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Analysis of Industry Linkage and Economic Contribution of Air Transport Industry

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Abstract: The air transport industry is closely related to the development of other industrial sectors and plays a significant role in promoting the economic development of countries and regions. Based on the 2017 input-output tables of China, the author calculates the cumulative input coefficient, cumulative distribution coefficient, pull force coefficient and driving force coefficient, analyzes the techno-economic correlation effect between the air transport industry and its upstream and downstream industries, and further accurately calculates the economic contribution to the national economy, finally puts forward some suggestions on the development of the air transport industry.

1. Introduction

In response to the negative impact of the economic downturn and the outbreak of COVID-19, the government has implemented New Infrastructure Construction and Dual Circulation successively in 2020 to ensure effective demand expansion, stability in employment, growth expectations in short term and achieve effective economic growth in long term. As a strategic industry of national economy, the air transport industry is a significant area for implementing New Infrastructure Construction and other policies. The air transport industry owns high-level informatization among transport industries, is armed with cutting-edge technology and has close connections with other industrial sectors. In addition to its own contribution to the economy, it also promotes economic and social development through its high-degree industrial associations. To accurately assess the significance of the air transport industry in the national economy, the author measures the industrial correlation effect of the air transport industry and its contribution to the economy by utilizing input-output analysis.

In the past two decades, many domestic scholars have utilized input-output analysis to research on industrial correlation and economic contribution of air transport industry. Wand and Xie [1]

analyzes the connection between the civil aviation industry and other industries of national economy based on 2002 input-output table. Niu [2] compares and analyzes the final product structure of civil aircraft manufacturing and civil aviation transport industry as well as economic correlation between them. Zhang [3] compares changes of the economic correlation between the air transport industry and other industries based on analyzing of the 2002 and 2007 input-output tables. Zeng *et al.* [4] investigate the direct and indirect contributions of air transport industry in Chongqing to local economy based on 2007 input-output table of Chongqing. Sun [5] evaluates the social and economic value of Tianjin Airport by utilizing input-output analysis and comprehensive assessment. Scholars above all used the traditional coefficient algorithm in analysis. Based on improved input-output correlation coefficient, this paper uses 2017 input-output table to analyze the industrial correlation and contribution of air passenger transport and air freight transport respectively, reflecting the economic and technical connections between sectors more accurately.

2. Correlation effect analysis

The correlation effect of air transportation on related industries is mainly reflected in pulling effects on upstream industries and pushing effects on downstream industries.

2.1. Pulling Effects on Upstream Industries

Productive activity in the air transport industry directly pulls intermediate inputs in other production sectors, promotes their production expansion and brings them more benefits. The expansion of production in these sectors creates further demand for intermediate inputs in some other sectors, thereby encouraging production expansion in others. The relationship between the air transport industry and the sectors that provide the intermediate products required by transport production is called upstream industry correlation. The effect caused by the air transport industry's demand for products from other sectors as intermediate inputs, is called backward pulling effect on the upstream industry. In general, the pulling effect is measured by three indicators: direct input coefficient, cumulative input coefficient and pulling force coefficient.

- Cumulative input coefficient in the air transport industry

Based on the direct input coefficient, the cumulative input coefficient represents the total consumption of goods or services of sector *i* whenever a unit output produced from sector *j*.

$$b_{ij} = a_{ij} + \sum_{k=1}^{n} b_{ik} a_{ki} \quad (i,j = 1,2,...,n) \tag{1}$$

In the equation (1), b_{ij} denotes cumulative input coefficient, and $a = \frac{x_{ij}}{x_j}$ denotes direct input coefficient. In the matrix form, $B = (I - A)^{-1} - I$, and $\bar{B} = (I - A)^{-1}$ is Leontief inverse matrix.

Table 1 lists the top 10 sectors strongly affected by the pulling force of the air transport industry. As shown in the table, cumulative consumption for manufacturing of refined petroleum products, processing of nuclear fuel, its own sector, extraction of crude petroleum and natural gas and other sectors is large. The development of the air transport requires a large amount of input in raw materials such as oil, electric power, coal, aviation infrastructure and equipment, and needs the support of business services such as enterprise management and maintenance, procedures and settlement and conference services. Meanwhile, the emergence of financial leasing of aircraft and aviation fuel import also play a significant role in developing monetary intermediation and capital services. Considering air passenger transport and air freight transport respectively, in addition to the above common industries, air passenger transport has a strong pulling effect on information

technology services, and air freight transport on the manufacture of electronic components and parts.

Table 1: Top 10 sectors in cumulative consumption coefficient of air transport in 2017

Sector	**air transport industry**	**Sector**	**air passenger transport**	**Sector**	**air freight transport**
Manufacturing of Refined Petroleum Products, Processing of Nuclear Fuel	0.1819	Manufacturing of Refined Petroleum Products, Processing of Nuclear Fuel	0.2075	Manufacturing of Refined Petroleum Products, Processing of Nuclear Fuel	0.1384
Air Transport	0.1429	Air Transport and its supporting activities	0.153	Air Transport and its supporting activities	0.1110
Extraction of Crude Petroleum and Natural Gas	0.1053	Extraction of Crude Petroleum and Natural Gas	0.1196	Monetary Intermediation and Capital Services	0.0919
Business Services	0.0921	Business Services	0.0937	Business Services	0.0894
Monetary Intermediation and Capital Services	0.084	Monetary Intermediation and Capital Services	0.0794	Extraction of Crude Petroleum and Natural Gas	0.0811
Manufacture of Other Transport Equipment	0.0538	Manufacture of Other Transport Equipment	0.0686	Manufacture of Electronic Components and Parts	0.0477
Retail Trade	0.0454	Retail Trade	0.0489	Production and Supply of Electricity and Steam	0.0461
Production and Supply of Electricity and Steam	0.0418	Production and Supply of Electricity and Steam	0.0393	Food and Beverage Services	0.0414
Food and Beverage Services	0.0383	Information Technology Services	0.0379	Real Estate	0.0404
Wholesale	0.0364	Wholesale	0.0374	Retail Trade	0.0395

- Pull force coefficient of the air transport industry

The pulling force coefficient is a modification of the traditional influence coefficient. The algorithm of the traditional influence coefficient is as follows:

$$F_j = \frac{\sum_{i=1}^{n} \bar{b}_{ij}}{\frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n} \bar{b}_{ij}} \quad (i,j = 1,2,...,n) \tag{2}$$

This method is based on the operation of the Leontief inverse matrix which can also be called as the complete demand matrix. Its element $\bar{b}_{ij}$ is Leontief inverse coefficient, which represents the

complete demand for the products or services of the sector *i* pulled by a unit final use created from the sector *j*.

This article adopts the improved algorithm advocated by Professor Q. Liu [6]:

$$F_j^{'} = b_{sj} \Big/ \sum_j b_{sj}\alpha_j \ \ (j = 1, 2, ..., n) \tag{3}$$

The numerator $b_{sj} = \sum_{i=1}^{n} \bar{b}_{ij}$ has the same algorithm as in the traditional influence coefficient, which means when sector *j* create a unit final use, how much output demand of all the department is being pulled.

While the denominator is changed to a weighted average, the final product structure coefficient is added as weight, as shown in equations (4) and (5), indicating that under a specific final product structure, each sector of the national economy increases by one final use unit the average of the demand for the total output of each sector.

$$\alpha_j = y_j \Big/ \sum_j y_j \ (j = 1, 2, ..., n) \tag{4}$$

$$\sum_j \alpha_j = 1 \tag{5}$$

y_j denotes the final use of the sector *j*, $\sum_j y_j$ denotes the total final use of all the department.

Based on calculation, the pulling force coefficient of the air transport in 2017 is 1.0032, which is greater than 1, indicating that the pulling effect of the air transport industry is above the average level of all sectors. It is worth noting that although the driving force coefficient ranks 89th among 148 sectors, most of the sectors with a coefficient greater than 1 belong to the secondary industry. The air transport pulling force coefficient Ranked 6th among the tertiary industry, which means compared to most of the tertiary industry sectors and some of the secondary industry sectors, the air transport industry has a strong pulling effect on the economy.

2.2. Pushing Effect on Downstream Industries

The air transport industry provides transportation services for other sectors, thus creating favorable conditions for their production expansion. For the production of these sectors, the products of the air transport industry are essential intermediate inputs. The expansion of production in these sectors lead to corresponding growth in other sectors that regard the product or services of these sectors as their intermediate inputs, thus bringing more benefits to more sectors. The relationship between the air transport industry and the sectors which take goods or services of the air transport as intermediate inputs is called downstream industry correlation. The effect where other sectors' demand for products or services from the air transport industry as intermediate inputs is called forward pushing effect on the upstream industry. In general, the indicators to describe the pushing effect are: direct distribution coefficient, cumulative distribution coefficient and diffusion coefficient.

- Cumulative distribution coefficient in the air transport industry

The construction of the cumulative distribution coefficient is similar to that of the cumulative consumption coefficient, but in an inverse dimension way. Cumulative consumption coefficient reflects the intermediate input of each sector to a specific sector from the column perspective, in contrast, the cumulative distribution coefficient reflects a specific sector's product flow and distribution from the horizontal perspective based on the direct distribution coefficient.

$$D=(I-H)^{-1}-I \tag{6}$$

In the equation (6), D denotes cumulative distribution coefficient matrix. H denotes direct distribution coefficient matrix.$h_{ij}=x_{ij}/X_i\ (i,j=1,2,....,n)$, represents the proportion of intermediate goods or services supplied by sector *i* flow to sector *j*.

Table 2 lists the top 10 sectors in 2017 strongly driven by the air transport industry. The air transport industry plays the strongest role in promoting business services, public management and social organization and itself. There are significant differences between air passenger transport and air freight transport: in addition to common industries, air passenger transport greatly promotes the development of education and professional technique services, while air freight transport significantly promotes the development of aviation itself, postal, manufacture of electronic components and parts and whole automobile.

Table 2: Top 10 sectors in cumulative distribution coefficient of air transport in 2017

Sector	**air transport industry**	**Sector**	**air passenger transport**	**Sector**	**air freight transport**
Business Services	0.2862	Business Services	0.4283	Air Passenger Transport	0.1910
Public administration and social organization	0.1764	Public administration and social organization	0.2683	Wholesale	0.1222
Air Transport	0.1429	House Building	0.1332	Business Services	0.1163
Business Services	0.1184	Education	0.1217	Air Transport and its supporting activities	0.1110
Wholesale	0.0990	Monetary Intermediation and Capital Services	0.1216	Postal	0.1084
Monetary Intermediation and Capital Services	0.0861	Civil Engineering Building	0.0841	House Building	0.1007
Education	0.0797	Wholesale	0.0796	Public administration and social organization	0.0665
Civil Engineering Building	0.0674	Professional Technical Service	0.0786	Retail Trade	0.0659
Retail Trade	0.0656	Real Estate	0.0715	Electronic Components	0.0538
Professional Technical Service	0.0572	Retail Trade	0.0654	Whole Automobile	0.0497

- Driving force coefficient of air transport industry

The driving force coefficient is a transformation of the traditional sensitivity coefficient. The algorithm of traditional sensitivity coefficient is:

$$E_j = \frac{\sum_{j=1}^{n} \bar{b}_{ij}}{\frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n} \bar{b}_{ij}} \quad (i,j = 1,2,...,n) \tag{7}$$

In order to show the driving force of a certain sector, this article uses the method of improving the sensitivity coefficient by constructing a complete supply matrix $\bar{D} = (I - H)^{-1}$ [6]. It is symmetrical with Leontief inverse matrix whose matrix element represent the complete supply for sector *j* by adding an initial input of sector *i*. The improved formula for calculating the driving force coefficient is:

$$E^{'} = d_{it} \Big/ \sum_{i} \beta_i d_{it} \tag{8}$$

The numerator $d_{it} = \sum_{j=1}^{n} \bar{d}_{ij}$ is the summation of the rows of the complete supply matrix, which represents the total complete supply of each department driven by adding one initial unit input of sector *i*.

While the denominator is also a weighted average, that is adding the initial input coefficient as the weigh, indicating that under a specific initial input structure, each sector of the national economy increases by one initial input unit the average of the supply of all the sectors.

Based on calculation, the driving force coefficient of the air transport industry in 2017 is 1.3823, which is greater than 1, indicating that the driving force of the air transport industry is greater than the social average driving force, and this coefficient ranks 27th among 148 sectors. Similarly, industries with a large driving force coefficient mainly belong to secondary industries, and the air transportation industry's driving force coefficient ranks third in the tertiary industry.

3. Analysis of economic contribution

The added value of the air transport industry in 2017 reached 291.46 billion yuan, ranking 67th among all the industries. Meanwhile, the air transport industry makes lots of contributions to the economy due to its industrial correlation.[1]

3.1. Backward Pulling Contribution to Upstream Industries

In the process of producing goods or services, the air transport industry consumes the products of manufacturing of refined petroleum products, processing of nuclear fuel, manufacture of other transport equipment, extraction of crude petroleum and natural gas and other sector, thus in turn promotes these sector's development and make more economic contributions beyond its own contribution.

$$Z_1 = z^{'} B \triangle Y = z^{'} (I - A)^{-1} \triangle Y - z^{'} \triangle Y \tag{9}$$

In the equation (9), $\triangle Y = (0,0,...,1,...,0)^T$ devotes the final use of the air transport is one unit while other sectors have no final use. $z^{'}$ devotes the row vector of added value coefficient matrix of each sector. Z_1 devotes the economic added value of backward industry driven by the addition of a final

[1]Since this paper mainly focus on correlation between the air transport and other industries, the author only utilizes the framework of static open loop analysis to calculate Leontief multiplier effect. Besides, the author does not take Keynesian multiplier effect into consideration, because from generalized Keynesian multiplier, generalized closed-loop Keynesian multiplier is equal for each sector, that is, national income increase driven by one unit of final is equal.

use by the air transport industry, which deducts the total product of one unit of air transport.

Based on calculation, the backward industry pulling contribution coefficient in 2017 is 0.65, which indicates that a 10-billion-yuan increase in the final use in the air transport industry will bring 6.5 billion yuan of backward industry pulling contribution. In 2017, the final use of the air transport industry was 335.51 billion yuan, and its contribution to the backward industry reached 218.08 billion yuan.

3.2. Forward Driving Contribution to Downstream Industries

The air transport industry provides aviation services to different sectors such as business services, public management, and education, etc. Thus promoting more economic contribution of these sectors.

$$Z_2 = z^{'} D \triangle X \tag{10}$$

In the equation (10), $\triangle X = (0, 0, ..., 1, ..., 0)^T$ represents the initial input of the air transport which is one unit, while other sectors have no initial input. $z^{'}$ devotes the row vector of added value coefficient matrix of each sector. Z_2 devotes the forward driving contribution of air transport industry.

Based on calculation, the forward industry driving contribution of the air transport industry reached 131.16 billion yuan in 2017. And the forward industry driving contribution coefficient value was 0.45, which means that for every 10 billion added value in the air transportation industry, there is a 4.5 billion forward-driving contribution to the downstream industry.

4. Conclusion and Proposal

In terms of the overall economic contribution, the added value of the air transport industry, that is, the direct contribution to national economy, reached 291.46 billion yuan in 2007, while the indirect economic contribution reached 394.23 billion yuan which is 1.2 times of the direct contribution. Meanwhile, the final consumption of the air transport industry contributes a lot. The expenditure on consumption accounts for 49% of the final use, which ranks 64th and is higher than the industry average of 45.7%. Therefore, it is encouraged to continue to increase investment in the air transport industry.

The added value of air passenger transport in 2017 is 151.96 billion yuan, while the added value of air freight transport and its supporting activities in 2017 is 139.5 billion yuan. Workers compensation in air passenger transport and air freight transport is 57.75 billion yuan and 58.71 billion yuan respectively. The operating surplus of air passenger transport reaches 151.96 billion yuan and that of air freight transport reaches 139.5 billion yuan. Both air passenger transport and air freight transport are equal in terms of the added value, household income and enterprise surplus. Therefore, air passenger transport and air freight transport should develop simultaneously and the idea of “Emphasizing on air passenger transport while disregarding air freight transport” should be changed. Besides, in terms of air passenger transport, import greatly exceeds export, which means Chinese residents’ expenditures on service of foreign aviation enterprises are more than expenditures of foreign counterparts on service of domestic aviation enterprises. Thus Chinese airlines should keep improving passenger’s travel experience and enhancing service quality. Also, Chinese airlines should provide passengers with accurate information and comfortable travel services to enhance their international competitiveness by making use of modern digital technology and intelligent equipment.

From the perspective of industrial connection, the development of civil aviation industry mainly depends on traditional industries instead of emerging industries. It is necessary to promote the

digitalization, intelligent transformation and intellectual upgrade of civil aviation, to accelerate the deep integration of traditional and new infrastructure and promote the high-quality development of aviation infrastructure.

Promoting industries' development by either air passenger or freight transport creates comparatively large difference, air passenger transport promotes high-end services such as business, public management, education and finance, while air freight promotes high-tech and high-value manufacturing such as electronic production and vehicle manufacturing. At present, domestic manufacturing is moving towards the high-end of industrial chain, which requires support from high-quality aviation logistics. Therefore, we need to attach great importance to the development of air freight transport and enhance its door-to-door serviceability. Besides, the further development of air freight transport also relies on manufacturing upgrading, so we should optimize the industrial layout centring on the air freight hub and promote the deep integration of the aviation industry and high-end manufacturing.

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