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Measuring the Status of Jiangxi Aviation Industry Chain Nodes under the New Pattern of Double Cycle and Improving the Path

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***Abstract*—Jiangxi Province's strategic pillar industry must strengthen its position in both the domestic and international double cycles to survive the window of 100-year transformation. This paper uses social network analysis to examine the position of Jiangxi's aviation industry in the domestic and global industry chain nodes in order to provide decision-making guidance for the scientific development of Jiangxi's aviation industry. The research findings indicate that: (1) there are 540 global aviation manufacturing enterprises, 60 domestic ones, and only 4 in Jiangxi, which are primarily in the downstream position in the industry chain; (2) the point degree centrality of Jiangxi's Changhe, Deli, and Hongdu enterprises is 2, 1, and 1, respectively in 2021, and the primary cooperative production companies are Sikorsky, Leonardo, Boeing, and COMAC.**

***Index Terms*—New pattern of double circulation, node status measurement, social network analysis**

I. Introduction

Aviation manufacturing businesses confront intense competition, but they also operate in a very open global market. China has grown to be a significant player in the chain-building process for the aviation industry globally. Jiangxi's aviation sector will generate 120 billion yuan in revenue in 2020, moving up to the top three in the nation and joining the exclusive "100 billion yuan aviation industry club" as a result of the aggressive implementation of the strategy of building the aviation province. However, in recent years, in addition to the effects of the new crown pandemic, the global economic crisis, and the struggle in the Russian-Ukrainian war, the security of the industrial chain has come under relentless attack. Jiangxi examines the trajectory of its aviation manufacturing enterprises from taking off to creating the world's aviation heights by relying on the dual domestic and international cycles against the backdrop of both opportunities and risks, which is not only of great practical significance for the development of Jiangxi's economy but also a reference for the central region to cultivate pillar industries to achieve.

In the realm of aviation, social network analysis techniques are frequently employed. One of them, Cao and Du (2022) used high-speed rail trains and flight schedules to develop network models and compare the structure of high-speed rail and civil aviation networks, are researchers who have investigated the network structure characteristics to construct aviation networks. In order to measure the spatial heterogeneity of the network's externality elements, Han *et al*. (2022) established a Chinese passenger airline network based on urban nodes and developed a network node structure assessment method. Some researchers also identified important nodes in the network; for example, Xu *et al*. (2023) constructed a two-layer weighted network model research framework for air-rail intermodal transport to identify and rank the nodes' significance. By using spatial distribution data from cities along the "Belt and Road" to build a network, Liu *et al*. (2020) were able to measure the influence of major node cities in China across various dimensions. Guan *et al.* (2020) used route data to build a weighted global liner shipping network to assess the value of Chinese container ports in terms of network structural relevance, location importance, and economic importance of port nodes. properties of a network. According to the data, low-cost carriers almost entirely developed a "hub-and-spoke" structure during the course of the four-year study period, and their impact on the centrality of airports in the area was growing. The application of network analysis for aviation-related studies is well-documented, although the majority of the literature focuses on air transport data rather than enterprise-level production relations data, and the measurement of node status has not yet included the aviation manufacturing chain.

On the other hand, as more academics have examined the key elements of the aviation sector, the corresponding theories have advanced. In their QAP analysis of the influencing factors of the spatial structure of the air logistics space among the host cities using national logistics data, Cao and Luo (2020) discovered that the degree of economic development, degree of openness to the outside world, industrial structure, and traffic accessibility are significant factors affecting the correlation network. The value-added service model and the service integration model, according to Han and Wu (2018), are significant avenues for the aviation sector to develop new value growth points and strengthen competitive advantages.

An upgrade path based on "Internet+coordinated manufacturing" was proposed by Xu (2018) for the aviation sector in order to reconfigure customer connections, improve supply chain management capabilities, execute smart manufacturing plans, and heighten awareness of service innovation. Based on TRIZ theory, Zhu *et al.* (2020) identified the main issues preventing the aviation industry from being upgraded, created a problem model and solution model, and suggested a focused upgrading plan for the sector. By developing a comprehensive evaluation index system for the aviation industry's competitiveness, She *et al*. (2017) assessed the sector's competitiveness and discovered that Jiangxi's aviation sector's overall competitiveness ranked in the middle of the nation and was on the rise. The aviation production network's characteristics, structural shape, and internal driving mechanism cannot be accurately captured by

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the existing studies, despite the fact that they have examined the aviation industry's enhancement path. Given this, this article uses data from Jane's all the world's Aircraft: Development& Production, published by Jane's Group, UK, from the years 1965 to 2021, based on the literature that is now available. In order to build a global aviation cooperative production network with enterprises as nodes and production relationships as links, we collected the production relationships between 1774 major aviation manufacturing enterprises in 48 countries between 1965 and 2021. We also used social network analysis and QAP analysis to try and assess the status of aviation manufacturing nodes in Jiangxi Province from the perspective of the new "double cycle" development pattern. Finally, we looked at the QAP data to determine the relationship between the production relationships between the aviation manufacturing nodes in Jiangxi Province. The goal of this paper is to quantify the node status of the Jiangxi aviation manufacturing sector, analyze the corresponding upgrading paths from the standpoint of the new "double-loop" development pattern, and provide a reference basis for Jiangxi aviation manufacturing enterprises' upgrading paths. The following are some potential contributions of this paper: First, this paper builds a global aviation production network using data from cooperative global aviation manufacturing enterprises rather than the previous literature, which primarily used shipping data. Second, rather than the macro data used in the prior literature to build the network, this paper uses the micro data of enterprises to build the network, which can measure the node status of the network more precisely. Third, the methodology used in this paper is novel. Third, different industries can make use of the node position measurement technique presented in this paper.

II. Data Sources and Methodology

In order to build a worldwide aviation manufacturer production network leveraging the cooperative relationship amongst aircraft manufacturers, which is the focus of this study, one must first understand the nodal position of Jiangxi aviation firms in the local and international production networks. The Jane's Group, UK publication Jane's All the World's Aircraft: Development & Production provided the data for the network construction. With users in more than 180 countries and regions, including universities, military institutions, and governmental agencies, the yearbook contains information on more than 1,000 military and civil aircraft produced by more than 560 companies globally. It also includes detailed company information and technical data on major aviation manufacturers. Name of the business, address, date of incorporation, number of employees, partners in production, information about customers, and details about the products are all included in the data. The co-production relationships necessary for this paper's design of the global aviation production network are covered in the aforementioned data. Therefore, six representative years were chosen from Global Aircraft: Development and Production for further analysis in order to accurately measure the changes in the node position of Jiangxi aviation manufacturing enterprises in the global aviation production network: 1966, 1975, 1985, 1992, 2005, and 2021.

The construction of the global aviation production network specifically consists of: 1) Enterprise data (nodes). The top worldwide aircraft manufacturing companies' names, establishment year, addresses, and other pertinent data are obtained from the data set "Global Aircraft: Development and Production" to build the network's nodes. 2) To obtain the cooperative production relationship between the enterprises, including cooperative development, joint venture and M&A, subcontracting production, etc., the production relationship data (linkage) is sorted out from the description information of the enterprises in the Global Aircraft: Development and Production dataset. 3) To create a final global aviation production network, the names of the companies in the previously sorted data are utilized as nodes, and whether or not they have co-production links is the basis for linking. The network in this research is an undirected network since the collaboration between businesses is reciprocal.

The development of production linkages within an airline company and, consequently, its position as a node in the production network are influenced by cultural, geographic, and economic considerations (She, 2017). The presence of a common official language across the nations where the partner enterprises are located serves as an expression of the cultural component. The presence or absence of a common official language among the nations where the cooperating enterprises are located is one of them. If there is a common language, the value is 1, otherwise, the value is 0, forming the common language matrix (LANG), whose data is obtained from the French CEPII database; the geographic distance between enterprises can affect the cost of transportation, and the closer the geographical distance between enterprises is, the higher the cost of transportation will be. The economic factor is represented by the economic scale indicator, and typically the larger the economic scale, the stronger the aviation manufacturing capacity, which is expressed as the sum of the GDP of the countries where both companies are located, forming the GDP matrix (GDP). The geographic factor is represented by the geographic distance difference indicator, which forms the geographic distance matrix (DIST), which is obtained from the French CEPII database.

Using the network as the variable and the relationship as the data, social network analysis is a technique for examining how social actors interact with one another, linking and constructing an overall network of interests. In this study, we build an aircraft production network using social network analysis, and we utilize the point degree centrality, intermediate centrality, and proximity centrality indices to examine the cooperative production connections between nations and Jiangxi aviation manufacturing businesses.

The investigation of the correlation between matrix data often employs the Quadratic Assignment Technique (QAP). In order to build a model of the driving factors of the airline production network in Jiangxi Province, the following sentences use QAP correlation analysis and regression analysis to further explore the intrinsic influencing factors of the evolution of the airline production network in Jiangxi Province.

III. Jiangxi Aviation Industry Chain Node Status

A. Jiangxi Province Aviation Manufacturing Enterprises Embedded in the Global Situation

Given the breadth of the aviation manufacturing industry chain and the significance of its upstream and downstream businesses as well as their relevance, it can be classified into three tiers: Upstream power units, which include airborne avionics systems, power systems, airframe components, etc.; midstream power units, which include electronic components, hydraulic systems, and airframe parts; and downstream power units, which include electronic components, hydraulic systems, and airframe parts, etc. This paper compares the fundamental situation of Jiangxi aviation manufacturing enterprises' production cooperation in accordance with the aforementioned hierarchical division of the aviation industry chain and draws Table I, from which we can learn that Jiangxi aviation manufacturing enterprises' participation in the global production network is still at a low level. The data used in this paper are taken from the Global Aircraft: Development and Production yearbook. Although they primarily collaborate with domestic commercial aircraft and foreign monopoly aviation enterprise groups like Boeing, Sikorsky, and Leonardo, their primary product categories are military aircraft and general aviation. Their production cooperation products are primarily downstream products like tail fins, rudders, and parts, and their primary method of collaboration is subcontract manufacturing. For huge domestic and international monopolistic aviation company groups, the cooperation primarily takes the form of subcontract production, which is still in the early stages.

Additionally, this paper compiles the number of Jiangxi, national, and international aviation manufacturing enterprises from the Global Aircraft: Development and Production yearbook for the period 1965-2021, as shown in Fig. 1, to illustrate the temporal evolution of Jiangxi aviation manufacturing enterprises' participation in global production. Fig. 1 reveals the following: (1) The number of worldwide aircraft manufacturing firms is changing phase, albeit demonstrating an overall increase tendency. In the years 1965 to 1991, there was a gradual increase. Between 1991 and 2005, it grew significantly, going from 190 in 1991 to 540 in 2021. It suggests that the global aircraft manufacturing sector entered a phase of significant development following the 1990s. (2) Between 2005 and 2021, China's aviation manufacturing enterprises had fast expansion, nearly tripling in number. This growth was also consistent throughout the study period. The state-owned aircraft manufacturing facility in Shenyang, China, which primarily received imported machinery and technical assistance from the Soviet Union and collaborated with the Soviet Union on the development of the MiG series of fighter jets, etc., was the only Chinese aviation manufacturing enterprise listed in the yearbook in 1965. (3) Next, take a look at the Jiangxi aviation manufacturing companies. Before 1985, there were no companies included in the yearbook; this changed in 1991 when Changhe and Hongdu Aviation were added. Possible explanations include the fact that aviation manufacturing businesses are a part of the national defense industry, confidentiality is strong, and information was not temporarily disclosed to the public before. There is still a lot of space for growth as the number of aviation manufacturing businesses held by Jiangxi Province is still quite modest as of 2021, making up only 6.67% of all domestic businesses and 0.74% of all worldwide businesses.

TABLE I: Jiangxi Aviation Production Cooperation Information

Company Name	Industry Chain Levels	Partner companies
Changhe	Downstream, Passage	Sikorsky, Leonardo, Boeing, Commercial Aircraft
Hongdu	Downstream, military aircraft	Boeing, Commercial Aircraft
Deli	through aviation	Konstruktorske Byuro Aerokopter

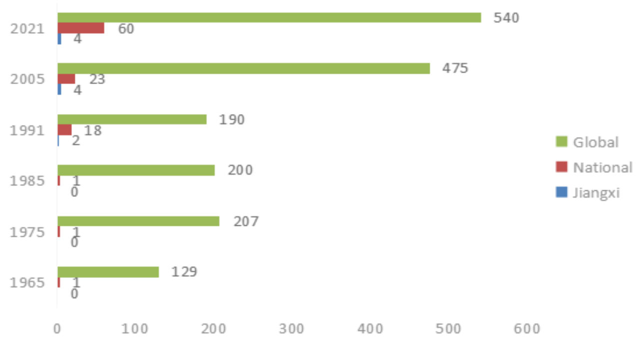

Fig. 1. Comparison of the number of aviation enterprises in Jiangxi.

B. Analysis of the Centrality of Aviation Enterprises

This section measures the position of Jiangxi aviation manufacturing businesses in the global production network over time using Ucinet software to analyze the centrality of the global production network over six time periods.

Point centrality evaluates a firm's relevance in the production network by indicating its centrality inside the network. Table II displays the results of the calculation of point degree centrality using data from the global production network collected between 1965 and 2021.

The cooperating companies were Sikorsky, Renaldo, Boeing, and COMAC, as shown in Table II, and their point degree centrality was 0 until 2005, 3 in 2005, and 2 in 2021. However, all of them were lower than the average value for that year, indicating a shallow degree of integration into the global aviation production network. Jiangxi Deli and a foreign business only worked together in 2021 to build light helicopters, demonstrating that Deli is actively pursuing collaboration and has already assimilated into the world's aviation manufacturing network. Jiangxi Hongdu's value, 1 in both 2005 and 2021, is considerably below average and shows that Hongdu firms have a low node position in the aviation production network and still need to further increase their embeddedness in the network. The three Jiangxi aviation manufacturing companies previously mentioned have been in a more peripheral position in the evolution of the global production network, with low influence in the network. In order to improve their position in the network, they must use their own advantages to accelerate their integration into the production network.

From 1965 to 2021, there were more enterprises integrated into the production network than there were nodes, with the sharpest growth occurring between 1991 and 2005. This shows that nations are actively growing their aircraft manufacturing businesses and leveraging their advantages to hasten the process of integrating them into the global network of aviation manufacturing output. The greatest value of point degree centrality, 4.53, was recorded in 2005. This indicates that, on average, there is a cooperative production relationship between each company and at least two other companies. The mean value of point degree centrality varies from 2 to 5 for each year. The standard deviation and variation for each year demonstrate that the point degree centrality value between enterprises fluctuates more widely as the international division of labor continues to grow and as the number of businesses integrated into the production network rises. As the global aviation production network evolves, large aviation enterprises are using their technological advantages to continuously seek out new low-cost partners, solidify their network node status, and exert significant influence within the network. This is indicated by the fact that the maximum value of point degree centrality in each year shows an increasing trend.

TABLE II: POINT DEGREE CENTRALITY OF AVIATION PRODUCTION NETWORK 1965–2021

Point Degree Center Degree						
Year	1965	1975	1985	1991	2005	2021
Changhe	0	0	0	0	3	2
Deli	0	0	0	0	0	1
Hongdu	0	0	0	0	1	1
Number of companies	35	50	70	58	151	153
Average value	2.34	3.24	3.11	3.21	4.53	2.97
Standard deviation	1.73	2.61	3.29	3.21	6.23	4.68
Variance	3.00	6.80	10.83	10.27	38.84	21.90
Maximum value	6 (Kawasaki)	11 (Lockheed)	18 (Boeing)	17 (Lockheed)	53 (AVIC)	32 (Airbus)

IV. THE EMPIRICAL ANALYSIS OF FACTORS INFLUENCING

With 2021 serving as the representative observation year, the aviation production network serving as the explanatory variable, and the common language matrix, the geographical distance matrix, and the sum of GDP matrix serving as the explanatory variables, QAP correlation analysis and regression analysis were conducted on the structure of the global aviation production network.

The findings of the QAP correlation analysis using the Ucinet program are displayed in Table III. There is a strong correlation between the aforementioned indicators and the airline production network, but this does not imply causation. Instead, the influence of each indicator on the airline production network must still be determined through additional regression analysis. The correlation coefficients of the common language matrix, the geographic distance matrix, and the sum of GDP matrix were 0.685, 0.781, and 0.842, respectively, and all passed the significance test.

TABLE III: RESULTS OF QAP CORRELATION AND REGRESSION ANALYSIS

Variables	QAP-related analysis		QAP regression analysis	
	Correlation coefficient	*P*-value	Regression coefficient	*P*-value
Common Language Matrix	0.685	0.000***	0.283735	0.000***
Geographical distance matrix	0.781	0.000***	0.399328	0.000***
Sum of GDP matrix	0.842	0.000***	0.200878	0.570

Using Ucinet software, additional regression analysis was carried out. The regression results were good based on the R2 results, indicating a good match, as shown in Table III. The common language matrix is significant and has a positive coefficient at the 1% level, indicating that the more companies that cooperate in the aviation production network share a common language, the more advantageous it is for cooperation and the more conducive it is to the formation of the aviation production network. aircraft manufacturing is a technologically advanced sector, and at the moment, the U.S., the EU, and China are home to most of the enterprises with strong aircraft manufacturing capabilities. A shared language can make cooperative production easier and hasten the development of cooperative networks with these aviation manufacturing behemoths. The geographic distance matrix has positive coefficients and is significant at the 1% level, suggesting that the greater the physical distance between two businesses, the easier it will be for them to collaborate. This year's GDP matrix total fails the significance test, proving that GDP is ineffective in explaining the organization of the aviation production network. This is so because there is only a correlation and little impact on how the aircraft production network is structured. The aircraft manufacturing industry may not be well established in some nations and areas despite having high levels of economic development due to their tiny domestic markets and poor demand for aviation-related products.

V. JIANGXI PROVINCE, AVIATION MANUFACTURING ENTERPRISES TO ENHANCE THE PATH

Based on data from Global Aircraft: Development and Production from 1965–2021, this study builds a global aviation production network, measures the domestic and global node status of Jiangxi aviation manufacturing enterprises using social network analysis techniques, and then employs the QAP method to empirically analyze the influencing factors that affect the structure of aviation production networks in order to provide a "double cycle". For the new development of Jiangxi aviation under the new development pattern, the QAP technique was utilized to empirically assess the elements impacting the structure of the aviation production network and to serve as a reference for decision-making. According to the analysis' findings, there are 540 global aviation manufacturing companies listed in "Global Aircraft: Sikorsky, Renaldo, Boeing, Commercial Aircraft, and other large monopolies are the primary cooperative production enterprises in Jiangxi in the global aviation manufacturing production network. The production relationship is primarily subcontracted production, and the products produced are primarily fighters and military transport aircraft. According to the QAP findings, sharing a common language helps to strengthen the node status of the aviation industry chain, and distance has little effect on the collaboration of aircraft manufacturing companies. GDP's influence on the organization of aircraft manufacturing networks is modest. In response to the aforementioned findings, this research suggests the following improvement routes to aid in Jiangxi Province's development of aviation manufacturing firms.

A. Enhancing the Status of Industry Chain Nodes by Relying on the Technical Advantages of Leading Businesses and Breakthroughs in Fundamental Technological Challenges

Industry chain to industry chain and industry cluster to industry cluster will be the future rivals in aviation production. To overcome challenges and boost core competitiveness, leading businesses should take the initiative to implement core technology. For key technologies, a scientific research team needs to be formed on the technical level to attack them. On the financial level, commercial institutions need to be actively sought out for investment, and on the talent level, a project reward and punishment system is needed to maintain the enthusiasm of scientific researchers. We will keep strengthening our position as a node in the aviation industry chain, from the subcontract manufacturing of parts and components to the upstream of the industry chain, such as the research and development of aircraft engines and the production of whole aircraft.

B. Hi-Tech Staff Introduction and Training to Improve Linguistic Proficiency

A unified official language can help aviation manufacturing businesses establish and strengthen their position in the industrial supply chain, according to empirical research. Powerhouses in the aviation industry like Boeing and Airbus are foreign-owned businesses. High-end technical talent should be regularly developed to better collaborate with these businesses, which calls for not only exceptional professional and technical skills but also effective communication skills in a foreign language. First, we should strengthen local training, encourage universities to establish aviation-related majors, and establish an industry-university-research platform to allow local talent to participate more actively in the development and construction of aviation manufacturing enterprises in Jiangxi Province. Second, the government should propose better policies to address the issue of the lack of professional high-tech talent in Jiangxi aviation manufacturing enterprises. Third, the government should actively promote scientific research institutions and innovation bases to draw more businesses and talent to Jiangxi for development. This support for aviation businesses might take the form of land, regulations, and financial subsidies.

C. Enhance External Practical Cooperation

Competition and collaboration have always existed in the history of industrial growth, and the goal of both is to obtain complementary favorable resources, strengthen one's position, and advance one's status. Jiangxi's aviation manufacturing businesses have relatively low levels of high-tech talent, core technology, capital investment, and other resource types. As a result, they must actively seek out opportunities for collaboration with other aviation-beneficial businesses, follow the path of win-win cooperation, forge strategic alliance relationships, and work toward common development and a shared future.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Liu Guoliang conducted the research; Jia Ling analyzed the work; Liu Guoliang and Jia Ling wrote the paper; all authors had approved the final version.

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