Study on the Influence Mechanism of the Development of China's Civil Aviation Transport Industry on the Upgrading Of Industrial Structure

Guodong Li[1], Yang Chen[2]*, Youzhi Xue[3], Long Dai[2], Xiangran Zheng[2], Shuting Yang[2], Meng Shao[4], Zongwei Li[4]

[1]College of Economics and Management; China Civil Aviation High-quality Development Research Center, Civil Aviation University of China, Tianjin, China

[2]College of Economic and Management, Civil Aviation University of China, Tianjin, China

[3]Business School；China Academy of Corporate Governance, Nankai University, Tianjin , China

[4]College of Transportation Science and Engineering, Civil Aviation University of China, Tianjin, China

*Corresponding Author: 986645148@qq.com

DOI: https://doi.org/10.30212/JITI.202503.002

Submitted: Dec. 09, 2024 Accepted: Feb. 01, 2025

ABSTRACT

China is currently in a critical period of transforming its development model, optimizing economic structure, and shifting growth dynamics. Addressing the issue of how to achieve industrial structure upgrading is an urgent task for the country. In the past, most of the literature focused on high-speed railway and road transport, and there is a scarcity of articles related to the civil aviation transport industry. The rapid development of the civil aviation industry in recent years has triggered population mobility, capital introduction, and scientific and technological innovation, which is of great significance to the upgrading of industrial structure. This paper takes the civil aviation transport industry as a breakthrough and explores the promotion effect of emerging civil aviation transport modes on industrial structure upgrading, which is quite innovative. This study employs panel data from Chinese cities from 2008 to 2019 to empirically examine the impact of civil aviation development on industrial structure upgrading. The findings indicate: (1) The development of civil aviation significantly promotes urban industrial structure upgrading. (2) A study of the mechanisms shows that civil aviation has a main effect on industrial upgrading by encouraging the pooling of labor and capital and improving the region's scientific and technological innovation capabilities. (3) In terms of industry heterogeneity, civil aviation impacts industrial development by promoting the growth of accommodation and catering, wholesale and retail, and finance sectors. In the Northeast, Central South, North China, East China, Southwest, Xinjiang, and Northwest regions, the effect of civil aviation on industrial structure decreases more slowly than in other regions. Period heterogeneity indicates a decreasing trend in the influence of civil aviation on industrial upgrading over time.

Keywords: Civil aviation transport, Industrial structure, Upgrading influence mechanism.

1. Introduction

Since 2021, China has entered a new stage of development— that is, from the stage of high-speed growth to the stage of high-quality development [1, 2]. Industrial structure upgrading is an important way to achieve high-quality economic development [3].

Kuznets' theory says that industrial structure upgrading happens when the share of primary industry in the national economy keeps going down while the share of secondary and tertiary industries, especially tertiary industries, keeps going up [4]. Some researchers think that improving the structure of industries doesn't just mean making tertiary industries bigger in the national economy [5]. They also think that it means changing and improving the manufacturing industry so that the share of industries that depend on labor goes down and the share of industries that depend on capital goes up [6, 7, 8], and the share of industries that depend on productive services goes up [9].

A lot of studies have shown that improving transportation infrastructure will help regional economic growth. It has a lot of different effects, such as making regional trade more active [10], making the manufacturing value chain better [11], and speeding up the flow of production factors [12]. Among them, many studies show that transportation can affect economic development by promoting the upgrading of industrial structure [13, 14, 15].

As a transportation infrastructure that plays a key role in the integrated transportation network, civil aviation is an important part of the modern integrated transportation system [16], which is of immense significance to promoting regional coordination and high-quality development [17, 18]. Getting the civil aviation economy growing and developing faster is a keyway to help improve the structure of industries and speed up the change in the way economies grow [19]. The relationship between the industrial structure and the civil aviation transport industry reveals a long-term co-integration between the civil aviation transport industry and the secondary and tertiary industries [20]. In promoting regional economic development, the civil aviation transport industry plays an increasingly important role. From the perspective of the industrial ripple effect, the civil aviation transport industry has the largest impact on the output value of the manufacturing industry. In terms of price, the price fluctuation of the civil aviation transport industry has the greatest impact on the manufacturing industry, followed by the tourism industry [21].

At present, there are few relevant studies on the relationship between civil aviation and regional industrial structure upgrading, and most of them focus on the relationship between input and output of civil aviation transport. This study mainly discusses the influence mechanism between the civil aviation transport industry and urban industrial structure. Firstly, we evaluate the overall effect of the development of civil aviation transport on the industrial structure by using urban panel data. Next, we use the traditional production function model to talk about in detail how the growth of the civil aviation transport industry helps to improve the regional industrial structure. We also do heterogeneity analysis based on various situations. This study can look at the effects of civil aviation on improving industrial structure using numbers. It can also help to make sense of the role of the civil aviation

industry in the strategic industry and give more specific advice on how to change and improve the regional industrial structure and build stronger civil aviation infrastructure.

2. Research Hypothesis and Research Design

2.1 Research Hypothesis

The development of the civil aviation transportation industry can significantly improve the accessibility between cities. According to statistics on the official website of the Civil Aviation Administration of China, in 2023, the industry carried 619.5764 million passengers, an increase of 146.1 percent over the previous year; domestic routes transported 590,516,900 passengers, up 136.3 percent over the previous year. The increase in passenger traffic brought about consumer demand, which in turn promoted urban economic growth, especially the development of the service industry. Wang Jianyu [22] found that the six sectors with the largest consumption in the civil aviation industry belong to the tertiary industry, namely wholesale and retail trade, public administration and social organizations, finance and insurance, civil aviation, leasing and business services, and education. The direct consumption of these six sectors on the civil aviation industry accounts for nearly half of the intermediate products provided by the civil aviation industry, accounting for 49.69%. It is impossible to separate the operation of these industries from the passenger flow that the civil aviation industry brings.

Business passengers are an important part of civil aviation passengers. The civil aviation transportation industry has improved the communication convenience and transportation accessibility of business passengers and has saved time and brought information. This reduces the investment risk for business travellers and brings investment, employment, and output to cities. For example, Yu Jian [23] finds that convenient transportation accelerates the intra-regional and inter-regional flow of investors. At the same time, the regional civil aviation transport network forms a huge civil aviation transport network with the widely established navigation routes in developed countries abroad and developed regions in China, which will also attract investors from other countries or regions to invest in the region. Jiang Yue [24] found that production service sectors like logistics, exhibition, training, finance, and consulting tend to gather in airport economic zones because airports with hub functions are easy to get to from all over the world and can handle a lot of passengers and cargo. To sum up, it is expected that the development of the civil aviation transport industry will play a positive role in the upgrading of the urban industrial structure.

Based on the above analysis, this study puts forward the following empirical research hypothesis: The development of the civil aviation transport industry will help promote the upgrading of the urban industrial structure. This is mainly because the development of the civil aviation transport industry promotes the frequent flow of people and brings the injection of advanced technology and capital.

2.2 Data Source and Variable Selection

Considering the late development of civil aviation in China, which entered the golden decade of China's aviation development only after the financial crisis in 2008, and that China's air passenger transport market has been severely hit since 2020 because of the impact of the New Crown Epidemic,

this study adopts Chinese city panel data from 2008 to 2019. In the empirical test, only the sample of prefecture-level cities with airports and civil aviation transport routes was selected, and some samples of prefecture-level cities that lacked statistical data were excluded, so the sample included 103 cities at prefecture level and above, covering 31 provinces, autonomous regions, and municipalities directly under the central government in China.

2.2.1 Explanatory variables

This study uses the scale of civil aviation transport as an indicator to measure the development level of the urban civil aviation transport industry, which covers two core transport measures: passenger throughput and cargo throughput. This is how Airports Council International figures out how busy an airport is every year: 1 workload unit = 1 passenger + 0.1 t of cargo. This means that an airport's annual workload is equal to the sum of its annual passenger throughput and annual cargo throughput times 10 [25, 26]. The letter "work" denotes the logarithmic treatment of the airport's annual workload. We obtain the annual passenger throughput and cargo throughput data from the "Civil Aviation Airport Production Statistical Bulletin."

2.2.2 Explained variables

This study uses the industrial structure index as the explained variable to measure the development level of urban industrial structure. The construction of industrial structure index refers to the methods of existing literatures, and is based on Kuznets' theory of industrial structure change. It is calculated by giving weight to the increasing output value of the primary industry, the secondary industry and the tertiary industry [27]. The data of the proportion of each industrial structure in a city comes from China Urban Statistical Yearbook.

$$\text{index inde} = \sum_{j=1}^{n} \binom{n}{j} \text{j} \times \text{P}_\text{j} \quad \text{[Formular 1]}$$

Pj: the proportion of the output value of the JTH industry in the total output value.

j: The value of this index ranges from 1 to 3, and the larger the value, the higher the level of industrial structure

2.2.3 Control variables

Based on other factors that may affect the development level of industrial structure, the following control variables are selected in this study. The first is the variable used to measure the characteristics of urban economic development. We obtained the following data from the China Urban Statistical Yearbook and processed them logarithmically.

(1) Economic development level (GDP), measured by the gross urban product [28]

(2) Level of opening up to the outside world (fore), measured by the amount of foreign capital actually used by a city [29]

(3) Local income level (wage), measured by the average wage of urban workers [30]

The second is the variable used to measure the level of urban resource endowment. We have processed the following data logarithmically from the China Urban Statistical Yearbook:

(1) The labor force is measured by the number of urban workers [31, 32].

(2) Technical resources (scie), measured by the number of employees in scientific research and technical services [33]

(3) Government support (reve), measured by the proportion of government fiscal expenditure to GDP [34]

(4) Human resources (coll), measured by the number of students in urban colleges and universities [35,36]

(5) Tourism resources (tour), measured by the number of 5A-level scenic spots in a city, data collated from the official website of the Ministry of Culture and Tourism [37,38]

We also add the HSR opening status (HSR) as a control variable [39, 40]. This is because high-speed rail and civil aviation are strong competitors and work well together. We collect data from the Special Issue of Railway Passenger and Cargo Transport to determine whether high-speed rail is open in each city annually.

2.2.4 Mechanism variables

According to the Solow model, economic growth is primarily driven by growth in labor, capital, and technology [41]. According to the research of Fang Fuqian and Fu Qi [42], since 2000, the coupling coordination degree between China's industrial structure and economic growth has been synergistic. In particular, the economic growth rate will rise by 11.4741 units when the level of upgrading industrial structure goes up by 1 percentage point. Of these, 11.5540 units will be the direct effect.

Transportation can improve the speed and frequency of population flow, reduce the flow cost, and improve the allocation efficiency of the labor force [43, 44]. The civil aviation transportation industry, as a transportation facility, can promote the flow of people by promoting the flow of people [45].

The development of the air transport industry requires a large number of aircraft and advanced equipment and technology, which will bring more investment in related industries [46, 47]. And, by attracting talent, the air transport industry can bring more investment opportunities and advanced technologies to the city, promoting the flow of information and capital accumulation in the city.

To sum up, the development of the civil aviation transport industry contributes to the improvement of factor allocation efficiency, which can be reflected in the optimization of resource allocation efficiency of labor, capital, and innovative technology, thus driving economic growth and upgrading the industrial structure. Therefore, this study chooses these three factors to carry out mechanism analysis. In the traditional production equation Y=AF (L, K), labor L is generally expressed by the number of employed people, capital K is expressed by the capital stock, and technological progress A cannot be directly observed, and is usually estimated by fitting the residual difference between the output value of labor and capital and the actual output. When measuring labor force elements, this study follows the method of existing literature, that is, the number of employees in the tertiary industry; Because the process of directly calculating the capital stock is complicated, and there are high requirements on data and assumptions, this paper chooses the fixed assets investment as an alternative index to measure the capital. The number of employees in the scientific

research and technical service industry is chosen as the substitute index.

2.3 Model Setting

This paper uses panel data and selects the dual fixed effect model to test the research hypothesis, that is, to explore the effect of the development of civil aviation transport industry on the upgrading of industrial structure:

Y_it =Alpha_0 +Alpha_1 Work_it + Alpha_2 X_it + U_i + R_i + Epsilon.....[Formular 2]

Yit: the industrial structure index of city i in year t

Workit: the annual airport workload of city i in year t

Xit: the control variables of city i in year t, including the level of economic development, the level of opening up to the outside world, the level of local income, the number of labor force, technical resources, government support, human resources, tourism resources, and the opening of high-speed rail

Ui: the city fixed effect

Ri: the time fixed effect

Epsilon: the random disturbance term, and the standard errors are clustered at the city level when the model is estimated

Alpha1: the impact of the development of civil aviation transportation industry on the upgrading of urban industrial structure

3. Empirical Test and Result Analysis

3.1 Descriptive Statistics

The descriptive statistics of the variables involved in this study are shown in Table 1. The descriptive statistical value of the industrial structure index of 285 prefecture-level cities in China is introduced for comparison and expressed by Inde-all.

In this paper, cities with airports and open-air routes are civil aviation cities, and cities without airports or airports but not open-air routes are called non-civil aviation cities. According to the statistical results, the maximum industrial structure index of civil aviation cities is 283.2, the minimum is 207.9, the mean is 246.07, and the variance is 14.58; the industrial structure index for non-civil aviation cities is 283.2 at the maximum, 172.14 at the minimum, 241.63 at the mean, and 161.32 at the variance.

By comparing the industrial structure index of civil aviation cities with that of non-civil aviation cities, it can be found that Beijing is the maximum in both samples. The average and minimum values of the industrial structure index in the civil aviation city are both higher than those in the non-civil aviation city. The minimum values are also very different, which suggests that the civil aviation transport industry can help improve the industrial structure of cities in a big way. The descriptive statistical structure of other variables is also within a reasonable range.

Table 1. Descriptive statistics

Variables	Observed	Mean	Standard	Minimum	Maximum
Inde	1236	246.0741	14.57569	207.9	283.2
Work	1236	14.19731	2.133511	6.068426	18.90539
Hsr	1236	0.4409385	0.4967005	0	1
Gdp	1236	16.16777	1.354974	12.37067	19.75978
Fore	1236	9.921672	2.327027	0.693147	14.94127
Wage	1236	10.84862	0.4020561	9.680125	12.06223
Labor	1236	13.28145	1.212758	9.539644	16.66568
Scie	1236	8.857941	1.522601	4.60517	13.48304
Reve	1236	0.1870751	0.2183131	0.000013	5.053074
Coll	1236	11.22186	1.401028	7.029973	13.95787
Tour	1236	0.8834951	1.219684	0	9
Inde-all	3420	241.6348	161.323	172.14	283.2

Source: By authors.

In conjunction with the air express, the cities with higher frequency of air express access are generally consistent with those with better air access in Table 1, all of which are international hubs in the airport clusters. But there is still much room for further development of air access and express construction in these cities. Table 2 shows the average daily frequency of air express routes between international aviation hubs within the four world-class airport clusters from 2015 to 2019. The frequency of flights between the six international aviation hubs has increased from 729 flights in 2015 to 835 flights in 2019, an increase of only 14.54%, whereas the national frequency has increased by as much as 35.03% in the same period. Figure 1 visualizes the average daily frequency of air express flights between Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu and Chongqing in 2019, showing that there is a serious imbalance in the efficiency of air operations between the six international aviation hubs within the world-class airport clusters. Air operation frequency of Beijing-Shanghai is much higher than that of Beijing-Guangzhou, Beijing-Shenzhen, Beijing-Chongqing and Beijing-Chengdu, while air operation frequencies of Shanghai-Beijing, Shanghai-Guangzhou, and Shanghai-Shenzhen are much higher than that of Shanghai-Chongqing and Shanghai-Chengdu.

3.2 Baseline Regression

Table 2 reports the baseline regression results of the impact of the air transport industry on the coordinated development of the regional economy. Among them, column (1) does not add control variables and fixed effects; column (2) adds control variables; column (3) further controls for individual and year fixed effects. According to the regression results, the estimated coefficients are significantly positive at the 1% level, indicating that the development of the civil aviation transport industry has significantly promoted the upgrading of the industrial structure. Therefore, this study has confirmed its hypothesis. From the estimation results of other control variables, it can be seen that the opening of high-speed railways, the improvement of economic development level, the enhancement of foreign capital utilization ability, the improvement of income level, the improvement of scientific and technological innovation ability and the increase of the number of talents have significant promoting effects on the improvement of the industrial structure index. The synergistic effect of high-speed rail and the civil aviation industry improves regional accessibility and promotes the agglomeration and optimal allocation of resources. Higher economic levels have increased capital

accumulation and provided a material basis for industrial upgrading. A better ability to utilize foreign capital requires capital, advanced technology, and management experience. With rising income levels, the domestic market expands, and consumption patterns are upgraded accordingly, which provides support for industrial transformation and upgrading. At the same time, the enhanced ability of scientific and technological innovation has directly promoted technological progress and spawned new industrial fields. In addition, the growth in the number of talents helps to enhance human capital and optimize the structure of the labor force, which in turn promotes the vigorous development of the modern service industry.

Table 2. Baseline regression results

Variables	(1) inde	(2) inde	(3) inde
work	3.786 ***	2.848 ***	2.845 ***
	(23.390)	(11.238)	(11.227)
hsr		2.969 ***	3.015 ***
		(3.472)	(3.470)
gdp		8.135 ***	8.491 ***
		(-8.817)	(-9.108)
fore		1.262 ***	1.318 ***
		(4.919)	(5.125)
wage		11.673 ***	13.273 ***
		(9.313)	(6.129)
labor		-0.778	-0.649
		(-0.895)	(-0.743)
scie		3.357 ***	3.443 ***
		(6.119)	(6.288)
reve		-2.095	3.275 *
		(-1.297)	(-1.815)
coll		2.409 ***	2.279 ***
		(4.960)	(4.681)
tour		0.223	0.232
		(0.716)	(0.749)
cons	192.317 ***	150.453 ***	137.531 ***
	(82.752)	(12.774)	(6.668)
N	1236	1236	1236
R^2	0.307	0.429	0.387
F	547.112	91.876	76.798

Source: By authors.

3.3 Robustness Test

The main independent variable and the dependent variable are swapped out in the alternative variable method, which is one of the most important ways to test how stable the econometric model is. In this research model, it is difficult to find a suitable replacement variable for the explained variable airport workload, and the volume of civil aviation passengers, cargo and mail transportation and turnover cannot be counted according to the city, so we do not consider the replacement dependent variable. If passenger arrivals or departures are used as variables, however, this study does not look at other dependent variables because passenger transport is usually two-way, and the results of passenger throughput and cargo and mail throughput are the same. The independent variable in the model, that is, the core explanatory variable, the industrial structure index, represents the industrial

structure. The index commonly used to explain the industrial structure primarily consists of two components: a value index and an employment index. The benchmark regression model uses the industrial structure index, which falls under the value index category. In this study, it can be replaced by the employment index, that is, the proportion of the number of jobs in the tertiary industry, to represent the characteristics of the industrial structure. Therefore, the bidirectional fixed model adjustment is as follows:

〖Tert〗_it=Alpha_0 +Alpha_1 Work_it + Alpha_2 X_it + U_i + R_i + Epsilon .....[Formular 3]

Tertit：tertiary employment as a proportion of total employment of city i in year t

Workit：the annual airport workload of city i in year t

Xit：the control variables of city i in year t, including the level of economic development, the level of opening up to the outside world, the level of local income, the number of labor force, technical resources, government support, human resources, tourism resources, and the opening of high-speed rail

Ui：the city fixed effect

Ri：the time fixed effect

Epsilon：the random disturbance term, and the standard errors are clustered at the city level when the model is estimated

Alpha1：the impact of the development of civil aviation transportation industry on the upgrading of urban industrial structure

Table 3 shows the test results, and the estimated coefficients of the core explanatory variables are significantly positive, which further verifies the robustness of the basic conclusions of this study.

Table 3. Robustness test results

	Robustness
Variables	tert
work	2.648 ***
	(12.886)
_cons	17.074 *
	(-1.785)
Control variables	YES
Individual and year fixed effects	YES
N	1229
R^2	0.446
F	97.135

Source: By authors.

3.4 Endogeneity Test

Since the effect transmission in the macroeconomic system has a certain time lag, it cannot be ruled out that the civil aviation transport industry has a more long-term impact on the urban industrial structure. Therefore, the explained variables are re-estimated with a lag of one and two periods

respectively. The following are the regression models for the explanatory variables lagged one period and lagged two periods, respectively.

Y_it1=Alpha_0+Alpha_1Work_it + Alpha_2 X_it + U_i + R_i + Epsilon.....[Formular 4]

Y_it2=Alpha_0+Alpha_1Work_it + Alpha_2 X_it + U_i + R_i + Epsilon.....[Formular 5]

Yit1：the industrial structure index of city i in year t+1

Yit2：the industrial structure index of city i in year t+2

Workit：the annual airport workload of city i in year t

Xit：the control variables of city i in year t, including the level of economic development, the level of opening up to the outside world, the level of local income, the number of labor force, technical resources, government support, human resources, tourism resources, and the opening of high-speed rail

Ui：the city fixed effect

Ri：the time fixed effect

Epsilon：the random disturbance term, and the standard errors are clustered at the city level when the model is estimated

Alpha1：the impact of the development of civil aviation transportation industry on the upgrading of urban industrial structure

The results are shown in columns (1) and (2) of Table 3. The regression results show that the estimated coefficients of the core explanatory variables are all significantly positive, which further verifies the robustness of the basic conclusions of this study.

Table 4. Results of endogeneity test

Variables	One stage lag inde	Two periods behind inde
work	2.808 ***	2.817 ***
	(10.660)	(11.037)
_cons	133.608 ***	134.585 ***
	(6.164)	(6.381)
Control variable	YES	YES
Individual and year fixed	YES	YES
N	1133	1030
R^2	0.387	0.424
F	70.190	74.412

Source: By authors.

3.5 Further Analysis

Kuznets' theory says that the added value of the first, second, and third industries all rises gradually. This means that the change from the first to the second and then to the third industry is seen as a key sign of how the industrial structure has changed over time. However, the transformation and upgrading of the economy is not only reflected in the improvement of the industrial structure index, but more importantly, the industrial structure should be developed in a more optimized

direction. Industrial structure upgrading cannot be evaluated solely by observing the proportion of the three industries, as this method may not account for the index decline caused by industrial structure optimization during industrialization. To make sure the research results were correct, the study only looked at urban samples that followed Kuznets' theory, or the industrial structure change law, and left out samples that didn't follow this path. These samples would have gone from the primary industry to the secondary industry and then to the tertiary industry during the development process. Through this method, we re-evaluate the impact of civil aviation transportation on the industrial structure index in order to get a more reliable and representative conclusion. This method helps to make sure that the study can more accurately show the role of civil aviation in improving the structure of industries in cities by avoiding the effects of changes in industrial structure that aren't typical.

Specifically, according to the statistical data for the 8 years prior to the study period (2000–2007), all cities were divided into two groups according to the change in the proportion of the tertiary industry's added value to GDP. Among them, 68 cities had a continuous increase in the proportion of the tertiary industry, while 35 cities had a decline in the proportion of the tertiary industry. It can be found that for cities that follow the Kuznets theory, the development of the civil aviation transport industry still has a very significant promoting effect on the industrial structure, and the coefficient is higher and the fitting effect is better. For cities that do not follow Kuznets theory, the influence of civil aviation transport development on the industrial structure index is not statistically significant.

Table 5. The regression results of the sample cities

	Follow the Kuznets Facts inde	Do not follow Kuznets Facts inde
work	2.953 ***	0.100
	(9.907)	(0.173)
_cons	131.283 ***	315.276 ***
	(5.129)	(5.133)
Control variables	YES	YES
Individual and year fixed effects	YES	YES
N	816	420
R^2	0.407	0.810
F	54.408	28.177

Source: By authors.

4. Mechanism Test and Heterogeneity Test

4.1 Mechanism Test

This paper uses the following three equation tests for each mechanism variable:

Y_it = beta_01 + beta_11 Work_it+ beta_21 X_it+ epsilon.....[Formular 6]

M_it = beta_02 + beta_12 Work_it+ beta_22 X_it+ epsilon.....[Formular 7]

Y_it =beta_03 + beta_13 M + beta_14 Work_it+beta_23 X_it+ epsilon .....[Formular 8]

Workit: the annual airport workload of city i in year t

Xit: the control variables of city i in year t, including the level of economic development, the level of opening up to the outside world, the level of local income, the number of labor force, technical resources, government support, human resources, tourism resources, and the opening of high-speed rail

M: the mediating variable

In the model, if all three coefficients of beta1, beta2, and beta3 are significant, then there is a mediating effect, and if beta4 is further found to be non-significant, then a fully mediating effect is indicated. After logarithmic processing of these three variables, we substituted M for the mediation effect test. The results of regression analysis are shown in Table 6.

Table 6. Regression results by city sample

	Concentration of labor		Capital concentration		innovation effect	
Stage 1	Civil aviation transport industry to employees	3.786*** (23.390)	Investment in civil aviation transport industry	3.786*** (23.390)	Civil aviation transportation industry to scientific and technological innovation	3.786*** (23.390)
Stage 2	Employees to industrial structure	0.033** (2.193)	Investment plays a crucial role in shaping the industrial structure	0.037** (2.081)	Scientific and technological innovation on industrial structure	0.055*** (2.702)
	Civil aviation transport industry to industrial structure	3.788*** (23.347)	Investment on industrial structure	3.784*** (23.328)	Civil aviation transport industry to industrial structure	3.789*** (23.327)

Source: By authors.

In the test of labor agglomeration mechanism, the coefficients of civil aviation transport industry on employees and industrial structure and employees on industrial structure are significant respectively, indicating that the intermediary effect is significant. In the test of capital agglomeration mechanism, the coefficients of civil aviation transport on investment and investment on industrial structure are respectively significant, indicating that the intermediary effect is significant. In the test of innovation effect mechanism, the air transport industry also plays a significant intermediary effect on the coefficient of scientific and technological innovation and scientific and technological innovation on industrial structure.

4.2 Difference Test

4.2.1 Industry heterogeneity

The impact of the civil aviation transport industry on different industries is different. The civil aviation transport industry can directly bring consumers and goods to some industries and directly

promote the development of the industry, which can be called a direct effect. Meanwhile, the development of the above industries will promote the growth of local employment and income and it will drive the development of other industries that are not directly linked to the aviation industry, which can be called an indirect effect. The above two effects need to be checked by looking at each sub-industry of the tertiary industry. This means doing sub-sample regression by industry and seeing how the civil aviation transport industry affects each one.

According to the China Urban Statistical Yearbook, the tertiary industry includes 18 subindustries. From 2008 to 2019, the top five economic output values for the primary industry, the secondary industry, and the tertiary industry were compared. Over time, the tertiary industries of wholesale and retail, accommodation and catering, real estate, and finance have slowly risen to the top five, and some of them have even passed the primary industries of agriculture, forestry, animal husbandry, and fishery. Therefore, these four industries are selected for industry heterogeneity analysis.

Table 7 visually shows the role of civil aviation in driving these four industries. According to Table 7, the civil aviation transport industry mainly promotes the upgrading of industrial structure by promoting the development of wholesale and retail trade, accommodation, and the catering industry. In addition, the civil aviation transport industry also plays a role in promoting the financial industry.

Table 7. Regression results of industry heterogeneity

Variables	Wholesale and Retail Trade where	Accommodation and catering hoca	Finance fina	Real estate esta
work	0.055 * (1.701)	0.081 ** (2.236)	0.045 * (1.722)	0.057 (1.560)
_cons	8.920 *** (5.895)	8.672 *** (5.128)	9.410 *** (7.768)	9.450 *** (5.565)
Control variables	YES	YES	YES	YES
Individual and year fixed effects	YES	YES	YES	YES
N	1236	1236	1236	1236
R^2	0.009	0.013	0.009	0.008
F	1.080	1.559	1.073	0.968

Source: By authors.

4.2.2 Regional heterogeneity

In China, different regions have different levels of economic development, resources, development direction, and infrastructure development for civil aviation transport. As a result, these regions have different connections with other regions in the civil aviation transport industry. Additionally, these regions have different ways to upgrade their industries, which means that the civil aviation transport industry plays a different role in this process. Using what other studies have found and taking into account how civil aviation is different, this study divides the sub-samples into seven areas and runs exploratory tests on each one.

Table 8 shows the estimated results of the impact of civil aviation on industrial structure

upgrading in each region. The estimated coefficients for Northeast, Southwest, Central South, North, and East China are all significantly positive. This means that civil aviation has a big impact on improving the structure of industries in those areas. However, in Xinjiang and Northwest China, this effect is weak or not important at all.

Table 8. Regression results of regional heterogeneity

	Northeast China inde	Xinjiang inde	Southwest inde	Mid-South inde	North China inde	Northwest inde	East China inde
work	3.073 ***	23.098 **	2.161 ***	3.039 ***	2.773 ***	1.352	2.698 ***
	(5.285)	(7.423)	(2.977)	(5.567)	(2.729)	(0.763)	(6.767)
_cons	143.978 ***	772.163 **	146.537 ***	182.541 ***	210.767 ***	170.400 **	114.174 ***
	(4.577)	(6.681)	(4.498)	(8.100)	(5.942)	(2.140)	(5.173)
Control variables	YES	YES	YES	YES	YES	YES	YES
Individual and year fixed effects	YES	YES	YES	YES	YES	YES	YES
N	204	24	144	276	108	108	372
R^2	0.535	0.989	0.590	0.502	0.415	0.242	0.482
F	20.956	18.667	17.541	25.579	6.112	2.746	32.532

Source: By authors.

The possible explanation is that the civil aviation transport links between Xinjiang, Northwest China, and other regions are weak, and the development level of its own civil aviation transport-related infrastructure is low, and the space for civil aviation transport to play a role is small. At the same time, Xinjiang and Northwest China are geographically far away from other regions, especially the economically developed East and North China, so the spatial interaction with other regions is more difficult to promote the upgrading of industrial structure. Correspondingly, North China, East China, Central South, Southwest, and Northeast China have strong civil aviation transport links with other regions, and their own civil aviation transport infrastructure development level is also high, which is more conducive to the role of civil aviation transport. It can be seen that improving the development level of regional civil aviation transport will help it play a role in promoting the upgrading of industrial structures.

4.2.3 Period heterogeneity

Since 2008, there have been great changes in China's macroeconomic environment, and the national and industrial development plans at different stages have different priorities. Especially since the 18th CPC National Congress, socialism with Chinese characteristics has entered a new era, and the corresponding civil aviation transport industry has also been developing continuously. Therefore, the role of civil aviation in upgrading the urban industrial structure may vary depending on the period, and this trend is likely to change over time.

Table 8 shows the estimated results of the impact of the civil aviation transport industry on the

upgrading of industrial structure in different periods. Comparing the estimated coefficients and their significance in the three periods, it can be seen that both the value of the estimated coefficients and the significance level have a decreasing trend. The possible explanation is that since 2008, China has continuously introduced various policies to promote the upgrading of industrial structure, and the development level of industrial structure has been continually improved. Therefore, the space for further improvement has been shrinking and the speed has been decreasing. At the same time, during this period, China's civil aviation transport industry has made great progress; its efficiency has been continuously improved, and its coverage has been continually expanded, which has had a great impact on the market demand of the civil aviation transport industry and has occupied the space for the improvement of the industrial structure upgrading of civil aviation transport to a certain extent.

Table 9. Results of heterogeneity regression in the period

Variables	From 2008 to 2010 inde	2011-2015 inde	2016 -2020 inde
work	3.293 ***	3.156 ***	1.962 ***
	(7.811)	(8.120)	(3.887)
_cons	110.191 ***	131.241 ***	179.263 ***
	(3.370)	(4.433)	(3.987)
Control variables	YES	YES	YES
Individual and year fixed effects	YES	YES	YES
N	309	515	412
R^2	0.513	0.501	0.256
F	31.138	50.246	13.703

Source: By authors.

5. Research Conclusions and Policy Recommendations

Based on 103 Chinese prefecture-level cities with airports and civil aviation routes from 2008 to 2019, this paper looks at how the growth of civil aviation transport has affected the upgrading of industrial structure and how it has affected it. The main research conclusions of this paper include: First, after controlling for other urban control variables, city fixed effects, and year fixed effects, the development of the civil aviation transport industry has played a significant role in promoting the upgrading of urban industrial structure by promoting economic growth, increasing residents' income, enhancing innovation ability, gathering capital, and attracting talents. Specifically, when the workload of an urban airport increases by 1%, the industrial structure index increases by 2.845%. Through the endogeneity test and robustness test, it is found that the benchmark results are reliable. Second, in the mechanism analysis, this paper finds that the civil aviation transport industry mainly affects the development of industrial structure by promoting labor agglomeration, capital agglomeration, and regional scientific and technological innovation ability, which is reflected as part of the intermediary effect. Especially in the test of improving regional scientific and technological innovation ability, the intermediary effect is the most significant. Thirdly, this paper analyzes the heterogeneity of the impact of civil aviation transport on the upgrading of industrial structure. In terms of industry heterogeneity, in the four industries with the largest proportion in the tertiary industry, the workload of urban airports

increases by 1%, and the pull of the above industries is 0.055%, 0.081%, 0.045% and 0.057%, respectively. Among them, the increase of the accommodation and catering industry is the most obvious, followed by the wholesale and retail industry and the financial industry. In terms of regional heterogeneity, the eastern region has the strongest promoting effect, which may be because the eastern region has strong inter-regional civil aviation transport links and its own civil aviation transport infrastructure development level is also high, which is more conducive to the role of the civil aviation transport industry. The civil aviation transport industry's positive impact on the industrial structure is decreasing over time. This could be because China has been promoting the upgrading of the industrial structure through a constant stream of new policies, and the level of development in the industrial structure has been steadily rising, leaving less room for further improvement and slowing down the rate of progress.

Based on the above conclusions, this paper puts forward policy suggestions from the following aspects. For starters, make it easier for people to use and build up infrastructure for civil aviation transport by optimizing routes and flight frequencies. This will also make it easier for people to travel between regions and play up the role of civil aviation transport in helping to improve the structure of industries. Second, businesses should be pushed to use civil aviation as their main mode of transportation by offering them better services and better policies. This will help bring in new talent, encourage trade and cooperation between regions, and make the urban market more vibrant and competitive. Third, promote business and international trade cooperation through the development of the civil aviation transport industry, attract external capital, and introduce advanced technologies to promote economic growth and upgrade the industrial structure. Fourth, by improving the distribution system and developing education and vocational training, we should promote the increase of residents' income level, increase residents' demand for high-quality services, and promote the increase of residents' demand for civil aviation travel and the upgrading of their consumption structure. Fifth, promote the coordinated development of the civil aviation transport industry with other industries. For example, we should cooperate with the tourism industry to develop special tourism products, such as the "air + tourism" model, to provide integrated tourism services; and cooperate with the hotel and catering industry to provide package services of "air + hotel" or "air + catering.". Partnering with wholesale and retail industries to sell aviation-related products and services, such as in-flight merchandise, travel supplies, etc.; We are also collaborating with financial institutions to offer aviation-related financial services, including aircraft leasing, aviation insurance, and other related products. The development of the civil aviation transport industry will drive the development of high-end manufacturing, modern services, and other industries and promote the development of the industrial structure in a more high-end, environmentally friendly, and intelligent direction. Sixthly, as the civil aviation transport industry has played a lesser role in driving the upgrading of the industrial structure in Xinjiang and the northwestern region than in other parts of the country, it is necessary to take targeted measures in terms of both policy and infrastructure. In terms of policy, the first is to implement a regional tilted subsidy policy, compared to the east, a substantial increase in the proportion of subsidies, dedicated to subsidising the construction of local airports, route operations,

with a focus on supporting routes connecting remote and speciality industrial regions; the second is to set up a policy on the integration and training of ethnic talents, taking into account the characteristics of ethnic concentration, with special funds for the training of ethnic civil aviation talents, and to promote the integration of employment; the third is to implement the policy of cross-border co-operation, and to explore flexible strategies for attracting international resources by virtue of Thirdly, the policy of cross-border cooperation should be implemented first, and a breakthrough should be made in the rules of international cooperation in civil aviation by virtue of geographical advantages. Flexible strategies should also be explored to attract international resources. In terms of infrastructure, the first step is to adapt to the unique geography, get past the difficulties of building in mountains and deserts, and raise the standards of runways and aprons so they can handle harsh conditions. The second step is to improve the link for ultra-long-distance traffic and construct a special high-speed freight line between airports and remote cities and mining areas to make up for the lack of space.

The empirical research presented in this paper still exhibits the following deficiencies: For starters, the industrial structure index used in this paper can better show how the industrial structure of cities has changed over time, but it can't show in great detail how work is divided between cities. In the future, researchers can build a combined index system that will help us understand the industrial synergy network and the way work is divided in industries across space. Second, some research says that as the economy grows, the share of tertiary industry should rise to boost total factor productivity and value-added rates. Other research says that secondary industry, led by manufacturing, is what makes the economy grow, and its share shouldn't be too low because it can lead to hollowing out and industrial exodus. Future research needs to reassess the optimal equilibrium of industrial structure and design the optimal route according to China's national conditions and endowments. In view of the limitations of this paper, we expect a more in-depth discussion in future research.

References

[1] Pang, M. Exploration and innovation of macroeconomic policies in the centenary of the founding of the party. Research on Financial Issues, 2021, (07), 11-26.

[2] Kuai, X.J. From backwardness to strength: The dream pursuit and road choice of China's economic growth in the century of the founding of the party. Journal of Xi'an University of Finance and Economics, 2021, 34(02), 47-55.

[3] Kuznets, S. Modern economic growth: Findings and reflections. American Economic Review, 1973, 63(3), 247-258.

[4] Guo, K.M. and Pan, S. New infrastructure investment and industrial structure transformation and upgrading. China Industrial Economy, 2020, (03), 63-80.

[5] Zhang, B., Jin, L. and Mi, Y. Inter-industry resource mismatch and industrial structure upgrading of heterogeneous manufacturing factor intensity in China. Contemporary Economic Management, 2019, 41(02), 60-67.

[6] Zhang, Q. and Li, L. Manufacturing transformation and upgrading and regional economic growth. Economic and Management Research, 2017, 38(02), 97-111.

[7] Xi, Q., Chen, X. and Li, G. Research on the choice of productive service industry model in Chinese cities - orientated to industrial efficiency improvement. China Industrial Economy, 2015, (02), 18-30.

[8] Ye, J. and Fan, J. Transport infrastructure, inter-regional trade and regional economic development--Taking highway as an example. Quantitative Economic and Technical Economic Research, 2023, 40(06), 48-68.

[9] Bao, Q. and Hao, T. The impact of transport infrastructure quality on manufacturing value chain upgrading. Contemporary Economic Research, 2023, (05), 84-96.

[10] Wang, Y., Zhou, X. and Wu, X. Study on the spatial spillover effect of transport infrastructure on regional economic growth. Price Theory and Practice, 2022, (06), 12-17.

[11] Shen, K. and Shen, D. Grey correlation analysis of the impact of transport development on industrial structure. SAR Economy, 2022, (03), 110-113.

[12] Li, Z. and Ou, G. Analysis of the impact of transport on factor prices, population mobility and industrial structure. Exploration of Economic Issues, 2019, (05), 13-21.

[13] Feng, X., Sun, Q. and Qian, K. Cointegration analysis of regional comprehensive transport demand and industrial structure. Transport System Engineering and Information, 2012, 12(06), 10-16.

[14] Lu, C. and Lu, W. Development strategy of comprehensive three-dimensional transport system. Railway Journal, 2022, 44(01), 1-7.

[15] Tang, K. Research on market effect of airside economy to promote regional economic development. East China Economic Management, 2019, 33(11), 54-61.

[16] Xia, X. Development of aviation economy to promote industrial structure adjustment and economic development mode transformation. China Party and Government Cadre Forum, 2011, (06), 4-8.

[17] Zhang, J. Empirical study on the relationship between industrial structure and the development of civil aviation transport industry. Enterprise Reform and Management, 2019, (12), 203-206.

[18] Wang, J. and Xie, M. The correlation analysis of civil aviation industry and other sectors of the national economy--Based on the national input-output table in 2002. Journal of Beijing University of Aeronautics and Astronautics (Social Science Edition), 2009, 22(03), 17-22.

[19] Yu, J. and Guo, Y. Research on the interaction mechanism between civil aviation transport and regional development. Academic Exchange, 2021, (04), 123-136.

[20] Jiang, Y. Discussion on the dynamic relationship between airside economic development and service industry--Taking Capital Airside Economic Zone as an example. Business Times, 2014, (21), 125-127.

[21] Jiang, H. and Ren, M. Research on the impact of air transport on regional industrial structure--Taking Shanghai Pudong Airport as an example. Urban Development Research, 2018, 25(03), 118-124.

[22] Fang, Z. and Wang, Z. Granger causality test of civil aviation transport growth and regional economic development--Taking Guangzhou Baiyun International Airport as an example. Urban Development Research, 2011, 18(06), 118-121.

[23] Xu, D. A theoretical explanation and verification of the determination and measurement of industrial structure upgrading pattern. Financial Research, 2008, (01), 46-49.

[24] Wang, W., Liu, Y. and Peng, D. Research on industrial structure upgrading effect of population aging. China Industrial Economy, 2015, (11), 47-61.

[25] Sun, W., Niu, D. and Wan, G. Transport infrastructure construction and industrial structure upgrading--An empirical analysis taking high-speed railway construction as an example. Management World, 2022, 38(03), 19-34+58+35-41.

[26] Ding, Y., Wang, C. and Liu, Y. Economic growth, industrial structure upgrading and civil aviation transport-A PVAR

empirical study based on provincial panel data. Comprehensive Transport, 2023, 45(12), 3-9.

[27] Ke, S. and Zhao, Y. Industrial structure, city size and urban productivity in China. Economic Research, 2014, 49(04), 76-88+115.

[28] Li, G. and Hu, Y. An empirical study on the interaction between the development of China's civil aviation industry and the increase of residents' income--And the intermediary transmission role of civil aviation fares. Price Theory and Practice, 2017, (03), 147-150.

[29] Foellmi, R. and Zweimüller, J. Structural change, Engel's consumption cycles and Kaldor's facts of economic growth. Journal of Economic Growth, 2008, 55(7), 1317-1328.

[30] Song, L., Wang, X. and Xu, X. Local officials lead industrial structure change. Economics (Quarterly), 2013, 12(01), 71-92.

[31] Zhu, L. and Yang, X. Research on the development of China's civil aviation manufacturing industry under international industrial transfer. Journal of Nanjing University of Aeronautics and Astronautics (Social Science Edition), 2011, 13(04), 30-33.

[32] Chen, P. Research on the role mechanism and path of financial support for aviation economic development. Enterprise Economy, 2015, 34(07), 174-178.

[33] Ngai, R.L. and Pissarides, A.C. Structural change in a multisector model of growth. The American Economic Review, 2007, 97(1), 429-443.

[34] Li, L. and Shen, G. Economic development zones, regional comparative advantages and industrial structural adjustment. Economics (Quarterly), 2015, 14(03), 885-910.

[35] Qian, Q. An empirical study on the influencing factors of Shanghai air transport development. Journal of Economic Research, 2010, (14), 27-30.

[36] Yu, P. and Su, Y. Western development of passenger transport--The Southwest Railway Passenger Transport Market Development. Railway Transport and Economy, 2000, (09), 1-4+39.

[37] Yang, L. and Liu, Q. Research on the impact of high-speed railway into Yunnan on the development of civil aviation industry in Yunnan Province. Jiangsu Business Theory, 2017, (03), 30-33.

[38] He, N. The impact of Hukun high-speed railway on the development of industries along Hunan. Co-operative Economy and Science and Technology, 2015, (05), 18-19.

[39] Solow, R.M. A contribution to the theory of economic growth. The Quarterly Journal of Economics, 1956, 70(1), 65-94.

[40] Fang, F. and Fu, Q. The economic growth effect of industrial structure upgrading--an empirical analysis based on panel data of 31 provinces in China from 2000 to 2020. Jianghan Forum, 2024, (01), 12-25.

[41] Zhang, G. and Song, R. Research on the impact of China's transport on the factor input of ‘Made in China’. Economic Research, 2013, 48(07), 63-75.

[42] Zhang, X., Chen, L. and Wu, W. Transport infrastructure, stratified agglomeration of human capital and regional total factor productivity-An empirical analysis based on panel data of 285 prefecture-level cities in China. Industrial Technology and Economics, 2016, 35(06), 92-102.

[43] Li, H., Wang, J. and Yang, K. Impact of China's international aviation network on population mobility space. Modern Computer (Professional Edition), 2017, (02), 10-15.

[44] Yang, N. Global alliance network and competition control in the aviation industry. Comparison of Economic and Social Systems, 2004, (01), 78-86.

[45] Zhang, W. and Zhai, B. The strategic choice of China's transport development under the threshold of spatial justice. Journal of Humanities, 2022, (06), 115-123. DOI:10.15895/j.cnki.rwzz.2022.06.006.

[46] Ray, R., Yin, X. and Li, W. Research on industrial transformation mode of Karamay city driven by air transport. Science and Technology Management Research, 2013, 33(16), 114-118.

[47] Zhang, L. and Chen, W. Characteristics of the evolution of industrial structure in airport economic zone--Taking Yangtze River Delta hub airports as an example. Progress in Geoscience, 2012, 31(12), 1685-1692.

[48] Li, F., Wang, X. and Jiang, F. Formation mechanism of airside economic zone and upgrading of regional industrial structure--Taking Guangzhou New Baiyun International Airport as an example. Academic Research, 2012, (01), 74-80+160.

[49] Chen, X., Jiang, W. and Zhu, J. A review of domestic innovation drive research based on knowledge mapping. Finance and Accounting Monthly, 2020, (16), 114-122.

[50] Zhang, J., Zhao, Y. and Liu, H. Research on transformation and upgrading of China's industrial structure under the perspective of domestic and international double cycle. China Industrial Economy, 2023, (09), 42-60.

[51] Shen, H. and Zou, P. Synergistic relationship between China's civil aviation industry and economic development. Economic and Management Research, 2016, 37(12), 98-104.

[52] Luo, L. Quantitative analysis of the impact of civil aviation transport industry on regional industries--Taking Hunan Province as an example. Economic Geography, 2011, 31(08), 1326-1331.

[53] Zhao, X. and Gao, C. Impact of transport infrastructure on industrial structure in central China. Social Science Dynamics, 2023, (06), 77-84.

[54] Chen, X. and Xu, W. Data elements, transport infrastructure and industrial structure upgrading-an analysis based on quantitative spatial general equilibrium model. Management World, 2024, 40(04), 78-98.

[55] Feng, R. and Chen, Y. Impact of circulation digitalisation on the efficiency of business circulation - Based on the perspective of regional market integration and industrial structure upgrading. Research on Business Economy, 2024, (20), 98-101.

[56] Yu, G. and Gong, Y. Financial structure, industrial structure upgrading and income distribution - An explanation based on new structural economics. Mathematical Statistics and Management, 2024, 43(04), 737-760.

[57] Wang, C. Industrial structure upgrading, energy structure optimisation and green total factor productivity enhancement - A panel threshold regression analysis based on 78 global economies. Ecological Economy, 2024, 40(09), 41-47.

[58] Li, Y., Yang, W. and Zhang, H. The promotion effect of digital economy on the advanced industrial structure--an analysis based on the demand side of consumption and investment. Research on Business Economy, 2024, (14), 92-96.

[59] Wang, L. and Li, P. Artificial intelligence, industrial structure service transformation and labour income share. Economic Issues, 2024, (08), 52-59.

[60] Wu, Y. and He, Z. Theoretical logic and group path of new quality productivity affecting industrial upgrading: a QCA analysis based on provincial dynamic panel. Journal of Yunnan University for Nationalities (Philosophy and Social Science Edition), 2024, 41(05), 72-83.

[61] Wang, L. Digital economy, new quality productivity and the construction of Chinese-style modern industrial system. Science and Technology Progress and Countermeasures, 2024, 41(18), 55-65.

[62] Mi, R., Ni, S. and Liu, S. Digital technology, economic efficiency and upgrading of urban industrial structure.

Technological Economy, 2024, 43(05), 107-116.