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The Global Economic Inter-relationships of the U.S. Air Transportation Services Industry using Input-Output Analysis

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Abstract

Global integration of economies over the past two decades has interconnected many of the countries and industries in the world. The World Input Output Database (WIOD) provides domestic output production and use information on 59 industries, in 40 countries that cover 85% of the global output. Using 2010 U.S. Air Transportation Services (ATS) industry growth as a proxy for change in the final demand variable, the additional output from each other industry necessary to supply the additional U.S. ATS growth was calculated using IO analysis. No real eye-opening trends in industries resulted from this limited analysis, perhaps because ATS is less than 1% of U.S. GDP. The aggregate GDP sectors receiving a positive boost from growth in the U.S. ATS industry were agriculture; mining; transportation & warehousing; and some manufacturing and service industries. The aggregate GDP sectors receiving a negative boost from growth in the U.S. ATS industry were construction; finance, insurance and real estate; wholesale and retail trade; and other service sectors.

JEL classification numbers: C67, R15
Keywords: US air transportation industry, input-output analysis

1 Introduction

Global integration of economies over the past two decades have interconnected many of the countries and industries in the world. The World Input Output Database (WIOD) provides domestic output production and use information on 59 industries, in 27 EU countries, 13

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other major countries and a rest of world (ROW) account [1]. These 40 countries account for more than 85% of world's Gross Domestic Product (GDP). Table 1 shows the list of the 40 countries represented in the WIOD. This research will explain the trend of U.S. Air Transportation Services (ATS) output from 1995-2009, including domestic use and exports by country and industry using the WIOD data. Information about the U.S. air transportation output and its ultimate destinations can be used for future empirical analysis and policy evaluations using Input-Output (IO) analysis. The WIOD was released to the general public in April of 2012 and limited use of this data for research has been done with the database but none specifically detailing the U.S. air transportation industry.

1.1 Research Questions

#1) Identify the principal trading partners for the U.S. ATS industry over the time period 1996-2009 using the WIOD.
#2) Identify the principal sectors both domestically and internationally that U.S. ATS industry has traded with over the time period 1996-2009 using the WIOD.
#3) Determine what impact a change to the output of ATS will have on other U.S. industries using the 2009 US Input Output table extracted from the WIOD.
#4) Identify future research.

2 Preliminary Notes

2.1 Input-Output Table Basics

Input-Output (IO) analysis, developed by Wassily Leontief in the 1930s, was a new method of analyzing the interdependence of industries within an economy for which he was awarded Nobel Memorial Prize in Economic Sciences in 1973 [2]. "Input-Output analysis is considered a practical extension of the classical theory of general interdependence that views the whole economy of a region, a country, and even of the entire world as a single system and sets out to describe and to interpret its operation in terms of directly observable basic structural relationships" [3, 4]. Leontief's [5] applied paper on input-output relations in the US is recognized as the beginning of a major branch of quantitative economics [6].
IO tables enable users to trace where each industry uses the product of another industry and how a change in final demand in as few as one industry can impact the each of the other industry's output because the inputs of a single industry can come from the outputs of multiple industries. Economic interdependencies can be described though the industry accounting and relationships between industries; furthermore it can be determined through analyzing an economy's IO accounts [7]. In short the IO model can be referred to as an impact model, tracing specified changes in final demand through the economy.
To recognize inter-industry demand relationships, IO transactions tables of rows and columns of data create a matrix of linear equations. Each row in the matrix generally represents one industry or sector of the economy that is used as an equation for total output of that industry. The equation for each row describes the total value of that industry's output as the sum of all the value of that industry's output sold as final demand, the value of the industry's output used in its own production process, and the value of the industry's output that is sold as an input to other industries. If x is the total output from industry i, z is the intermediate output used as inputs required from industry for that industry in all other

industries 1 through n, and f is the final demand of i's output, each row's equation can be represented as Equation 1. Final demand columns are included in the matrix that detail which sectors of final demand the industry output terminates. These final demand sectors are the major GDP accounts: personal consumption, gross private domestic investment, government purchases, and net exports (exports minus imports).

$$x_i = z_{i1} + \ldots + z_{in} + f_i \quad (1)$$

Each column of the matrix represents what inputs are required from all the other industries in the economy to produce a single industry's output. The equation for each column describes the total value of an industry's required inputs as the sum of all the inputs that are needed from each industry, inputs needed from its own industry, and value-added inputs to total production. If x is the total value of inputs needed from industries 1 through n for that industry plus value-added for that industry, each column's equation can be represented as Equation 2. Value added includes labor wages and profits, depreciation of capital, and taxes [8, 2].

$$x_i = z_{1i} + \ldots + z_{ni} + va_i \quad (2)$$

Using national income and product accounting rules, the value of gross national income (va_i) less the final demand (f_i) is equal to the intermediate consumption or production (x_i) for one country. This relationship is considered the core of the mathematical depiction of the interrelatedness of the industries in the economy. This matrix of simultaneous equations represents the total accounting for production in the economy for one year for one country. Table 2 is an example of an input-output table of an economy with two sectors –manufacturing and services. The equation for each row describes the total value of that industry's output as the sum of all the value of that industry's output sold as final demand, the value of the industry's output used in its own production process, and the value of the industry's output that is sold as an input to other industries. In Table 2, the manufacturing sector uses $10 of its own production, it sells $40 to the service sector, and sells $50 as final demand. The equation for each column describes the total value of an industry's required inputs as the sum of all the inputs that are needed from each industry, inputs needed from its own industry, and value added inputs to total production. In Table 2, the services sector requires $40 from the manufacturing sector and $25 from its own sector as inputs as well as $75 of value-added inputs to show a total outlay of $140. Value added represents employee compensation, government services paid for by taxes, interest payments, rental payments, and profit. It is possible to expand this economy internationally by adding a column for outputs destined for export and a row for inputs from imports.

The IO table can be used by simulating a change in final demand to the entire economy or a change in final demand in one industry to trace its expected effects in all the other industries [8]. This manipulation is essentially solving a matrix algebraic problem of the number of industries or sectors by 1 vector representing the changed final demand using numerical analysis software and noting the resulting vector representing the change in output for each industry. Changes in one industry affect other industries and are allowed to feed back on the original industry until the disequilibrium from the shock significantly dampens [9, 10, 11].

2.2 Input Output Analysis Usefulness

IO analysis is useful for descriptive analysis, forecasting, and assessment of policy impact scenarios. IO models usefulness is the ability to estimate the indirect impacts of a final demand change by detailing the interdependency of the economy's industry. Isard et al. [12] maintain that because of IO's interdependency of industry capabilities, it is an indispensable part of impact research. IO models produce a multiplier index that is useful in measuring the total impact of a change in final demand on inter-industry demand that can be used for forecasting, and by extended application, employment impacts [13].

IO accommodates or accounts for three types of effects or impacts in the economy: direct, indirect, and induced. Direct impacts are those effects from business activity. Indirect impacts are those caused by inter-industry changes in business. Induced effects are those impacts created by the household sector spending of those employed by the direct and indirect altered industries [2]. Since the IO approach accounts for changes of inputs to industries based on changing outputs of industries, it is possible to achieve a more precise calculation of the impacts of a given or potential change in the economy. "Input-output analysis can be thought of as documenting and exploring the precise systems of inter-industry exchange through which different components of regional product become different components of regional income" [14]. From IO analysis, one can get a comprehensive description of the inter-industry structure of an economy where strategic industries and opportunities for income and/or employment impacts can be analyzed.

2.3 Other Impact Analysis Models

There are other methods of economic analysis, specifically, various types of econometric modeling. Econometric models used for impact analysis or forecasting typically take three forms: autoregressive models, reduced-form models, and large scale structural models [15]. Leontief, Bergmann, and Lucas were among the strongest advocates of solving problems through the application of economic tools to real-world data. Leontief and other followers critiqued the other methods of studying economic impacts by way of economic methodology. The main critique centered on contemporary economists who spent more time on building sophisticated statistical analysis on data with possible meaning and validity issues [16].

Econometrics modeling creates models that either abstractly or theoretically describe relationships that Leontief argued had the conclusions essentially built in. Model builders create assumptions and then create models that incorporate the assumptions. The model works if the assumptions are true. Leontief, Samuelson, Mayer, and Lucas critiqued economic modeling because assumptions embodied within models were many times unrealistic, but models that behave statistically well could be considered a good model. The Lucas critique went even further, saying that once policy was changed, the econometric model used in forecasts was invalid [16]. Friedman [17] argued in a controversial paper that a theory's validity should be based on its predictive accuracy rather than consideration of realistic assumptions. Focusing on the predictive validity of models negates or shadows understanding the underlying relationships in the economy when making policy and predictive statements.

Econometric testing assumes economic relationships are stable over time and can shadow any weaknesses in the data [15]. Because economic relationships are dependent on individual relationships, it is unrealistic to assume the structure of those relationships do not change over time. Leontief believed that economists should look at the empirical data and the relationships within them to then determine how to solve economic problems.

IO became popular after World War II as governments began to work on comprehensive economic development projects and this tool would allow policy makers to project the consequences of changes in economic policy. But, because Leontief derived IO analysis from early Soviet economic planning methods and Hungarian economists and other countries were adopting this method as a tool of socialism, IO analysis quickly became a casualty of the political environment in the US [18]. In the 1970s, the economic environment moved from government planning and directed changes toward more of a market-directed form of economic development and IO analysis interest waned as economists turned more to modeling [15]. Moreover, IO analysis required vast amounts of data and considerable computer time for modeling; data was frequently out of date when published (the US Bureau of Economic Analysis (BEA) updates a benchmark IO table every five years and publishes a yearly higher level aggregated IO table for use) and access to computing power was limited.

Another method of studying economic impacts is to use a simple economic base model where only basic and non-basic sectors are detailed. Any economic impacts can be traced through multiplier effects or what are commonly referred to as ripple effects that only analyze at the basic and non-basic sector levels and gross changes are aggregated to those levels. Inter-industry transactions and financial flows are not included. Typically economic base analysis applies broad multipliers to the sectors and the entire economy.

Another form of economic impact analyses sometimes used is evaluation of policies using a cost benefit analysis (CBA). CBA compares the gross benefits of a policy or change with the opportunity costs of that change. If the benefits are greater than the costs, then typically the policy is considered positive or economically viable. CBA formats vary greatly as some seek to include estimating social benefits or costs, environmental impacts, efficiency estimates, and price impacts [19]. IO analysis deals strictly with transactions. IO analysis does not have the problems that limit the usefulness of the other methods.

2.4 Weaknesses of Input Output analysis

IO analysis is not without its weaknesses. In doing an analysis, one has to assume there are no substitutions of inputs within the production process. For example, a change in final demand that would lead to a shortage of inputs in certain sectors of the economy would most likely induce higher market prices for those inputs and some processes might try to adopt a change in the input mix of production. Unfortunately IO matrices are based on transactions over the period of one year and any irregularities or short term trends can been exacerbated or lost in the analysis [14]. IO assumes a linear relationship between a change in demand and a change in inputs and outputs that minimizes the impacts of externalities and changes in returns to scale. IO does not capture natural resource externalities that are not traded in the markets such as pollution. Moreover, it does not answer the more subjective question of whether a society has become better off as a result or if resources are allocated more efficiency [20]. Despite those limitations, IO analysis is an accepted, respected and useful method for descriptive analysis, forecasting, and assessment of policy impact scenarios.

3 Main Results

3.1 World Input Output Database

Country-by-country IO tables are the inputs to the WIOD. Typically, each country releases a complete IO table every five years and rarely revises the table. Comparing results from analysis from one IO release to IO another release is statistically unwise as industry classification schemes, methodologies, and accounting rules change over time and among countries. However, in the construction of the WIOD, each country's supply and use tables (SUT) and the national accounting system (NAS) was benchmarked in order to make the accounts internationally consistent and appropriate for time series comparisons [1]. The WIOD industry classification has 59 products within 35 industries. The transport sector is so vital to international trade and therefore is disaggregated so that the air transportation services product group can be isolated. Industry classifications were defined according to the definitions used in the EU KLEMS database that incorporates the International Standard Industrial Classification (ISCS) definitions [1]. EU KLEMS stands for European Union capital (K), labor (L), energy (E), materials (M), and service (S) [21]. The ISCS codes also correspond with the Statistical Classification of Economic activities in the European Community most commonly referred to as NACE (Nomenclature des Activites Economiques dans la Communaute Europeenne) [22].

The ISCS is published by the United Nations to classify economic data and facilitate statistical analysis of output and productivity across countries. It quantifies the air transportation industry as comprised of passenger and freight air transport. This division is further defined as the transport of passengers or freight by air or via space whether by regular services or private charter while excluding the repair of aircraft or aircraft engines and their support activities, the operation of airports, and activities that make use of the aircraft for other than transportation (crop dusting, aerial advertising, or aerial photography) [23]. ISCS definitions for ATS is consistent with the North American Industry Classification Strategy (NAICS) published by the United Nations that also classifies economic data and facilitate statistical analysis of output and productivity across countries [24].

The WIOD is compiled using constant prices by deflating product level deflators based on industry gross output deflators. All elements of the table are presented at previous year's purchasers' price basis for goods and services and allow for comparison over the time period without further adjusting for inflation [1]. All numbers are converted to US dollars based on average currency exchange rates for the year in question.

The data retrieved from the WIOD database for this analysis included the intermediate output of U.S. ATS product to each country and the final demand of U.S. ATS product by country for the years 1995 to 2009. Intermediate output is defined as that output that is used as inputs in other industries production processes. Total output for the industry is comprised of intermediate output and final demand output. Exports of ATS by country can be calculated by extracted the supply of intermediate U.S. ATS product by country.

3.2 Descriptive Results Extracted from WIOD

Total output growth of the U.S. ATS industry averaged 3% per year over the time period. However, excluding years of significant contraction in output growth (2001 and 2009), total U.S. ATS output growth averaged 7% (Figure 1).

ATS industry had diminished importance as an industry in the U.S. economy. Total ATS output as a percentage of total US industry output decreased from 0.72% to 0.54% over the time period studied. The major decrease in percentage of total output was in 2001, presumably as a result of the decrease in passenger travel after the terrorist events of 2001. Output in the U.S. ATS industry has not recovered to its previous share of the U.S. economy since 2001 (Figure 2). The correlation of ATS output growth with U.S. GDP growth was 0.596. Even though the time frame studied was limited, it makes economic sense that the ATS sector was influenced by changes in the U.S. economy.

U.S. industries consistently have been the largest consumers of U.S. ATS output, consuming, on average, over 80% of the ATS output domestically while 20% is exported to the rest of the world. In years 2008 and 2009 the share of domestic consumption of ATS output dipped below 80%. No one country on the list of 40 contained in this database accounted for greater than 1% of the exports from the ATS industry. The main exports from this sector go to the geographic category 'rest of world' that represents 15% of global economic output from less developed countries (Figure 3). The percentage of exports of total ATS output has been growing in recent years, perhaps reflecting the globalization of the U.S. economy and the industry itself. As an accompanying piece of evidence of globalization's impact on the ATS industry, imports of ATS output from other countries required as inputs to U.S. ATS production has definitely increased over the time period with the exception of 2009 (Figure 4).

The descriptive data extracted from the WIOD on domestic and international demand of U.S. ATS industry indicated that US industries' consumption of U.S. ATS output was the principal and predominant destination This means that in the short term the biggest potential negative effect on the ATS industry would be a shock or change in the US domestic output rather than a shock in the European Union or China. However, as exports to the rest of the world were clearly trending up over the time period studied, that relationship may change in the future as those countries' economies develop and mature (Figure 5).

3.3 IO Analysis on the U.S. ATS Industry

The change in U.S. ATC output from 2009 to 2010 as defined by GDP by Industry accounts from the Bureau of Economic Analysis ~~(BEA)~~ was used as a proxy as a change in ATC final demand. This change in final demand then was applied as the change vector to the U.S. Input Output table extracted from the WIOD for 2009 to simulate the output effects of the ATS industry on other industries. For consistency purposes between the WIOD and BEA databases, the U.S. ATS output amount in the WIOD corresponds to the ATS output amount in the U.S. BEA GDP by industry accounts. U.S. ATS output grew 10.75% or $14.4MM in 2010. Using this growth proxy for the U.S. ATS final demand variable, the additional output from each other industry necessary to supply the additional U.S. ATS growth was calculated using IO analysis.

Mathematically, the resulting change vector is calculated as $(I\text{-}A)^{-1}$ f = x. (I-A)-1; this is known as the Leontief inverse or the total requirements matrix in IO analysis (Blair & Miller, 2009). The total requirements matrix creates a series of equations that detail the dependence of each of the gross industry outputs in the values of each of the industry final demands. The letter F is the change vector that indicates the U.S. ATS growth of 10.75% and 0% for each other industry, thus isolating the resulting changes to industry demand attributed to the U.S. ATS industry. The letter x is the resulting vector that indicates the change in output from each industry as a result of the U.S. ATS growth.

The results show a breakdown of the resulting change in industries' output, some positive and some negative. U.S. ATS was a small part of each industry input requirements (Table 3, column 2). Therefore, it was not surprising that the actual percentage change in industries output was overall very small in relative dollar terms. Table 2 details the IO analysis prediction in output changes to U.S. industries as a percentage of the total industries' output, ranked from most positively affected to most negatively affected.

No real emerging trends in industries resulted from this limited analysis, perhaps because ATS is less than 1% of U.S. GDP. The aggregate GDP sectors receiving a positive boost from growth in the U.S. ATS industry were agriculture; mining; transportation & warehousing; and some manufacturing and service industries. The aggregate GDP sectors receiving a negative boost from growth in the U.S. ATS industry were construction; finance, insurance and real estate; wholesale and retail trade; and other service sectors. The overwhelming conclusion is that industries, as expected, did react to the change in the U.S. ATS output growth; however, there was not a dominate trend or conclusion.

4 Labels of Figures and Tables

Table 1: List of countries included in the WIOD

European Union			North America	Asia & Pacific
Austria	Germany	Netherlands	Canada	China
Belgium	Greece	Poland	United States	India
Bulgaria	Hungary	Portugal		Japan
Cyprus	Ireland	Romania		South Korea
Czech Republic	Italy	Slovak Republic	Latin America	Australia
Denmark	Latvia	Slovenia	Brazil	Taiwan
Estonia	Lithuania	Spain	Mexico	Turkey
Finland	Luxembourg	Sweden		Indonesia
France	Malta	United Kingdom		Russia

Table 2: Simple Input Output table for a two-sector economy

	Manufacturing	Services	Final Demand	Total Output
Manufacturing	10	40	50	100
Services	30	25	85	140
Value Added	60	75	135	
Total Output	100	140		240

Table 3: Rankings of industries most affected by a change in U.S. ATS output

Industry	ATS output as a % of total consumption per industry	actual change in industry output from ATS output growth (dollars)	change in industry output as a % of total output
Agriculture, Hunting, Forestry and Fishing	0.06%	$ 1,399	4.085382E-09
Mining and Quarrying	0.07%	$ 4,849	1.388148E-08
Air Transport	0.01%	$ 1,013	7.616072E-09
Inland Transport	0.39%	$ 1,433	4.204925E-09
Rubber and Plastics	0.20%	$ 481	2.869715E-09
Hotels and Restaurants	0.26%	$ 1,361	1.785906E-09
/ehicles and Motorcycles; Repair of Household Goods	0.22%	$ 1,130	9.548743E-10
Electrical and Optical Equipment	0.17%	$ 307	6.337892E-10
Coke, Refined Petroleum and Nuclear Fuel	0.01%	$ 230	4.850066E-10
Pulp, Paper, Paper , Printing and Publishing	0.39%	$ 206	4.834876E-10
Transport Equipment	0.13%	$ 233	3.936979E-10
Other Community, Social and Personal Services	0.40%	$ 143	1.495889E-10
Basic Metals and Fabricated Metal	0.18%	$ 52	1.087461E-10
Health and Social Work	0.19%	$ 101	5.980043E-11
Renting of M&Eq and Other Business Activities	0.61%	$ 80	2.785375E-11
Construction	0.13%	$ (45)	-3.932604E-11
Post and Telecommunications	0.43%	$ (34)	-5.481665E-11
Financial Intermediation	0.39%	$ (143)	-5.891972E-11
Public Admin and Defence; Compulsory Social Security	0.40%	$ (277)	-9.395513E-11
Real Estate Activities	0.06%	$ (255)	-1.107974E-10
Textiles and Textile Products	0.16%	$ (26)	-4.324100E-10
Chemicals and Chemical Products	0.10%	$ (355)	-5.917730E-10
Food, Beverages and Tobacco	0.12%	$ (529)	-6.811546E-10
Manufacturing, Nec; Recycling	0.25%	$ (144)	-1.042271E-09
sion Trade, Except of Motor Vehicles and Motorcycles	0.39%	$ (1,123)	-1.112801E-09
Wood and Products of Wood and Cork	0.20%	$ (206)	-2.614930E-09
Private Households w ith Employed Persons	0	$ (57)	-3.196389E-09
of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.23%	$ (672)	-3.196584E-09
Machinery, Nec	0.16%	$ (1,155)	-4.165974E-09
Electricity, Gas and Water Supply	0.11%	$ (2,363)	-6.098254E-09
Other Non-Metallic Mineral	0.21%	$ (857)	-9.361673E-09
liary Transport Activities; Activities of Travel Agencies	0.41%	$ (2,123)	-1.082168E-08
Education	0.31%	$ (2,569)	-1.147589E-08
Water Transport	0.22%	$ (9,248)	-2.739881E-07
Leather, Leather and Footw ear	0.13%	$ (57,422)	-2.099482E-05

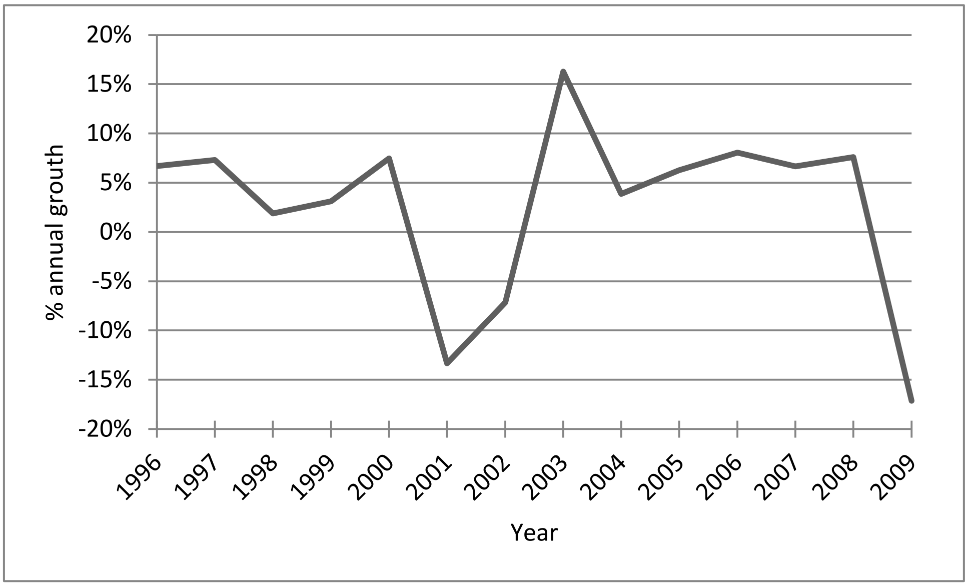

Figure 1: Total air transportation services output growth, year over year

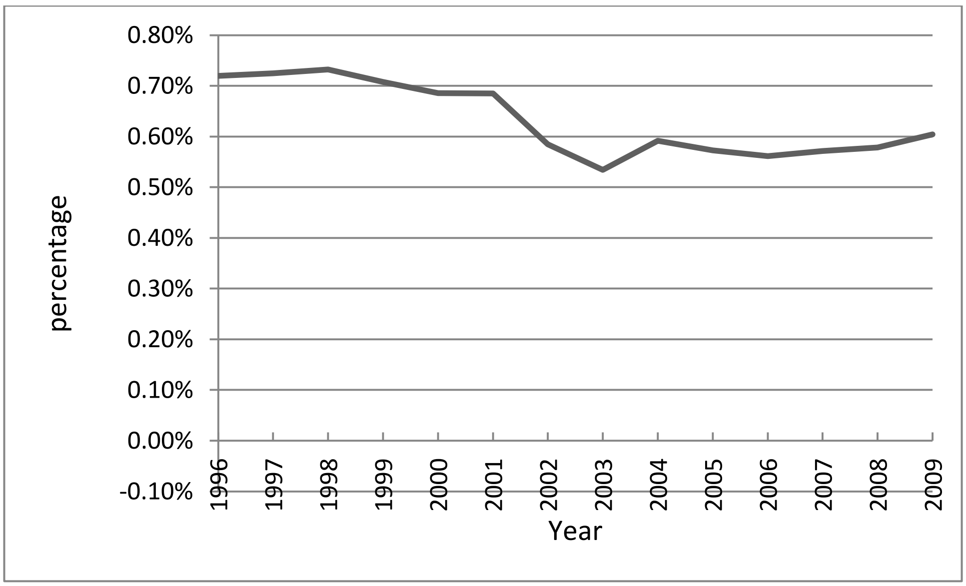

Figure 2: Total air transportation services as a percentage of total US output, yearly

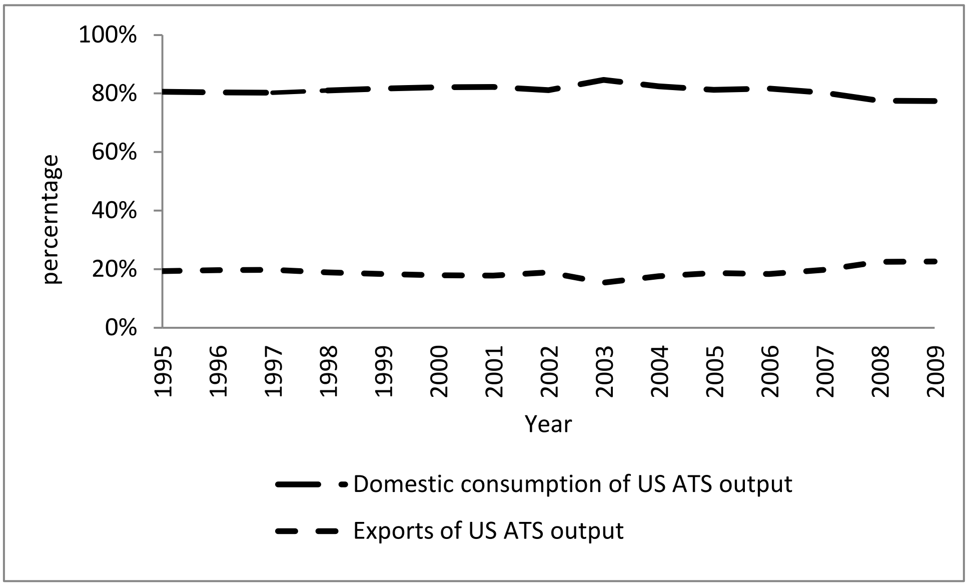

Figure 3: Domestic and export ATC output as a percentage of total U.S. ATC output, yearly

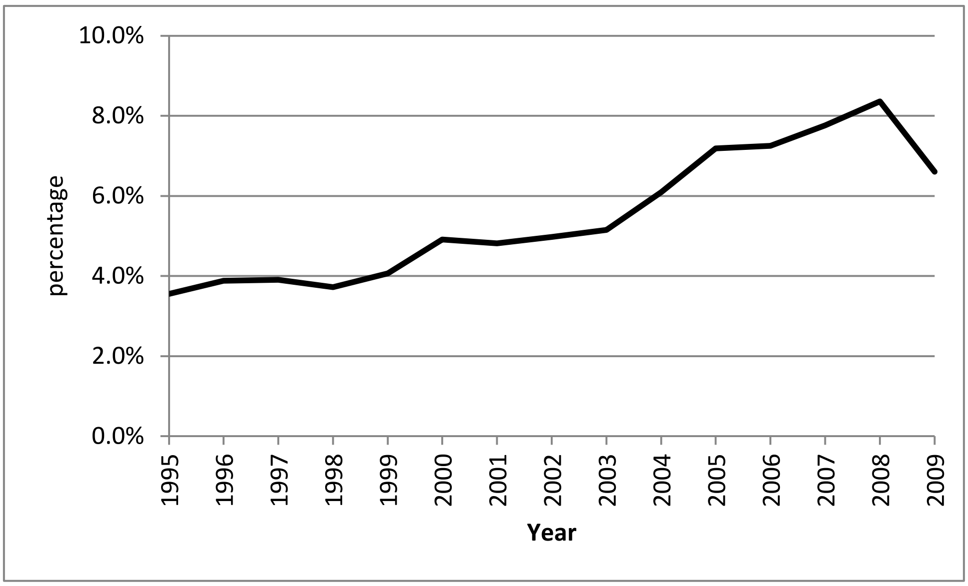

Figure 4: Imports to U.S. ATC industry as a percentage of total US ATC inputs, yearly.

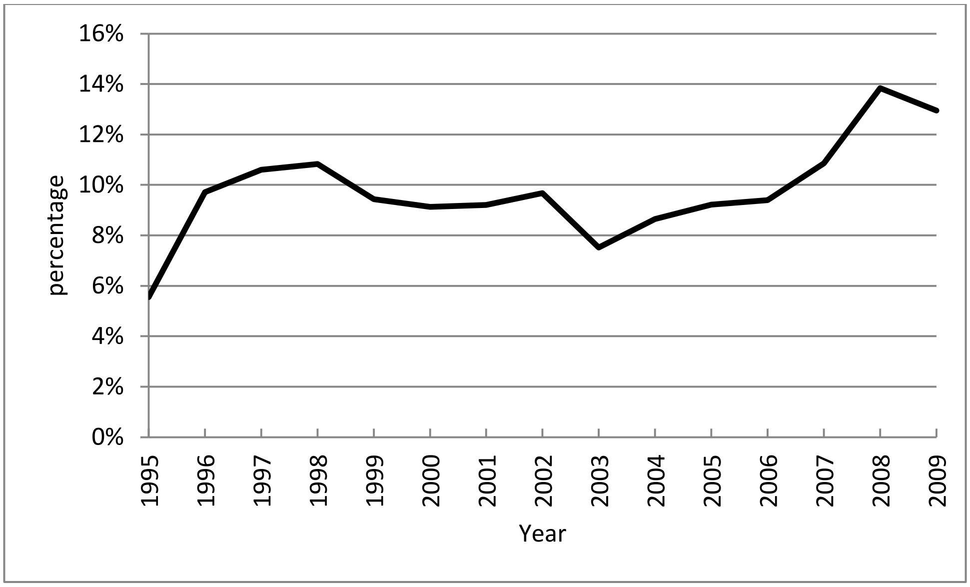

Figure 5: Exports to ROW as a percentage of total U.S. ATS output.

5 Conclusion

It is apparent from this research that additional IO analysis for the aerospace and aviation industries should be done with the WIOD. The above research only included the U.S. ATS sector and did not include the much larger aerospace and aviation manufacturing sector. The WIOD is still the most current IO database, even with the updated benchmark U.S. IO tables due to be released at the end of 2013. Additionally, the benefit of the WIOD is the ability to track trade from industry to industry in 40 countries over a time period.

The U.S. ATS industry is also expanding as private space transportation grows. In October 2012, Space Exploration Technologies (SpaceX), a private company, completed the first of 12 supply runs to the international space station as part of a $1.6B contract. Orbital Sciences is another private company pursuing this business and has a potential $1.9B contract in negotiation [25]. Those two contracts alone would grow the US ATS industry by 3%.

One could estimate the aerospace manufacturing output from the WIOD and do the same industry descriptive analysis as done in this research with U.S. ATS industry. Then, one can conduct an IO analysis for the entire aerospace and aviation industry for a more complete picture of the U.S. economic dependence on the aerospace and aviation industry. An IO analysis using the full aerospace and aviation industry can inform the sensitivity of employment, both U.S. and by state, of other industries to impacts from changes in the aerospace and aviation industry. There are a number of aviation economic impact studies that use IO analysis, but the data they are using is from the 2002 U.S. IO table that represents industry relationships from a decade ago.

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