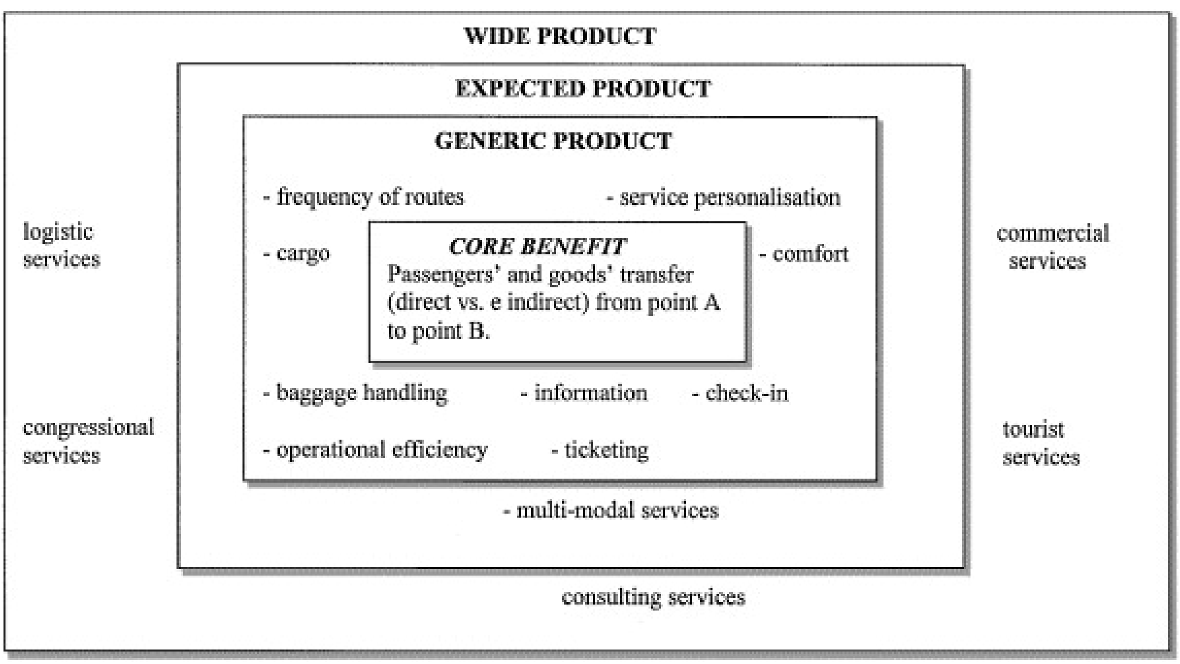
Table 9. Approach to Reporting Economic Multipliers

	Indirect and Induced Economic Impacts Reported Separately	Indirect and Induced Impacts Reported Combined
Number of Airports Studied	992	957
% of Airports Studied	51%	49%

6 OVERVIEW OF AIR CARGO AND THE U.S. ECONOMY

Airport services are organized around the primary output the airport is designed to deliver: facilitation of the transfer of passengers and goods to and from their catchment areas (Jarach, 2001). This operational perspective can be expanded to encapsulate a strategic vision where the airport serves as a catalyst for economic activity (Canaday, 2000, InterVISTAS-ga[2] 2006, ACRP Synthesis 7, 2008) and as impetus of national industries and a gateway to economic globalization (Wang and Hong, 2011). Specifically, airports have gradually transformed themselves into self-supporting economic zones (Lee and Yang, 2003), with some emerging as greater entities referred to as airport cities (Charles et al., 2007). A general scope for an airport city is portrayed in Figure 2, depicting a framework for the commercial multi-service airport. In promoting the view of a more sophisticated and integrated factor, airports can learn a lesson from related experiences (such as the port in Rotterdam and the development of the district parks) and seek to provide enriched cargo services. That is, airports should strive to transition from being an external medium in facilitating interaction between spokes in a supply chain into a more integrated factor in firms' logistic chains (Jarach 2001).

Figure 2: The Service Scope of the Commercial Airport Approach



Source: Jarach (2001)

The economic impact of airports has traditionally been classified into five primary categories: direct effects, indirect effects, induced effects, additional consumer welfare benefits, and environmental effects.

A variety of literature has examined the economic impact of airports.[13] In an early study, Goetz (1992) finds a link between population and employment levels and air passenger traffic; yet, the strength of the relationship has eroded over time. Goetz cautions, however, that adding airport capacity to stimulate growth has to be conditioned on a history of passenger demand from within a given region. By contrast, Irwin and Kasarda (1991) argue that air traffic is "a cause rather than a consequence of this employment growth." This notion is shared by Debbage (1999) and Ivy et al. (1995), who state that positive changes in air service connectivity stimulate increases in administrative and auxiliary employment. Robertson (1995), who focuses his analysis on economic regeneration and the impact of airports on employment, notices that airports create opportunities for less skilled labor. Button et al. (1999) indicate that hub airports increase high-technology employment by 12,000 on average. Airports also have a significant role in promoting national industries (Canaday, 2000).

It is natural to distinguish an airport's economic impact driven by air cargo and logistics from that stimulated by the transfer of passengers.[14] According to the Air Transport Association (IATA), Air Cargo is a US$50 billion business that transports 35 percent of the value of goods traded internationally, is estimated to support 32 million jobs and US$3.5 trillion of economic activity.

Limited studies have been conducted on the gross impact of access to air cargo and the economy. Zhang and Zhang (2002) state that air cargo has grown (1.5-2 times) faster than global GDP, and Kasarda and Green (2004) find that there exists a high correlation between air freight and GDP based on data spanning 1980-2000, finding that air cargo has outpaced growth of trade and GDP, They also find strong positive correlations between aviation liberalization (measured as number of bilateral agreements) and levels of air cargo, trade, GDP, and foreign direct investment. The authors conclude that liberalization stimulates air cargo flows, and hence, trade, GDP, and direct foreign investment. Cech (2004) complements Kasarda and Green's (2004) assessment with his finding that accessibility to air cargo services has a positive catalytic effect on local economies as well. While hard to generalize due to large variations among airports, according to Cech air cargo activity has been shown to increase job creation and regional productivity.

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[13] See previous sections of this Technical Memorandum 1.

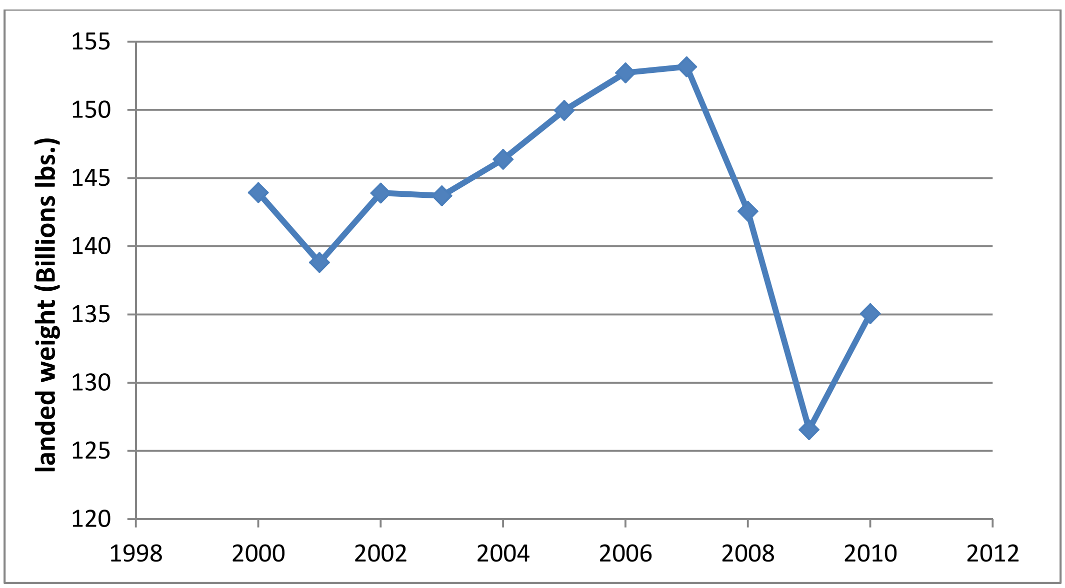
14 Sellner and Nagl (2010), for example, study the impact of air accessibility of economic growth with a focus on air passenger traffic, whereas Button et al. (1999) focus some of their discussion on the benefits hub airports offer to passengers.

6.1 Importance of Air Cargo

The importance of air cargo has already been recognized by the DOT and the Department of State, who stated in a 1987 presentation to Congress that although it represents only a small portion of trade in terms of weight, it makes a vital and growing contribution to the national economy (House Committee on Public Works and Transportation, U.S. International Aviation Policy – cited from O'Connor 2001).

Between 1992 and 2002 air freight value increased by 83 percent (Kasarda and Green 2004), and even after the slowdown in the early 2000s it kept increasing steadily through 2007 (see Figure 2). Data reported in Wang and Hong (2011) reveal more pronounced growth patterns between 2001 and 2008 in Far East Asia. The downturn in 2008 has significantly affected the industry, which has not yet fully recovered according to recent IATA data. Yet, future growth projections are rather optimistic: Boeing expects the amount of air cargo to triple between by 2027, while Airbus forecasts 5.8 percent average annual growth through 2026 and OAG forecasts 8.5-10.1 percent annual growth between China and North America for 2008-2017.

Figure 3. Air Cargo in the U.S



Source: faa.gov

Air cargo plays a major role for airlines as it represents a large portion of the world's scheduled airline output (over a quarter in 1989) according to Doganis (1991), and it could yield greater benefits with improved revenue management practices (Talluri and van Ryzin 2004). Considering the variation among airlines, a dispersed picture is revealed (Doganis, 1991): for some cargo accounts for as little as 5-10 percent of their total production in terms of ton-kilometers (Eastern and LOT), while for others it is about 50-55 percent

(Korean, Air France, Lufthansa and El Al). Some, such as Flying Tigers and Cargolux, are simply freight dedicated carriers.

Traditionally the airline cargo supply chain has organized itself around the freight service provided by the airline with shippers and freight forwarders—who act as the interface between shippers and airlines—acting as the complementary players in this chain. An illustrative supply chain is featured in Figure 4 shows the different players add value along the supply chain, and it is argued that when a player is located closer to the consumer (further down the stream), more value is added (Grin 1998 as cited by Zondag 2006). The air freight industry has transformed itself over the past 30 years with the emergence of the express parcels sector (led by Federal Express) and other integrated carriers (such as Emery Worldwide, Airborne Express, UPS, DHL Airlines and TNT)—the latter group has also accepted larger consignments (Doganis 1991). These integrated providers offer a complete handling of the cargo from origin to destination. Additional ad-hoc services are provided by charter airlines (such as Cargolux), who complement the offerings by the two structural types of services mentioned above (Doganis 1991).

Demand for cargo is heterogeneous and can be categorized by the motivation of the shipper[15] (Doganis 1991). This includes emergency freight (such as medicine and spare parts when surface routes are disrupted[16]), goods with ultra-high value with respect to weight (such as jewelry and rare metals)[17], and routine freight. In the latter case, the shipper decides whether to ship the good by air or other modes (if at all) based on the assessment of the transportation option. This category is further split into perishable and non-perishable goods. For such non-perishable goods the higher air freight cost could be offset by the savings from the alternative distribution/logistics channels.[18] Naturally, air freight competes with alternative modes of transportation (truck, ship, less so from rail) and offers a faster and safer mode of transportation with advantages primarily over long distances (O'Connor 2001).

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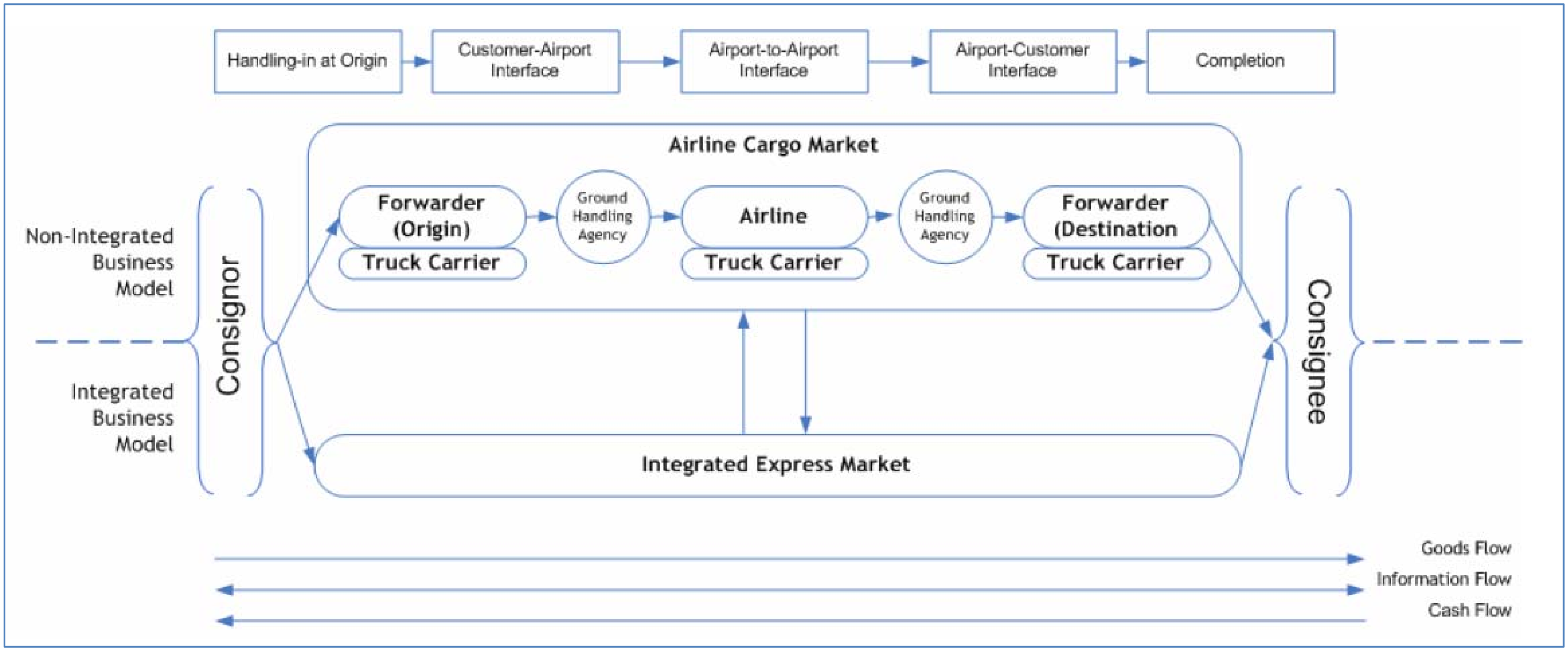
[15] Schneider (1973) classifies air cargo into emergency, routine perishable, and routine surface-divertible, whereas O'Connor (2001) lumps these three into airfreight and considers two additional categories: mail and small packages (expedited services as offered by air express providers). The Air Transport Association (1972) considers some 20 categories in its list of "Major Commodities Moving in Air Freight".

[16] For example, access to airports has offered some relief in Japan after the earthquake.

[17] While air cargo accounts for 40% of the world trade, it represents less than 2% by weight (Kasarda and Green 2004). Additionally, earlier figures indicate a reduction trend in the weight of air freight shipments (Taneja 1987 cited from O'Connor 2001).

[18] Carefully selected, air freight can assist firms in crippling their competitors. For instance, back in 1997, when most computer manufacturers were shipping their goods by sea, Apple has decided to buy up the entire airfreight space available for the holiday season to ensure the competitive advantage of its new iMacs. This handicapped competition stemming from players such as Compaq. Similarly, Apple designed packaging of iPods to make it economically deliverable by air (BW 2011).

Figure 4. Air Cargo Supply Chain



Source: Zondag, 2006

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7 AVIATION AND PRODUCTIVITY

In this section, the Research Team explores how aviation contributes to national productivity by linking with other modes as a vital link in national supply chains. All passenger and cargo trips to and from airports are by definition multi-modal. People and products arrive and depart from the airport system by ground transport, primarily car and truck, but also by transit and rail.

Air transport enables industries to expand markets by sales of products and services, import intermediate products "just in time," and use the world as a market place that enables production of lower cost products that in turn are sold domestically and internationally. This form of transport also expands markets for industries that can take advantage of airports for business travel and cargo, and to generate income that in turn is reinvested in industries that benefit from aviation connections, support spending to suppliers of goods and services to those industries, and pay wages that are spent on consumer expenditures, ultimately expanding demand for those goods and service.

7.1 Linkages between Intermodal Connectivity and Productivity

To better understand what has been done to date in investigating the linkages between intermodal connectivity and productivity, this literature review consists of the following three sections, addressing the following topics:

- The first section reviews the definition of the term, "productivity."
- The second section reviews the definition of the term "intermodal connectivity," and briefly explores the research conducted on the economic benefits of intermodal connectivity. This includes looking at the association between trade, business activities, and intermodal connectivity (multimodal transport) .[19] This is important, especially when only a limited number of studies have explored the link between productivity and intermodal connectivity.
- The third section looks specifically at the macroeconomic models used in research concerning the association between public infrastructure, transportation, and productivity, and explains the results derived from these models. Although the results taken from some of the past papers may not fully explain the question of interest, understanding the macroeconomic models used in past research can help

[19] Technically, multimodal transport is not exactly equivalent to intermodal connectivity. For simplicity, we use the two terms interchangeably in this note.

researchers determine the most appropriate model (methodology) to use for future studies in finding the association between intermodal connectivity and productivity.

What is Productivity?

Before undertaking any in-depth analysis, it is important to answer the following questions – "*What is productivity?"* Productivity measures come in numerous forms. Researchers tend to define the term "productivity" differently, and different information may be used to capture this concept. Variability in this term could lead to inconsistent findings in this area of research.

According to Weisbrod and Treyz (1998), productivity can be affected by transportation investment, by the level of technology, and by the quality and capacity of the supporting infrastructure. Supporting infrastructure includes education, financial networks, and transportation networks (Weisbrod and Treyz 1998).

Currently, researchers do not have a standardized definition for the term, "productivity," which is one of the factors contributing to contradictory or inconclusive results in this area of research. Allroggen and Malina (2010) use output growth as a proxy for productivity. Weisbrod and Treyz (1998) define productivity as the ratio of output per unit of total factor inputs. Inputs can be in the form of labor, capital, or fuel. For example, Antunes et al. (2010), Romer (2006), and Wylie (1995) express productivity as output per labor units. Specifically, Antunes et al. (2010, ii) define labor productivity as the "amount of output produced for each hour of work, and is therefore a measure of how efficiently goods and services are produced." On the other hand, Aschauer (1989) uses the percentage change in output per unit of capital as a measure of productivity.

The definition of productivity also depends on the level of aggregation and the type of data used in the analysis. At the regional level, Chandra and Thompson (2000) use earnings instead of output data as a substitute measure for productivity, since output data is not available at the county level and earnings data is reflective of value-added output.

Transportation research such as Alstadt et al. (2012) defines productivity as the ratio of business output over production cost. Production cost includes costs arising from labor, materials, utilities, transportation, and other related services. The motivation for using this measure is to capture two effects if improvements to transportation infrastructure were made. The first effect is captured by reduction in time, in travel costs, and in inventory costs, which is reflected by a reduction in the denominator (Alstadt et al. 2012; Weisbrod and Treyz 1998). The second effect happens when there are expansions in market access, operating scale, and connectivity, and this effect is reflected by an increase in the numerator (Alstadt et al. 2012). Economies of scale are realized via expansion in market opportunities, which allow broader markets to be served economically and improve access to specialized labor skills and input products (Weisbrod and Treyz 1998).

Intermodal Connectivity

Intermodal connectivity is another complex dimension to this area of research. Effects of intermodalism tend to vary depending on the model selection and data disaggregation. Authors such as Jennings and Holcomb (1996) and Debrie and Gouvernal (2006) suggest that the term, "intermodal," is not standardized across studies. Berrittella (2010) defines intermodal transport as the door-to-door movement of goods that involves two or more modes of transportation. Alstadt et al. (2012, 3) defines connectivity as "the ease, time or cost of traveling between different transportation route systems or modal systems." Alstadt et al. (2012) also refer to "connectivity" as the link to terminals or interchanges. For example, connection between road transport and another mode of transport is one common use of such a term (Alstadt et al. 2012). Shepherd et al. (2011) suggests that intermodalism involves multiple dimensions:

- the quality and quantity of the infrastructure;
- private sectors' ability to coordinate intermodal linkages; and
- the network of links (i.e., roadways, railways, and transport routes) and nodes (i.e., port terminals and airports).

A favorable intermodal connectivity is associated with reductions in business operating costs (transport and logistics expenses), improvements in supply chain management, and expansion of trade and foreign direct investment opportunities (Shepherd et al. 2011). Any one of these factors contributes positively to output, thereby to productivity (holding all else constant).

To evaluate the relationship between exports and transport infrastructure, Shepherd et al. (2011) use the gravity model, as well as data on total exports from Asia-Pacific Economic Cooperation (APEC) members to up to 229 overseas markets. The authors calculate the multimodal transport variable using the principal components analysis, where this variable incorporates air, maritime, land transport, and logistics competence indicators.[20] Elasticity measures for the multimodal transport indicator are greater than the elasticity measures for any single transport mode.[21] They also find that the gains from reforming multimodal

[20] The air indicator is a weighted average of the number of primary airports and the number of secondary airports in each member economy; the maritime indicator is a weighted average of the number of ships, container-carrying capacity, vessel size number of services, and the number of companies deploying containerships to and from an economy's ports; the land indicator is a weighted average of the road infrastructure density and rail infrastructure density; and the logistics environment indicator is based on survey responses given by logistics professionals around the world relating to competence and quality of logistics services. All of these indicators are calculated based on the principal components analysis (Shepherd et al. 2011).

[21] According to Shepherd et al. (2011), the elasticity of exports with respect to multimodal transport is 3.2%; with respect to maritime transport is 1.2%; with respect to air transport is 0.9%; and with respect to land transport is 0.5%.

transport translate to an average of $500 billion in increased exports per APEC member region (or 4 percent export growth), and "economies that are open, highly integrated into world markets, and with strong multimodal connectivity gain even more" (page 646).

In other words, intermodalism contributes more to exports than what any single mode of transport can do. Shepherd et al. (2011) suggest that the multimodal transport variable has a higher variable than the variables capturing single transport mode because the overall performance is strongly influenced by how the transport modes work together efficiently and effectively. This explanation implies complementarity between the transport modes. Shepherd et al. (2011) also argue that trade performance depends to a large degree on the quality and competence of private logistics services than on the other aspects of multimodal transport, which suggests that the multimodal result is more demand driven than supply side driven.

After correcting for reverse causality via the use of an instrumental variable, the same paper finds the elasticity of exports with respect to multimodal transport index to be at 1 percent. With favorable intermodal connectivity, output is anticipated to go up due to larger export numbers, holding all else constant.

Limao and Venable (2001) and Micco and Serebrisky (2006) also use the gravity model to show that trade and transportation infrastructure are strongly linked. Micco and Serebrisky (2006) find that greater investment in airport infrastructure helps lower overall transport costs, and Limao and Venable (2001) find that poor infrastructure accounts for 40 percent of transport costs for coastal countries and up to 60 percent for landlocked countries. It is important to note that transport costs negatively influences trade volumes. Furthermore, landlocked countries are disadvantaged in terms of trade due to accessibility issues, but they could overcome some of this by improving their own infrastructure (Limao and Venable 2001).

Targa et al. (2005) use an econometric model to show that a statistically significant association exists between business activity and various transport access measures. The authors find that the magnitude of the coefficient capturing primary highway facilities is substantial relative to other transport access variables. The positive coefficient suggests that more roadway access translates to a higher number of business establishments per square kilometer, holding all else constant. The authors find primary highways to play a more important role than secondary highways, which implies that primary highways are more spatially associated with economic activity. The authors obtain mixed results for airport access – the variable capturing access time to Dulles airport has a negative coefficient, while access time to DCA and to BWI have positive coefficients. The authors suggest that the proximity to local economic centers may influence the sign of the airport access time coefficients. Targa et al. (2005) also find a positive and statistically significant coefficient for the rail transit access variable. These findings seem consistent with Notteboom (2008) and Rodrigue (2012) that road and rail transport are complementary and are critical components to favorable intermodal connectivity.

Berrittella (2010) uses a multi-country computable general equilibrium (CGE) model[22] to analyze the macroeconomic impacts that investments in intermodal connectivity in Europe have on the European Union and on the other economies. The paper looks specifically at the construction of the four major corridor rail lines in Europe: the North-South; the Betuwe; the France-Italy; and the East European. Her simulation results show that increased investments in combined transport (intermodalism) contribute to negative trade balances (higher imports), positive economic growth (higher GDP), and larger welfare for the European nations. However, in terms of overall welfare, the other economies are losers from this intermodal investment, in particular for regions such as the U.S., Japan, and South America. Intermodal connectivity appears to benefit the home country, but not the foreign regions. Berrittella's (2010) findings seem to be consistent with Chandra and Thompson's (2000) results, which show that economic activity tends to increase for counties which highways directly pass through and decrease for adjacent counties.

Some studies find mixed results regarding intermodalism. Black (1974) uses a multivariate time series methodology and finds a negative relationship between Interstate highway construction and passenger enplanement (which is a proxy for air transport services) for non-hub airports in Indiana. The construction of the Interstate highway is intended for increases in accessibility, and the author suggests that benefits would be derived only for large airports. Small airports would lose passengers, as the passengers are willing to substitute highway travel for a portion of the trip. Black (1974) also suggests that the measures of connectivity used in his model, such as the number of routes connected to and airport, number of routes passing through the terminal, or number of trunk lines using the terminal, are more influential than expected. Buckley and Westbrook (1991) use the cost function approach to explore the relationship between truck and rail and obtain a high measure of substitutability between the two modes of transport. The elasticity measures imply vigorous competition between the two modes of transport, which seems to be contrary to the objective of intermodal connectivity. Lim and Thill (2008) conclude that intermodalism enhances average accessibility and their model shows that all other things held constant, accessibility gains[23] are on average higher for regions with poor highway accessibility.

In summary, it remains ambiguous whether intermodal connectivity is associated with economic growth, and whether economic growth necessarily *implies* productivity growth. Using the definition of productivity specified as the total or aggregate output per unit of factor inputs, the answer also depends on factor inputs such as labor and private capital. Furthermore, economic growth generally refers to the national gross domestic product

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[22] CGE models are based on the general equilibrium framework and comparative methodology. The behavioral assumptions of the rational economic agent are taken into consideration, and policy changes are simulated by altering the policy parameters in order to calculate the new equilibrium (Berrittella 2010).

[23] Accessibility is defined in a geographical manner in Lim and Thill (2008). See Lim and Thill (2008) for how they define "accessibility gains".

(GDP). However, GDP includes government expenditures, which would also include public infrastructure spending into the dependent variable. Models that have public infrastructure investment in both sides of the model equation are inappropriate. Gillen (2000) suggests that the more suitable treatment is to use private sector output instead as the dependent variable. The subsequent sections explore more formal econometric models to help better understand the causal link between intermodal connectivity and productivity growth.

Models for Linking Productivity and Infrastructure Investment

Studies analyzing the relationship between intermodal connectivity and productivity are in preliminary stages. This area of research is incomplete and relatively few researchers look specifically at this topic. Instead, more studies investigate the relationship between public infrastructure and productivity and the results are somewhat variable. Allroggen and Malina (2010) and Baird (2005) suggest that some of the problems with this estimation include the lack of consistent measurement of public capital, as well as differences in data classification and model specification. Moreover, rresults from public infrastructure studies may not answer our question of interest, since public infrastructure also includes other categories of public investment such as water and sewage systems and recreation facilities. The movements in the public infrastructure aggregate may mask the activities at the transport level. However, it would also be flawed to not look at literature that explore the relationship between public infrastructure and productivity growth, as benefits derived from intermodal connectivity more or less depend on public infrastructure development (see for example, Limao and Venables 2001; Micco and Serebrisky 2006). In Canada, transportation and transit infrastructure comprise more than half of the total municipal infrastructure[24] (Mirza 2007).

Some research looks specifically at how one mode of transportation influences productivity growth. However, as noted above, studies such as Shepherd et al. (2011) show that the overall performance from multimodal transport is greater than the performance from any of the individual transport mode[25]. As such, results derived from models looking specifically at how one transport mode influences productivity growth would be underestimated. Research from Black (1974), for example, shows how Interstate Highway construction in the U.S. influences air passenger enplanement, which is a proxy for air transport demand. This implies that highway development has implications on intermodal connectivity. Vespermann and Wald (2011) also show that road transport composes the biggest share of access and egress trips to an airport. Lim and Thill (2008) suggest that minimal information would be lost if their model only consisted of shipping by rail and truck combinations, and neglect shipping by the waterways. These findings further imply that papers exploring the

[24] This estimate is as of year 2000.

[25] See footnote 3.

relationship between highway development and productivity can provide additional insights into the link between intermodal connectivity and productivity.

Nonetheless, understanding the models used in past papers that evaluate the relationship between public infrastructure and productivity growth is important. These form the foundation for future work in evaluating the link between intermodal connectivity and productivity growth. As such, the following sections review the literature conducted to explore the relationship between public infrastructure (expenditure) and productivity growth, in addition to papers that have evaluated the association between transportation and productivity growth.

The Production Function

According to Antunes et al. (2010), the production function model is one of the earliest methodologies to evaluate the association between public infrastructure and productivity. Literatures have generally found the elasticity of output with respect to public capital ($\frac{\%\ \Delta output}{\%\ \Delta public\ capital}$) to be between 0.2 and 0.4 using national data; around 0.15 using state or regional data; and approximately 0.04 using city-level data (Weisbrod and Treyz 1998). In other words, for every additional percentage increase in public capital investment, output would increase by 0.2-0.4 percent at the national level; around 0.15 percent at the state level; and approximately 0.04 percent at the city-level. The economic effect arising from public capital spending is the lowest at the city-level because "many of the broad network interconnection benefits to businesses are outside of the [city regions and] the net sum of these effects is reflected in the national measures of productivity" (Weisbrod and Treyz 1998; page 75).

The conventional production function sets output (Y) as a function of three main components: 1. Labor (L); 2. Capital (K); and 3. Total Factor Productivity (A), where it is a proxy for "knowledge" or "effectiveness of labor" (Romer 2006). Graduate level macroeconomics textbook, such as Romer (2006) suggest the following production function form, where total factor productivity (TFP)[26] is multiplied by labor stock to reflect "effective labor":

Equation 1

$$Y_t = F(K_t,\ A_t L_t)$$

Major assumptions applied to the baseline production function are constant returns to scale, homogenous of degree one, and competitive factor markets (Aschauer, 1989; Antunes et al, 2010; Romer, 2006). Other inputs excluded from the baseline model, such as

[26] For the rest of this note, the terms "total factor productivity" and "TFP" are used interchangeably.

environmental considerations, pollution, and natural resources (to name a few), are unimportant (Romer, 2006).

Early work that uses the production function generally finds a strong association between public infrastructure and productivity growth. One of the pioneers of this area of research is Aschauer (1989), which uses the following baseline Cobb Douglas production function to estimate how public expenditure relates to output per unit of capital (productivity capital):

Equation 2

$$Y_t = A_t * f(N_t, K_t, G_t)$$

Where,

$Y_t = real\ aggregate\ output\ of\ goods\ and\ services\ of\ the\ private\ sector$
$A_t = total\ factor\ productivity$
$N_t = aggregate\ labour\ employment$
$K_t = aggregate\ nonresidential\ capital\ (private\ capital)$
$G_t = flow\ of\ services\ from\ the\ government\ sector\ (public\ stock\ capital)$

Aschauer uses two equations for his analysis: 1. modeling output per unit of capital input with respect to private labor-capital ratio, ratio of public capital stock to the private capital input, and capacity utilization; 2. modeling total factor productivity with respect to the ratio of public capital to a combination of labor and private capital inputs and capacity utilization. Econometric models such as the ordinary least squares (OLS), two-stage least squares (2SLS), and first order autocorrelation (FOAC) are used in his analysis to determine whether public expenditure is productive. Lagged values of the government variable are used as instruments for the 2SLS estimation. Capacity utilization is used to control for the influence of business cycle and to account for the declining capacity use due to productivity slowdown in the 1970s and 1980s.

Using annual U.S. data between 1949 and 1985, Aschauer finds positive and significant relationship between output per unit of capital, private labor-capital ratio, and the ratio of the public capital stock to the private capital input. The government variable used in his model is the net stock of non-military public structures and equipment. The elasticity of output per capital unit (productivity capital) with respect to labor-capital is 0.35; and the elasticity of total factor productivity with respect to public to private capital ratio is 0.39. Using output per capital unit for the private business economy as the dependent variable, the author finds the elasticity of productivity capital with respect to labor-capital ratio continues to be near 0.40. In particular, the core infrastructure component, which consists of streets and highways, airports, electrical and gas facilities, mass transit, water systems, and sewers, contributes most to productivity capital (an elasticity of 0.24).

Similarly, Canadian data yields strong positive association between productivity capital and public expenditure. Based on Aschauer's (1989) model, Wylie (1995) uses the following model to estimate Canadian data for the 1946-1991 period[27]:

Equation 3

$$Y_t - N_t = \alpha_0 + \alpha_k(K_t - N_t) + \alpha_i(G_t - N_t) + \beta_T T + \beta_U UN_t + \epsilon_t$$

One subtle difference exists between the models used in Wylie (1995) and Aschauer (1989). Aschauer uses productivity capital in his estimation. On the other hand, Wylie (1995) expresses productivity in terms of labor units. As such, Wylie includes the unemployment variable to proxy business cycle effects instead of using the capacity utilization rate variable. Despite this subtle difference, Canadian data exhibits stronger elasticity values than those using U.S. data. The elasticity of labor productivity with respect to *aggregate* infrastructure variable is 0.52. Consistent with Aschauer (1989), public infrastructure also shows up as a strong and significant variable with elasticity in the range of 0.40 – 0.44 (depending on what infrastructure variables were inserted into the regression model). In any case, both authors find a strong link between public infrastructure and productivity growth. Wylie (1995) suggests "network externality" to be one of the contributing factors to the high elasticity results.

However, many researchers have disagreed with these findings. They argue that the elasticity measures are too high (Antunes et al. 2010; Gillen 2000; Helling 1997). Firstly, studies such as Tatom (1991) suggest that the productivity slowdown could be attributed to rising energy prices, and should have been entered into the production function model. Tatom (1991) finds that the public infrastructure coefficient is insignificant at the 95 percent significance level if energy prices were included into the model. If first differenced data were used instead to account for unit root issues, the same paper also obtains insignificant result for the public infrastructure variable even if energy prices were *excluded* from the model.

The high elasticity estimates are subject to numerous estimation errors. Tatom (1991) mentions that the variable term capturing time trend appears to be missing from Aschauer's (1989) model. Allroggen and Malina (2010) and Tatom (1991) suggest that Aschauer's methodology fails to account for parameter endogeneity, non-stationary, potentially co-integrated series, and measurement errors relating to public capital stock. Allroggen and Malina (2010) and Lau and Sin (1997) also mention that reverse causality is a source of estimation bias in this area of research, which is not correctly accounted for in Aschauer's (1989) methodology. Allroggen and Malina (2010) propose using models such as

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[27] Note that all variables in Wylie's (1995) model are expressed in logarithms. Note that Wylie (1995) uses the variable I_t to express infrastructure fixed capital stock instead of the variable G_t, as noted in equation 2. G_t is used in equation 3 to be consistent with the notations used in Aschauer (1989).

simultaneous equations, generalized methods of moments (instrumental variable estimation), vector autoregressive (VAR), and vector error correction model (VECM) to address reverse causality problems. Lau and Sin (1997) uses the VAR (multivariate stochastic cointegration) model with linear trend as proposed by Johansen (1994) to model the association between per capita output, private capital, and public infrastructure, using US data from 1925 to 1989. Their estimate of the elasticity of per capita output with respect to public capital is 0.11, which is much smaller than the estimate that Aschauer (1989) obtains when using productivity capital as the dependent variable.

Helling (1997) summarizes the following criticisms about Aschauer's (1989) model, which are contained in the academic literature:

- Public expenditure values used in Aschauer (1989) do not systematically reflect market-determined values. Utilization (depreciation) of public infrastructure is also not properly accounted for.
- Value of adding transportation improvements exhibits diminishing marginal returns. Since the effect of productivity in early years is high, the mean effect estimated by regression models would be over-estimated.
- Public infrastructure investments are long-term and effects are not expected to happen instantly. Thus lags should have been included into Aschauer's model to account for effects that flow through over time. However, some of the productivity improvements may result from increase in aggregate demand, rather than from infrastructure improvements.

At the regional level, Baltagi and Pinnoi (1995) also show that the conventional model suffers from both endogeneity and state-specific effects. Conventional Ordinary Least Squares (OLS) models that do not take these two effects into account create upward biased results. Prior to correcting for these errors, Baltagi and Pinnoi find the highway and streets capital variable to be significant and ranges from 0.06 to 0.16 (depending on the type of panel regression used for estimation). However, after accounting for state-specific effects and measurement errors (endogeneity issues) via instrumental variable estimation, the authors find both the aggregate infrastructure variable and the highway and streets capital variable to be insignificant. If the infrastructure variable were to be disaggregated, they find only the variable capturing water and sewage capital to be positive and significant (elasticity of 0.22); and the variable capturing public buildings and structures to be negative of roughly equal magnitude (elasticity of -0.20). So, the overall effect from infrastructure development nets out. Vespermann and Wald (2011) find that the most common airport access modes are road transportation. This implies that one form of intermodal connectivity depends on highways, streets, as well as other publicly-developed infrastructure. As such, following Baltagi and Pinnoi's (1995) results, the negligible effect from the infrastructure variable implies that intermodal connectivity has minimal impact on productivity growth.

In fact, the production function approach has several limitations. Critics have argued that the assumptions applied for the production function are not realistic. Assumption about competitive market factors is problematic since public capital is provided by the state and does not have market prices (Allroggen and Malina 2010). The Cobb-Douglas production function also does not account for inefficiencies in the public sector. Consistent with the criticisms for Aschauer's (1989) model, Baird (2005) suggests that econometric issues such as non-stationary time series, failure to account for state-specific effects, and reverse causality are the primary problems with using the production function approach. If the models were to account for these problems, Baird (2005) suggests that the relationship between public spending and productivity would be zero.

In another literature review concerning productivity and accessibility, Weisbrod and Treyz (1998) summarize the following limitations with using the production function approach:

- Limited amount of information on "how productivity effects of transportation investment can differ by specific combinations of mode, industry and region" (page 76).
- Few papers have looked at *future* highway spending. Most studies are retrospective. However, future effects are more important, as location and technology changes over time and congestions grow significantly (in particular for urban areas).
- Estimates of aggregate productivity do not take household activities into account.

Alternative Approaches

Other researchers have used alternative approaches to model the relationship between public infrastructure and productivity. One of the alternative approaches is "Growth Accounting", which is a variation of the production function form. Instead of analyzing levels, growth accounting looks at the change of the variables defined in logarithmic terms (which approximately equals percentage change). Romer (2006) argues, "growth accounting examines the immediate determinants of growth: it asks how much factor accumulation, improvements in the quality of inputs, and so on contribute to growth while ignoring the deeper issue of what causes the changes in those determinants" (page 30). A good deal of the literature has used growth accounting to analyze the productivity slowdown that happened in the 1970s for the western economies (Romer 2006).

Gu and MacDonald (2009) and Antunes et al. (2010) calculate total factor productivity[28] as the difference between the rate of growth of business sector output and the rate of growth of labor and capital inputs used by the business production process. Gu and MacDonald look at national data, whereas Antunes et al. (2010) focus on Ontario data. Both studies use the following functional form to determine how much of the labor productivity and total factor productivity can be attributed to investments in public infrastructure:

[28] Note that Gu and MacDonald (2009) refers "total factor productivity" as "multi-factor productivity".

Equation 4

$$\Delta \ln\left(\frac{GDP_t}{Hrs_{\ t}}\right) = \Delta \ln(TFP_t) + \ \beta_l \Delta \ln\left(\frac{L_t}{Hrs_t}\right) + \beta_k \Delta \ln(\frac{K_t}{Hrs_t})$$

$$\Delta \ln(TFP_t) = \Delta \ln(TFP_t^*) + \ \beta_g \Delta \ln(G_t),$$

Where,

$G_t is\ the\ public\ capital\ stock\ and\ B_g\ is\ the\ elasticity\ of\ public\ capital$

$TFP^*\ excludes\ public\ capital\ stock$

However, growth accounting methodology also faces limitations. Firstly, public capital has no explicit markets, so it is not possible to accurately calculate public sector GDP. Gu and MacDonald (2009) suggests that user cost of capital should include rate of return (r) and depreciation rate (δ); however, since it is unclear what value to use for "r", the author has decided to exclude "r" from the point estimate calculations. As such, it becomes a challenge to find a reliable elasticity measure for public capital. For point estimate calculations, both studies use 0.1 as the elasticity for public capital. Another problem in this research is about the appropriateness to use constant returns to scale as one of the assumptions of this model (Gu and MacDonald 2009).

Using national data, Gu and MacDonald (2009) find public infrastructure to have the most impact for data prior to 1980s. The TFP estimates with and without public infrastructure components widen for data prior to 1980s, which was when the inter-provincial highway system was built; estimates converge for periods post 1980s. The TFP result holds under various sensitivity analyses such as analysis using variety of elasticity values or another analysis using either fixed versus variable interest rates (Gu and MacDonald 2009). If the TFP calculation excludes the effect from public capital, the estimated contribution that TFP brings to labor productivity would be doubled. The authors find the contribution that public capital brings to labor productivity is roughly 0.2% per year and contributes to about 9% of Canadian labor productivity for periods between 1962 and 2006.

Using 0.1 as the elasticity of public capital, results from Antunes et al. (2010) appear to be consistent with those found from Gu and MacDonald (2009). Due to data limitations, Antunes et al. look at data between 1980 and 2008. Their analysis thus misses the periods that include the most growth in infrastructure development. Antunes et al. (2010) find that public capital contributes up to 12 percent of the labor productivity growth in Ontario, and public capital's contribution to labor productivity is on average 0.2% per year.

Another variation of the production function involves the use of interaction terms and quadratic terms. Allroggen and Malina (2010) suggest that the following production function can help measure the association between productivity and German airport performance:

Equation 5

$$Y = A(airport\ capital, movements, infrastructure) * L^{\alpha} * K^{\beta}$$

where “airport capital” captures the capital stock of the airport; “movements” captures the number of commercial aircraft movements; and “infrastructure” captures the performance of other surface transportation infrastructure to avoid omitted variable bias. According to the authors, the infrastructure variable captures the access times in an airport catchment area. A high value for the infrastructure variable implies a less competitive surface infrastructure. Model results show that the variable relating to surface infrastructure is -0.411, which suggests that output grows if the access time falls. This indirectly implies the importance of intermodal connectivity.

Connectivity is critical for economic development. Model results from Allrogen and Malina (2010) suggest that the elasticity of output with respect to airport capital is positive only for third tier airports. Third tier airports generate a positive effect by their existence (even without using it to full capacity) “due to signalling of site-specific quality and the provision of basic air services” because they provide connections to hub airports and to other economic centers (Allrogen and Malina 2010, page 16). On the other hand, first and second tier airports generate positive effects from air traffic, which facilitates potential for cost reductions and productivity gains. In any case, their model results suggest that economic benefits depend on connectivity. Although the study does not specifically address intermodalism, airport choice depends on accessibility. As such, intermodal connectivity should also play a role in this (and other) model, of which Allroggen and Malina’s (2010) model does not fully account for.

Researchers have also searched for alternative methods to model the relationship between productivity and public infrastructure. Utilizing a cost function is one of the alternative approaches to tackle the problems faced by the production function methodology. A cost function includes input prices for labor, materials, and capital, allows the incorporation of firm behavior or decisions over acquisition of factor inputs, and captures the cost savings from an additional unit of public infrastructure investment and the complementarity between private and public capital (Antunes et al. 2010; Baird 2005; Gillen 2000). However, cost-based valuations cannot address inefficiency issues, as public expenditures do not usually account for measures such as sunk costs (Allroggen and Malina 2010).

According to Antunes et al. (2010, page 9), an example of the cost function approach is based on the following form:

Equation 6

$$\begin{aligned} &Private\ Production\ Cost \\ &= f(Output, Flow\ of\ services\ from\ public\ capital\ stock, Vector\ of\ factor\ input\ prices, \\ &\quad Technical\ change) \end{aligned}$$

Using disaggregated data of 37 Canadian industry sectors for the period 1961-2000, Harchaoui and Tarkhani (2003) use both the cost function and demand function approaches to assess the productivity benefits derived from public capital. In general, cost savings for every additional public capital investment, which is represented by the elasticity of output with respect to public capital, varies across the industry sectors. In absolute value terms, the transportation industry has the largest cost elasticity measure, implying that firms in this industry can sell their products at lower prices, which translates to higher output growth. The authors suggest that industries with high cost elasticity values are intensive users of public capital. Transportation and other vehicle-intensive sectors experience the largest marginal benefit of public capital, which also measures the public capital's externality benefits to industries. In other words, transportation and other vehicle-intensive sectors exploit the most productivity growth from public expenditures. These results are consistent with Fernald's (1999) result that vehicle-intensive sectors experienced more productivity growth than those that are less vehicle-intensive.

Upon examination, these results indirectly link intermodal connectivity with productivity and public infrastructure. Transportation industries benefit from public capital, which translates to more efficient flow of goods and services. Weisbrod et al. (2003) suggest that congestion reduces agglomeration benefits by reducing access to specialized labor and delivery markets, and hurts more those firms requiring highly-skilled labor. Congestion and productivity benefits thus are negatively related. As such, the large magnitude for cost savings and marginal benefits for the transportation sector implies that public investment directed primarily to transportation system facilitates intermodal connectivity, which fosters efficient movement of goods and services, thereby enhancing productivity. These all work out in a virtuous cycle.

Alstadt et al. (2012) also look at how market access and business productivity are related via three different econometric equations: 1. employment per population as a function of worker skill and access measures; 2. output per employment as a function of worker skill and access measures; and 3. exports per output as a function of access measures. They use OLS to estimate the first equation and 2SLS to estimate the other equations. The econometric models are based on the following access measures:

- Access to employment within 3 hour driving distance. The authors suggest the "3 hour market size" variable to be a proxy for same day delivery.
- Access to population within 40 minute driving distance. The authors suggest the "local 40 minute market size" variable to be a proxy for effective labor market or "shopping market".
- Access to major marine port, to major commercial airport, to major international freight airport, and to intermodal rail terminal.
- Access to closest border to Canada and to Mexico.

Similar to Fernald (1999) and Harchaoui and Tarkhani (2003), Alstadt et al. (2012) find productivity benefits derived from the accessibility measures to differ depending on the industry sector. Manufacturing industry benefits most from same-day delivery access, but derives less benefit from effective labor market measures. On the other hand, service industries, in particular highly-skilled service industries benefit most from airport access and from access to effective labor market. Elasticity of productivity with respect to effective labor market is larger for service industry (0.05 - 0.10) than for the manufacturing industry (0.01 – 0.04). Industries such as mining, wood and paper, and retail derive more productivity benefits from intermodal freight terminal access. In any cases, the results suggest that market access and intermodal connectivity influence the productivity benefits derived by the various industry sectors.

As Alstadt et al. (2012) suggests, research concerning the relationship between intermodal connectivity and productivity are still at infancy stage. Some of the improvements needed in this area of research include finding an improved measure for intermodal connectivity and a better definition of market access (Alstadt et al. 2012).

7.2 Exploring Linkages between Supply Chain and Productivity

Exploring the linkages between supply chain and productivity is more complex relative to the research concerning intermodal connectivity. The research barriers mentioned in section 7.1 also applies in this area of research. However, intermodal connectivity is just one element of supply chain management, so the number of problems encountered in supply chain-related research would be magnified. More academic research seems to be conducted for intermodal connectivity than for supply chain management. Supply chain papers are primarily done by practitioners or consultants. Bichou and Gray (2004) argue that the academic literature has been less successful in coming up with performance measures for supply chain management. This implies that minimal number of economic studies has been done to find the factors that are related to supply chain management. After a review of the academic literatures, relatively few research papers have been done to find the link between productivity and supply chain management, especially through a macroeconomic approach.

Supply chain performance depends on both qualitative and quantitative measures and encompasses many industries and sectors (Beamon 1999; InterVISTAS 2007). Beamon (1999) suggests that qualitative measures such as customer satisfaction, information flow, supplier performance, and risk management should be incorporated into supply chain analysis. Organizational partnerships and coordination are also important for a supply chain's success (Bichou and Gray 1994). However, these factors have not been included in any official supply chain modeling research (Beamon 1999), which also implies that the intermodal studies discussed in section 3.3 would not have fully taken these components into account. Incorporating service or quality components into economic models is not easy. Furthermore, the supply chain process used by each company is unique, since each business is different and the logistics network depends on the nature of the business. Therefore, supply chain processes cannot be analyzed at the aggregate level. Some form of micro-data analysis may need to be used instead. As such, modeling the relationship between supply chain performance and productivity via econometric or macroeconomic means would not be as direct as the intermodal studies. The level of difficulty in this area of research is further magnified.

The use of a productivity measure to proxy supply chain performance appears to be an alternative to tackle the omitted variable bias problem. The productivity measure should implicitly encapsulate all of the qualitative and quantitative components of supply chain performance. However, even coming up with a productivity measure specifically designed for logistics context is confusing. The generic definition of productivity is output over inputs (Alstadt et al. 2012; InterVISTAS 2007; Stainer 1997), but it is ambiguous what components should be included into the output measure. This ambiguity adds another layer of complexity to this analysis.

This section is divided into two sub-sections. The first sub-section reviews the definition of the term, “supply chain management” and explains the challenges with finding variables to proxy supply chain performance for econometric or macroeconomic analysis. As noted above, it is not easy to directly model the relationship between supply chain management and productivity. Supply chain performance depends on infrastructure development and intermodal connectivity. As such, the second section reviews the models used in research concerning the association between intermodal connectivity, infrastructure, and productivity and relate these results to a supply chain context.

Supply Chains and the Problems with Defining Supply Chain Measures for Econometric Models

Similar to intermodalism, researchers have not agreed on the definition for “supply chain management” (Bichou and Gray 2004). Other terms, such as “network sourcing”, “value chain management”, “supply pipeline management” have been used interchangeably with the term “supply chain management” (Bichou and Gray 2004; Sydor 2012). Most papers define supply chain management to be a one-way process, where the product or service is distributed from the raw material stage to the end-customer stage (Beamon 1999; Bichou and Gray; Sydor 2012). However, Industry Canada (2011) suggests that the supply chain involves two-way directions. Purchases usually involve after-sales services, such as repair and maintenance and these after-sales services would involve moving the product from the final customer back to the factory-level.

Supply chains involve multiple parties and regions. Beamon (1999) suggests that many facilities and procedures may be involved in between each supply chain stages, which adds to the complexity of the whole system. These value chains usually involve strategic partnerships, process integration, and co-operative arrangements across the upstream and downstream organizations in order to produce value in delivering the good or service to the end-customer (Bichou and Gray 2004). Globalization has boosted international trade flows, and many production activities within a supply chain have been segregated and located across various sites in multiple locations (DeBacker and Yamano 2012; Globerman 2012; Sydor 2012).

Supply chain designs are multi-dimensional and are influenced by various factors. As supply chains become more globalized, gateways, corridors, and port operations have played increasing roles in supply chain design. (Bichou and Gray 2004; InterVISTAS 2007). A gateway requires intermodal connectivity consisting of marine, road, and rail operations to help extend international trade flows beyond the immediate catchment area (InterVISTAS 2007). In general, intermodalism and organizational integration are associated with supply chain management; and organizational partnership is needed within an intermodal system in order to achieve connectivity (Bichou and Gray 2004).

Cost and customer responsiveness are important ingredients to supply chain management (Beamon 1999). Beamon (1999) suggests that cost measure consists of inventory costs and operating costs; and customer responsiveness depends on lead time, stockout probability, and fill rate (Beamon 1999). Successful supply chains heavily depend on on-time and reliable deliveries (Industry Canada 2011; InterVISTAS, 2007). Yeung (2006) obtains results consistent with the conjecture that customer responsiveness is one of the important elements to supply chain management. Using stepwise regression model and survey data obtained from Hong Kong-based manufacturers and trading companies, he finds timeliness and pricing of third party-logistics service providers to be positively related to the logistics performance of users. In particular, Yeung (2006) finds timeliness to be positively associated with users' export performance[29] relative to major competitors; and timeliness is the only variable that is statistically significant in his model (with export performance as dependent variable). The author concludes that timeliness is the number one priority for obtaining favorable logistics performance.

Yeung's (2006) model results indirectly show that supply chains and productivity are related, since export numbers enter into the output component of the productivity measure. Similar to research on exploring how intermodalism relates to productivity, *bilateral (two-way)* relationships exist for supply chain models. Increase in international trade, which helps stimulate economic growth and productivity has translated to growing demand for global supply chains (Industry Canada 2011).

[29] Export performance index is constructed based on the following measures: "company's achievement of export goals and objectives, relative exports sales and performance growth, market share in the target markets, and perception of export profitability with respect to major competitors" (Yeung 2006, page 128).

Greater demand for global supply chains tends to be associated with greater investment in distribution centers. Industry Canada (2011) finds that the investment in Canadian distribution centers has increased by 106% between 2005 and 2010 period. This form of investment would be classified as non-residential investment under the national accounts in calculating the gross domestic product measure. Holding all else constant, the increase in investment of distribution centers would translate to higher economic growth, and possibly greater productivity levels. Good supply chain practice also facilitates cost reduction and increases firm's competitiveness, which helps improve business output and productivity (Industry Canada 2011; InterVISTAS 2007). Thus, a virtuous cycle also exists in this area of research.

Despite that supply chain and productivity appears to be associated, finding the link between these two variables is difficult. Firstly, multiple dimensions and inter-linkages are involved. As noted above, supply chains involve more than just transport modes. In intermodal connectivity research, access measures for each transport mode can be more easily incorporated into econometric models. However, supply chains also involve qualitative measures (such as customer satisfaction, information flow, supplier performance, and risk management[30]), as well as interdependencies across the supply chain partners. These cannot easily be expressed in numerical forms. So, omitted variable bias problems may exist if not all of the supply chain factors are incorporated into econometric models to estimate the causal relationships between supply chain performance and productivity. If omitted variable bias exists, the standard errors would be small; thus the estimated coefficients would be biased upwards (Davidson and MacKinnon 2004). In other words, econometrics model may not be able to provide a correct representation of the causal relationship between supply chains and productivity.

Other barriers exist with using econometric models to *directly* measure the linkages between supply chains and overall economic productivity. Firstly, each firm has a unique supply chain process, because the logistics process applied by each firm depends on the nature of the business. So, the analysis cannot be conducted at the aggregate level. Some form of micro-analysis may need to be used. Even at the micro-level, finding a variable to proxy supply chain performance is difficult. Bichou and Gray (2004) and Chow et al. (1994) suggest that performance measures for supply chain management are not consistent across studies. Bichou and Gray (2004) argue that performance measures for supply chains are usually initiated by consultants or by practitioners, and not by academic researchers. So, these performance measures may not be able to accurately estimate the *economic* effect that this logistics practice has on overall economic productivity. These claims imply that the search for variables to proxy supply chain performance is not simple.

[30] See Beamon (1999) for more information.

InterVISTAS (2007) and Stainer (1997) also argue that the economic productivity measure is not the best proxy to estimate supply chain performance. Similar to the intermodal context (see section 3.3), InterVISTAS (2007) argues that productivity calculations under this context can have multiple forms, depending on the information selected for this measure.

Productivity is generally referred to as "output over inputs", where inputs include labor, capital, energy, and materials (Alstadt et al. 2012; InterVISTAS 2007; Stainer 1997). Studies such as Aschauer (1989) and Wylie (1995) tend to use single factor productivity measures, such as labor productivity (output per labor hours worked) or capital productivity (output per unit of capital) for their analysis. However, under the supply chain context, inputs tend to interact with each other, so the input measure should be a weighted index comprising of the four main inputs (InterVISTAS 2007). As such, the single factor productivity measures are incomplete in a supply chain context and total factor productivity should be used instead. Equations 1 and 2 show an example of a total productivity measure, as suggested by Stainer (1997):

Equation 7

$$Total\ productivity = labour\ productivity * \frac{labour}{capital} * fractional\ capital\ costs$$

which also equals to:

Equation 8

$$Total\ productivity = \frac{output}{labour} * \frac{labour}{capital} * \frac{capital}{input}$$

As noted above, gateways play an important role to supply chain process, but the productivity measure may not capture the contribution of *all* gateway components (InterVISTAS 2007). InterVISTAS (2007) suggests that improvements in gateway performance help reduce delays and transport cost for distributing the goods and services through the gateway, so strategic investments conducted by different levels of government for the gateway should also be considered for the input measure. Furthermore, improvements arising from efficient supply chain processes spill over to other sectors via agglomeration effects, which facilitate new business opportunities and investment (InterVISTAS 2007). However, it is unclear if the productivity measure can capture these spill-over effects. Iacobacci and Schulman (2009) also suggest that the transportation productivity measure involves multiple services simultaneously, so an index of output and an index of inputs should be used. Equation 3 shows an example of productivity measure, which incorporates indices of inputs and outputs via the hedonic adjustment approach[31] (InterVISTAS 2007):

Equation 9

$$Total\ Factor\ Productivity = \frac{(Aggregate\ index\ of\ hedonically\ adjusted\ gateway\ output)}{(Aggregate\ index\ of\ nodal\ infrastructure\ inputs\ plus\ strategic\ investments\ and\ initiatives)}$$

The index of output produced by the transportation sector, however, may not take social and environment costs into consideration (Iacobacci and Schulman 2009). So, the productivity measure would be underestimated.

The output produced by supply chains (gateways) is also unclear. Again, it is not easy to find a variable to represent supply chain process. In the transportation context, a single firm can produce multiple numbers of outputs. The same good that gets transported to different geographical regions would be considered as different outputs; and each of the commodities transported by rail would be considered as different outputs because each item has a different cost structure. This complication is further magnified in a supply chain / gateway context, since gateways involve multiple carriers handling multiple goods over multiple locations (InterVISTAS 2007).

To tackle this problem, InterVISTAS (2007) and Iacobacci and Schulman (2009) suggest using an output index weighted either by the mass of the goods, by the value of the goods, or by the revenue shares of each of the outputs produced. However, InterVISTAS (2007) explains that any weighting methodology is problematic due to the following reasons:

- Mass-based approach fails to recognize the value to the economy of gateway output.
- Value-based approach produces volatile results because the value of the goods can be affected by factors not related to gateway performances (for example, the price of the goods can be affected by supply-shortage which can be entirely not related to the supply chain process).
- Revenue-based approach is commonly used for firm's productivity performance measure; but retrieving revenue data is challenging as businesses fear disclosing sensitive / confidential information.

Furthermore, the output measure is *incomplete* especially under the supply chain context. As noted above, supply chains consist of time and reliability (service quality) components. In typical productivity analysis, the gross domestic product (GDP), firm income, or sales figure has been used for the output component of the productivity measure. However, any of

[31] See InterVISTAS (2007) for details regarding hedonic adjustments.

these measures may exclude service quality aspects (InterVISTAS 2007; Stainer 1997). These service quality components are not easily quantified and most likely are not incorporated into the typical output measures. Stainer (1997) suggests using the following form as a proxy for productivity for the service industry: $\frac{(Quality\ of\ service\ index)}{(Total\ cost\ index)}$. InterVISTAS (2007) recommends using the hedonic adjustment approach to incorporate service quality into the productivity measure, where the hedonic approach includes the measurement and valuation of reliability and timeliness. However, it remains ambiguous as to what service indicators to be included into this revised productivity measure, since some of the service quality components may not be easily expressed in numerical forms.

Economic Measures and Models for Linking Productivity and Supply Chain Process

Models exploring the linkages between productivity and supply chains are incomplete, and the supply chain process itself is multi-dimensional and unique to a particular firm. However, models usually *do not and cannot* include all of the factors that affect supply chain performance into the analysis. As noted above, researchers such as Bichou and Gray (2004) and Chow et al. (1994) suggest that performance measures for supply chains are not consistently defined across studies. It is also not easy to come up with an indicator that embeds the whole supply chain process. Furthermore, each firm employs different supply chain process, depending on the nature of the business. So, it is even more challenging to come up with a generic indicator to represent such logistics networks. Direct examination of the association between supply chain and productivity is nearly impossible at an aggregate level through econometric or macroeconomic means. Therefore, it should not be surprising that relatively few academic papers have *directly* explored the relationship between supply chains and productivity through economic methodologies. As such, this sub-section does not cover any research papers and does not provide any elasticity figures that directly describe such a relationship.

Upon examination, numerous research papers have been done on relating public investment with productivity and some on relating intermodal connectivity with productivity. Since infrastructure investment and intermodal connectivity are factors contributing to supply chain performance, results from these areas of research can provide some *indirect* evidence on how supply chains relate to productivity. Given the incompleteness in this area of research, this section reviews the models done on linking public spending / infrastructure and intermodal connectivity with productivity[32]. The intent of this section is to take the model results from the public infrastructure and intermodal connectivity papers and relate them to a supply chain context.

[32] Section 3.3 has covered some of the models. See Section 3.3 for model details.

As noted above, infrastructure development is one of the contributors to supply chain performance. In general, a favorable infrastructure can lower transit time, reduce logistics (trade) cost, improve service levels, and thus increase productivity (InterVISTAS 2007; Limao and Venables 2001). Globerman (2012) also argues that firms can enjoy more efficient global supply chains via improvements in transportation infrastructure, which facilitates trade integration with other global economies. Reduction in trade barriers encourages more trade activities across the economies and has positive implications on productivity growth.

The models in Section 6, which explore the relationship between public infrastructure and productivity growth, should have implications on the relationship between supply chain and productivity. However, research results have shown ambiguity for papers concerning the link between productivity and public infrastructure investment. For example, Aschauer (1989) and Wylie (1995) show strong positive relationship between public infrastructure and productivity (elasticity in the neighborhood of 0.4); Lau and Sin (1997) find marginal effects for the elasticity of output with respect to public capital (elasticity of 0.11); and Baird (2005) suggests that the relationship between public spending and productivity is zero[33].

Ambiguity about the link between public infrastructure and productivity also exists at a disaggregated level. Brox (2008) finds cost elasticity to be -0.476 for the Canadian manufacturing industry, which implies that for every 1% increase in the stock of infrastructure, the production cost would reduce by 0.476%. This shows that manufacturing firms enjoy reduction in production cost due to public infrastructure development. Harchaoui and Tarkhani (2003) also finds similar results using disaggregated data of 37 Canadian industry sectors for the period 1961-2000. Harchaoui and Tarkhani (2003) find the transportation industry to experience the most cost reductions for every additional investment in public capital, which allow firms to set prices lower to achieve competitive advantage. Brox (2008) and Harchaoui and Tarkhani's (2003) results are consistent with Industry Canada's (2011) argument that firms are relying on logistics innovations in order to improve and streamline their supply chain processes to help reduce inventory and transport-related costs. Supply chain management is important to the manufacturing sector especially when a lot of the production processes are segregated across various geographical regions along with growing volumes of international trade flows (Industry Canada 2011). However, using U.S. data, Baltagi and Pinnoi's (1995) results show that the infrastructure variable is not statistically significant after correcting for measurement errors. This implies that intermodal connectivity has minimal impact on productivity growth. Since supply chain processes depend on connectivity, this would suggest that supply chains and productivity are not related. Baltagi and Pinnoi's (1995) findings appear to contradict with Brox's (2008) results. It is unclear if the variability in results is due to the country of interest, due to methodological differences, or due to data issues.

[33] See Section 3.3 for details.

Using a model different from the production function or the cost function approach, Shirley and Winston (2004) do not find highway spending to substantially raise productivity. This result seems to be consistent with some of the research papers as discussed in section 3.3. The authors conclude that highway spending nonetheless should raise productivity via improvements in cost, speed, and reliability of highway transportation. These improvements should contribute to reductions in inventories. Shirley and Winston (2004) modify the Economic Order Quantity (EOQ) model to estimate the effect that different supply chain factors have on raw material inventories. The modified EOQ model sets the expected inventory level as a function of expectations of and variation in demand; order, handling, and stockout costs; and other transportation system attributes. The econometric model used in Shirley and Winston (2004) is shown below:

Equation 10

$$\log(expected\ raw\ material\ inventory\ level) = \beta_1 * \log\left(annual\ demand^{\frac{1}{2}}\right) + \beta_2 * year * \log\left(annual\ demand^{\frac{1}{2}}\right) + \beta_3 * variability\ in\ demand + \beta_4 * industry + \beta_5 * location + \beta_6 * year + \beta_7 * interest + \beta_8 * work + \beta_9 * infra + \beta_{10} * dereg + \beta_{11} * congest + \epsilon$$

Where,

- The “industry” and “location” dummies capture the effects of warehousing costs, stockout costs, and order processing information on inventory levels.
- The “interest” variable is a proxy for the inventory holding costs, since these holding costs are affected by interest rates.
- The “infra” capital captures the highway capital stock, which is a proxy for the effects of cost, speed, and reliability of transporting freight between city pairs.
- Public policies such as deregulation and the level of congestion have implications on the speed and reliability of highway transportation system. The variables, “dereg” and “congest” capture these effects.
- The “work” variable captures just-in-time practice. Just-in-time practice is expected to lower work-in-progress (WIP) inventories, so this variable is included into the model as the ratio of WIP inventories to final inventories.

Shirley and Winston (2004) find the highway capital variable to have negligible effect. The estimated coefficient for the highway capital variable is in the eighth decimal place, which suggests that highway capital spending has near zero impact on inventory levels. This translates to minimal reduction in inventory costs34. Shirley and Winston (2004) also find that an additional dollar in highway capital stock generated 7 cents of inventory cost reduction in the 1970s, but generated roughly 0.33 cents in the 1990s. The same study also suggests that highway investments generated rates of return of 15% in the 1970s, but less than 5% between 1980s and 1990s. They argue that inefficiency in transportation policies may have contributed to the decline in returns. Poor transportation policies or infrastructure developments tend to be associated with poor intermodal connectivity and increase in trade cost (see Limao and Venables (2001) and Micco and Serebrisky (2006), for example). It is possible that the negligible relationship between intermodal connectivity and productivity in previous work is due to poor transportation policies. Poor transportation policies may have net out the overall productivity benefits derived from infrastructure development. Since the success of supply chains relies on connectivity, poor transportation policies can negatively affect supply chain performance. This translates to reduction in productivity in terms of higher logistics cost, greater transit times, and lower service levels (reliability).

Pathomsiri et al. (2006) find that time and reliability are important factors for an airport's success. Freight movements measured in terms of cargo throughput and reduction of delayed flights contribute to more efficient use of airports (i.e. increase in airport productivity). The authors use the directional output distance function approach and the dataset containing 56 U.S. airports for periods between 2000 and 2003 to determine the level of inefficiency for each individual U.S. airports. The authors split the output set into two categories – desirable output and undesirable output. They create 3 cases for the model:

- The base case consists of land area, number of runways and runway areas as inputs and includes passengers and aircraft movements as "desirable" outputs;
- The second case includes cargo throughput into the "desirable" outputs set, which proxy the freight services at airports; and
- The third case includes delayed flights into the "undesirable" outputs set, in addition to the sets used by case 2, to proxy the contribution freight transportation and delayed flights contribute to airport productivity.

Freight movements and reductions in delayed flights are proxies for timeliness and reliability of goods and services movement, which are essential factors contributing to favorable supply chain performance. Pathomsiri et al. (2006) suggests that airport services help create jobs and stimulate economic activity at both the regional and the national level.

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[34] Cost reductions are calculated by multiplying the econometric model estimates with the net investment in the road system and the holding costs of inventories. Cost reduction estimates are then inflated to account for materials inventories in the economy not included in the sample (Shirley and Winston 2004).

Indirectly, model results from this paper imply that supply chain performance has implications on the overall economic productivity, not just on airport's productivity.

As discussed in section 6.1, Alstadt et al. (2012) explore how market access and business productivity are related. Their models include variables that act as proxy for supply chain management, and these variables include:

- Access to employment within 3 hour driving distance: a proxy for same day delivery.
- Access to population within 40 minute driving distance: a proxy for effective labor market or "shopping market".
- Access to major marine port, to major commercial airport, to major international freight airport, and to intermodal rail terminal.
- Access to closest border to Canada and to Mexico.

Alstadt et al. (2012) find productivity benefits derived from the accessibility measures to differ depending on the industry sector, but the overall results are consistent with supply chain practice. The same-day delivery variable is important for supply chain process, in particular for the manufacturing sector, because on-time shipment of goods is important to meet increasing customer service level requirements. Consistent with expectations, the manufacturing industry benefits most from same-day delivery access according to Alstadt et al's. (2012) model.

Retail and natural resource industries are also relying on supply chain processes and logistics innovations to streamline their processes. Global trade management are also included in supply chain designs (Industry Canada 2011). Expansion of international trade flows, such as exports of natural exports or imports of retail goods, has encouraged the development of gateways and corridors. The performance of these gateways and corridors depend on rail and truck traffic (InterVISTAS 2011). Consistent with these conjectures, Alstadt et al, (2012) find that industries that export or import natural resource and retail products derive more productivity benefits from intermodal freight terminal access. In any case, Alstadt et al. (2012) indirectly suggest that supply chain factors and productivity are related, but the productivity benefits derived by each industry vary.

In another study, Iacobacci and Schulman (2009) find that the annual productivity growth (measured in terms of total factor productivity) is greater for the transport sector relative to the average productivity growth for the Canadian business sector for the periods between 1981 and 2006. The annual productivity growth is 3.6% for the rail sector; 2% for the airline industry; 1.8% for the trucking industry[35]; but 0.2% for the whole Canadian business sector (Iacobacci and Schulman 2009). These results are consistent with the findings in Fernald

[35] Iacobacci and Schulman (2009) mention that the result for the trucking industry is based on data series between years 1981 and 2003.

(1999) and Harchaoui and Tarkhani (2003), where vehicle-intensive sectors experience the most productivity benefits. The rail industry experiences the most productivity growth in Iacobacci and Schulman's (2009) calculations, which matches with current supply chain trends. Both Iacobacci and Schulman (2009) and InterVISTAS (2007) suggest that expansions in international trade have encouraged the development of supply chains, gateways, and corridors; and rail freight is an important component to global supply chains. Furthermore, the authors attribute the stronger transport productivity growth to infrastructure investments and intermodal connectivity, where infrastructure investments facilitate efficient flow of goods and services that allow Canadian firms to compete more competitively in global supply chains. The efficient flow of goods and services is also a byproduct of intermodal connectivity.

In terms of connectivity, some of the model parameters in Shirley and Winston (2004) also indirectly suggest that supply chain and productivity are positively related. As shown above, the authors link firm productivity with reductions in logistics and inventory costs. Cost savings allow firms to become more competitive and encourage more business investments. Their EOQ inventory model shows the following results:

- Highway congestion raises inventory cost. Logistics cost increase by $1 billion for every 10% increase in vehicle-miles traveled. Improvement in delivery times and reliability resulting from good supply chain management can reduce the number of freight movements on the road.
- Variability in materials demand and work-in-progress inventory cause raw materials inventories to rise. The authors argue that faster and more reliable transportation system enables firms to lower reorder point due to less uncertainty over when the orders will arrive. Increased reliability in speed and cost facilitates just-in-time inventory management, which helps lower inventory and warehousing-related costs.
- Deregulation dummy variables show negative coefficient, which suggest deregulation leads to lower raw material inventories. The authors argue that deregulation allows trucking firms to compete and offer improved service levels that foster more timely and reliable logistics services. This improved service level facilitates just-in-time management, as well as favorable supply chain processes.

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8 VARIABLES FOR ECONOMIC IMPACT ANALYSIS

In Task 5 of ACRP 03-28, the Research Team is scheduled to present a final draft approach for a top-down and bottom-up national analysis.

The top-down approach uses national data on the aviation system and associated economic data to estimate the national economic impact. To begin the top-down effort, the research team reviewed national level studies (reported in Section 3.2, above), and reviewed national economic and demographic data sets. These data sets are summarized in Table 10.

The bottom-up approach obtains the economic impact for a reasonably large sample of airports and then expands the estimated economic impact from the sample of airports to give an estimate of the national economic impact based on the number of airports in the system compared to the number in the sample. Based on the review of data sources, economic impact studies and literature for this review, we have developed a list of variables to record from state system and single airport studies, as well as from economic and demographic data sources, which we expect to be the basis for the "bottom-up" analysis. These data are presented in Table 10. All variables listed in Table 10 may not be included in the final regression equations (or other "bottom-up" analytical framework); however column *"Notes—Reason for Inclusion of Variable"* indicates the reasons for collecting the variables cited.

Table 10. Variables for Constructing the "Bottom-Up" Analysis for the Economic Impacts of U.S. Airports

Category	Variable	Data type/unit	Purpose	Potential source	Notes -- Reason for inclusion of variable
Regional/County Economic and Demographic Data	Population	Number of persons	Explanatory variable[2]	Census	
(Annual)	Employment (total)	Number of jobs	Explanatory variable	BLS, BEA	Indicator of employment in airport-reliant businesses
($ converted to 2012 $)	Share of employment in high technology sectors and professional service sectors	%	Explanatory variable	BLS, BEA	Significant in study by Button (1999) of 300 airports and Brueckner (2003); Oxford (2011) study for UK airports considers only employment in aerospace and allied industries
	Share of employment in FIRE (finance, insurance, real estate) sectors	%	Explanatory variable	BLS, BEA	Control variable in Green (2007) study to account for industrial structure
	Share of employment in manufacturing sector overall	%	Explanatory variable	BLS, BEA	Control variable in Green (2007) study to account for industrial structure
	County/regional GDP or personal income	$	Explanatory variable	BEA	Indicator of regional economic activity; may be correlated with economic activity at airport
	County/regional GDP or personal income *per capita*	$		Calculate from above data	
	Average home price in county/region (if available)	$	Explanatory variable		Indicator of economic activity; Proxy for GDP; Significant in regression study for Canadian airports by Bennell and Prentice (1993)
	Top personal state tax rate and corporate tax rate	%	Explanatory variable	Statistical Abstract of the U.S.	Control variable in Green (2007) study because taxes appear to have an impact on economic development; city tax rate variables are significant, state tax rates are not
	Share of population over 25 with high school diplomas	%	Explanatory variable	Census of population and housing	
	Share of population over 25 with college degrees	%	Explanatory variable	Census of population and housing	

Table 10. Variables for Constructing the "Bottom-Up" Analysis for the Economic Impacts of U.S. Airports *(Continued)*

Category	Variable	Data type/unit	Purpose	Potential source	Notes -- Reason for inclusion of variable
Airport Data	Airport location	City/MSA	Identifier	FAA	
	Airport code	3-letter code	Identifier	FAA	
	Airport type	Hub, Non-hub, General Aviation	Explanatory variable	FAA	Significant in Chattanooga Met Airport regression study and Green (2007); hub airports have greater economic impact
	Has Maintenance Base or not	1 or 0 (dummy)	Explanatory variable		Presence of maintenance base significant in regression for Canadian airports
	Has Air Traffic Control Tower or not	1 or 0 (dummy)	Explanatory variable		Presence of these usually indicates a certain level of airport activity
	Has Flight Service Station or not	1 or 0 (dummy)	Explanatory variable		
Operational Data	Passenger enplanements + deplanements (arrivals + depatures) by origin [3, 4]	Total number	Explanatory variable	FAA/Transtats	Reflects impacts of business and tourism development; Significant in regression study for Canadian airports by Bennell and Prentice (1993); studies by Green (2007), Brueckner (2003), CRC-Chattanooga (2008) -- in Green study, boardings/capita is used
(Annual)	Domestic/resident				
	International/non-resident				
	Business & military				
	Leisure & personal				
	In-transit				
	Commercial				
	General aviation				
	Aircraft movements (takeoffs + landings), by aircraft size	Total number	Explanatory variable	Transtats database, BTS	
	Large aircraft (>35,000 kg)				Significant in regression study for Canadian airports by Bennell and Prentice (1993)
	Medium aircraft				Not significant, but included in above study
	Small aircraft				Not significant, but included in above study

Table 10. Variables for Constructing the "Bottom-Up" Analysis for the Economic Impacts of U.S. Airports *(Continued)*

Category	Variable	Data type/unit	Purpose	Potential source	Notes -- Reason for inclusion of variable
Operational Data	Air cargo activity (freight loaded + unloaded)	Total number	Explanatory variable	Transtats database, BTS	Reflects impact of goods distribution, but not significant in several studies -- Green (2007), Brueckner (2003) -- in Green study, cargo tonnage/capita is used
(Annual)	Domestic	$ and tonnage			
	International exports	$ and tonnage		WISERTrade/Census FTD	
	Scheduled commercial flights per day	Number	Explanatory variable	FAA	Significant in Chattanooga Met Airport regression study
	Number of destinations served	Number	Explanatory variable	FAA	Significant in Oxford (2011) study for UK airports
	International destinations				
	Domestic destinations				
Airport Economic Data	Airport Employment Generated (full-time equivalents -- FTE)[5]	Number	Dependent variable	FAA ATADS database	The variables below are typically listed in all airport economic impact studies
(Annual)	Total				
($ converted to 2012 $)	Direct (at airport)[6]	$	Dependent variable		
	Indirect (off-airport businesses)				
	Induced (re-spending of income)				
	Airport Personal Income (Wages) Generated	$	Dependent variable		
	Total				
	Direct (at airport)				
	Indirect (off-airport businesses)				
	Induced (re-spending of income)				
	Airport Revenues (Output or Business Sales)	$	Dependent variable	FAA ATADS database	
	Total				
	Direct (at airport)				
	Indirect (off-airport businesses)				
	Induced (re-spending of income)				

Table 10. Variables for Constructing the "Bottom-Up" Analysis for the Economic Impacts of U.S. Airports *(Continued)*

Category	Variable	Data type/unit	Purpose	Potential source	Notes -- Reason for inclusion of variable
Airport Economic Data	Airport capital investment (construction and maintenance)	$	Explanatory variable	State DOT or Airport Authority	
($ converted to 2012 $)	Airport tax and fee contributions (federal, state, local)	$	Explanatory variable	www.taxfoundation.org	The variables below are typically listed in all airport economic impact studies
	State and local taxes (income, sales, property tax)				
	Federal aviation fees				
Visitor Data	Average duration of stay by visitors	Days	Explanatory variable	Survey data	
	Domestic/resident				
	International/non-resident				
	Average visitor spending per day[7]	$	Explanatory variable	Survey data	
	Domestic/resident				
	International/non-resident				

Table 7 Notes:

1: Categories of airport-related economic activity may not be consistent across studies

2: All variables listed as "Explanatory variable" are potential explanatory/independent variables that may be tested in the regressions to explain airport economic impact, but may not feature in the final regression model.

3: Depending on the study and its data sources, this number can differ -- airlines generally count the passengers who board their aircraft, while airports count the passengers arriving or departing the airport; the latter number is sometimes larger than the former

4: For regional economic impact studies, "domestic" and "international" may not be the terms used; instead it would be "residents" and "non-residents"

5: In some cases, employment is provided as FTE, in others as head counts. There is a conversion relationship to convert all full-time and part-time head counts to FTEs (FTE to headcount = 1.17 (source is BEA, quoted in South Dakota Airports study)

6: Direct impacts at airport include those associated with airport management, tenants, government and ground transportation services

7: Visitor spending and business sales should not be double counted for those businesses engaged in visitor services; this will be difficult to ascertain in the reviewed studies.

9 Literature Review & Discussion of How Multi Factor Productivity Has Been Applied

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.[36] Productivity can be expressed in terms of a single factor, labor productivity or in terms of many or multiple factors, termed multifactor productivity (MFP).

There are two approaches. In the growth accounting methodology (see Solow, 1957), MFP is typically estimated as a growth rate. In the second approach, the Tornquist methodology, MFP is calculated as an index number (level), which is obtained by dividing the output index by a combined input index (see Hulten 2001). These two approaches can be computed as:[37]

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.

Multifactor productivity, the second approach, is the ratio of the output index to a weighted average of the input indexes. A Tornqvist formula expresses the change in multifactor

[36] 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.

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

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,

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

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.

Output of an industry and inputs as well, 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 and are used to estimate the contribution of each input to change or increases in inputs.

Any change in output(s) is a result of a number of different changes including changes in the quantity of inputs, changes in the productivity of the inputs (MFP) and changes, potentially, due to changes in the technology of production.[38] 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

[38] 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 factor could develop new skills through, for example education.

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 but 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, that measures of MFP are concerned about maximizing output 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 with a resulting higher output. Other factors influencing MFP are changes in industry structure. Mergers, acquisitions and bankruptcies can affect the productive efficiency of the resultant firm.

Increases in MFP have important benefits for the economy and society. Productivity increases result in output increases that allow the incomes of various groups to improve. The output increases are a direct contribution to economic growth. The increase in ‘real’ incomes contributes to a rising standard of living. Real income can increase when there is an increase in a person’s money income or there is a net decrease in the price of goods or services (due, for example, to improved efficiency), leading to a drop in the consumer price index.

Increases in productivity can affect profits, prices and labor compensation. The basic benefit of increased labor productivity is that more output can be produced with the same or fewer inputs. Therefore, other things equal, increases in productivity result in larger differences between total revenues and total costs, hence higher profits. A decline in productivity can have the opposite effect and could result in lower incomes, profits and less employment.

The three impacts of increased productivity result in higher real incomes in an economy. As business enterprise productivity rises, higher profits and incomes result. Firms can keep a portion of profits as retained earnings, to finance future investment, a portion can go to the firm’s owners or shareholders, which would increase their incomes and a portion can go to labor in the form of higher wages. Customers may also gain if the productivity increase results in lower costs and therefore lower prices.

MFP measures can be used in several ways. They are an indicator of the efficiency of an economic unit – firm, industry or macro economy. Higher MFP growth is a sign of increasing efficiency, resulting in increased productivity from the way in which all the factors of production are used. Therefore more benefits or value are obtained from available inputs. And more people can share the benefits of higher output. The productivity of industries affects the overall productivity of the entire economy. Thus if MFP in air transportation grows faster than other industries it contributes more to overall economic growth. If changes in air transportation result in other industries becoming more productive, again overall economic growth is higher.

MFP can be used as an indicator of the rate of return to resources used in an industry. The MFP numbers measure the benefit, from an increase in output, that an industry, sector or economy gets for investing resources - labor, capital, land and intermediate inputs – in a particular way. This 'way' may refer to a pattern or mix of inputs, laws or regulations affecting the use of inputs and the intensity with which resources are used. If MFP is higher in one sector or industry relative to another it is a signal that more investment should take place in these sectors or industries with the higher productivity as they yield a higher return.[39] If so, the entire economy is better off. The MFP numbers can also direct public policy. If for example, an increase in connectivity in air transport is shown to improve GDP, efforts should be made to ensure the connectivity continues to be improved by, for example, more liberal air service agreements. In another case, if research finds that congestion has a sizable negative impact on MFP, this provides a metric of the amount of investment that should be made in strategies to reduce congestion.

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[39] There is an argument that investments should also be made in low productivity sectors to improve their productivity. Such a decision would be based on something other than maximizing efficiency or economic returns.

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