Chin. Geogra. Sci. 2010 20(5) 471–480
DOI: 10.1007/s11769-010-0421-5

Identification and Comparison of Aircraft Industry Clusters in China and United States

CHU Bo[1, 3], ZHANG Hua[2], JIN Fengjun[1]

(*1. Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; 2. School of Geography, Beijing Normal University, Beijing 100875, China; 3. Graduate University of the Chinese Academy of Sciences, Beijing 100049, China*)

Abstract: Aircraft industry is very important to the economy and security of a country, and aircraft industry clusters have already existed in the world. Based on Input-Output data and Czamanski′s method, the aircraft industry clusters in China and USA were identified quantitatively in this paper. Furthermore, this article carried out comparison analyses of the identification results. The research finds out: 1) a mature aircraft industry cluster would be generally composed of 7 industrial subgroups, including aircraft industry, metal making and products manufacturing industry, machinery and equipment industry, electronics industry, automobile industry, material industry and others, and electronics industrial subgroup will play a more and more important role in the cluster; 2) in the range of industry-covering, the level of industry-linkage, and the economic performance, there is a tremendously large gap between the aircraft industry cluster of China and that of USA; 3) the spatial evolution of these clusters or centers is highly consistent with the diffusion of a country′s industrialization. Finally, based on those findings, the paper gives some advice on how to improve Czamanski′s method and what China should do to develop its own competitive aircraft industry: 1) China should employ institutional innovation, and turn to be market-oriented; 2) China should abandon the traditional pattern of closed-development, and strengthen the interaction and collaboration between aircraft industry and related industries, especially the electronics industry; 3) China should rectify and perfect its spatial development planning of aircraft industry.

Keywords: aircraft industry; industry cluster; Czamanski′s method; Input-Output

1 Introudction

Under economic globalization, the success of a country′s economy depends largely on the degree to which it participates in global production networks. This prompts countries to accelerate industrial restructuring and upgrading. For the great powers, the industrial restructuring and upgrading is aimed at winning in super industries and core technology. There is no doubt that aircraft industry is an important super industry and a significant symbol of great power. Its development is of great strategy significance to both the national economy and the national security (Lin, 2008).

Aircraft industry was born in the early 1900s. By the outbreak of World War II, it had become one of the world′s largest industries (Cunningham, 1951). Nowadays, it has been one of the largest high-technology industries in the developed countries (Nolan and Zhang, 2003; Niosi and Zhegu, 2005). With the prevalence of Porter′s competition theory (Porter, 1998), studies about aircraft industry clusters are growing simultaneously, and academic literatures concerning aircraft industry cluster mainly focus on three aspects as follows.

The first one is concerning the demonstration of aircraft industry cluster′s positive influence on regional or national development. Based on census data from European Association of Aerospace Industries (AECMA), Fichtmüller (1999) pointed out that the aircraft industry cluster had contributed a lot to balancing a nation′s international trade. Researches on UK (Beaudry, 2001) and USA (Morris, 2003) concluded that the aircraft industry cluster was the key driving force of regional de-

Received date: 2009-03-16; accepted date: 2010-04-13
Foundation item: Under the auspices of National Natural Science Foundation of China (No. 40635026, 40801050), Knowledge Innovation Programs of the Chinese Academy of Sciences (No. KZCXZ-YW-Q10-4)
Corresponding author: ZHANG Hua. E-mail: zhanghua@bnu.edu.cn

velopment. The second one is concerning the reasons for agglomeration of aircraft industry. With statistics and questionnaires, Scott and Mattingly (1989) suggested that external economies should be the major sources of the long-term success of the aircraft and parts of manufacturing cluster in Southern California. Libby (1992) also discussed the aircraft industry cluster in Southern California, and in his view, the agglomeration was derived from the development of a strong economic-industrial base depending upon high technology, public organizations and business-science coalition. Goldstein (2005) suggested that international industry shift, especially multinational enterprises′ location choices played a vital role in the agglomeration of aircraft industry in developing countries. The third one is concerning the internal firm relationship in the aircraft industry cluster. Using Kauffman′s NK-model, Frenken (2000) modeled the network of aircraft industry cluster, and considered the complementary competencies between the members as the key to the cluster′s success. Niosi and Zhegu (2005) provided an analysis on some of the most dynamic aircraft industry clusters in the world, and emphasized the anchor firm′s effects as labor pools for geographical clustering. Aguilera *et al*. (2006) investigated the evolution of the aircraft industry cluster in the Andalusian region, and thought the extended enterprise structure was beneficial to the cluster′s competitiveness. Li and Liu (2008) discussed the development ideas about Tianjin aircraft industry cluster of China in different stages from the perspective of promoting industry interaction and rooting.

The existing literatures about aircraft industry have covered almost all the research topics related to industry cluster, however, because of difficulties in data collection and calculation, few papers dealt with the quantitative identification of aircraft industry cluster so far. Consequently, the majority of studies unconsciously mistake ′aircraft industry′ for ′aircraft industry cluster′, which ignores the increasingly close linkages between aircraft industry and other related industries and weakens the validity of conclusions. Therefore, this paper attempts to identify aircraft industry clusters of USA and China quantitatively based upon the Input-Output (I-O) data using Czamanski′s method, and to clarify the linkages among the industries within the cluster by analyzing the industry composition of the two countries (specially in USA). Another purpose of this study is to find out the gaps in industry composition, industry linkages, spatial organization and economic performance between aircraft industry clusters of two countries, and provide some constructive advice for the development of Chinese aircraft industry cluster.

2 Data and Method

2.1 Data

The data used in this paper mainly contain two I-O tables. The one is China I-O Table of 2002, which is provided by the National Bureau of Statistics of China, and made according to *the GB/T 4754-2002 Industrial Classification for National Economic Activities*. In China I-O Table, there are 122 four-digit industries, of which 72 are manufacturing industries. The other is USA I-O Table of 2002, which is prepared by the Industry Benchmark Division, Bureau of Economic Analysis, Department of Commerce of USA. USA I-O Table is made according to the North American Industry Classification System (NAICS). And there are 133 four-digit industries in USA I-O Table, of which 53 are manufacturing industries.

Both of the I-O tables are calculated at producers′ prices of 2002. Because the latest data, 2007 I-O tables, have not been finished and released in USA and China yet, the 2002 I-O tables are employed here. Considering our research aims, the 2002 I-O tables can also completely meet the requirements.

2.2 Methods

2.2.1 Method comparison

In fact, there are several methods that have been applied to identifying industry clusters based on I-O Table (Kaufman and Rousseeuw, 1990; Feser and Bergman, 2000). The methods frequently adopted in researches may fall in two categories: Multivariate Clustering (MC) and Principal Component Analysis (PCA).

MC methods have insights into the interdependence among industries; however, their results have some unreasonable property. On the one hand, the clusters identified by MC methods cover the entire industries. This is inconsistent with the meaning of ′industry cluster′, which only include the export-oriented industries with regional competitiveness, not all the industries. On the other hand, MC methods suppose mutually exclusive groups of industries, which is not consistent with the reality of regional economic development since some basic industries tend to belong to several clusters due to the complexities of inter-industry linkages (Bergman *et al*., 1996).

Although they have the advantages of data reduction, according to the algorithm, PCA method tends to produce groups of industries that have similar input and output structure rather than clusters of industries with strong internal linkages (Slater, 1977; Rey and Mattheis, 2000). In other words, PCA method tends to highlight complementary linkages instead of vertical (forward and backward) linkages.

The focus of this paper lies on the approach proposed by Czamanski (1974). Czamanski′s method seems to be appropriate for our purposes since it could give prominence to the interrelations among industries in a certain cluster. As a matter of fact, because the thoughts of Czamanski′s method are highly consistent with the cluster theory, it has been adopted by some academic researches (Liang *et al*., 2005), which achieved good performance.

Due to the inherent limitation of current industrial classification, several tests show that the results will make no sense if we take the tertiary industry into consideration. Therefore, only manufacturing industries are involved in this research.

2.2.2 Czamanski's method

In order to make better use of the I-O tables, we make some necessary improvement on Czamanski′s method. The revised Czamanski′s method is presented step by step as follows.

Step 1: Calculating intermediate transactions coefficients matrix. From the I-O tables, we can form an inter-industry transactions matrix, in which each element, x_{ij}, gives the value of goods or services sold by industry i to j. And then, we can calculate the intermediate sales coefficients and the intermediate purchase coefficients to express the types of functional relationship between any 2 industries, i and j. Given that, for each industry, p presents total intermediate purchases, and s presents total intermediate sales, then:

$$a_{ij} = x_{ij} / p_j,\ a_{ji} = x_{ji} / p_i$$
$$b_{ij} = x_{ij} / s_i,\ b_{ji} = x_{ji} / s_j \qquad (1)$$

where a_{ij} (a_{ji}) is a proportion of intermediate goods purchases by j (i) from i (j) in j′s (i′s) total intermediate goods purchases. A large value for a_{ij} suggests that industry j depends on industry i as a source for a large proportion in its total intermediate inputs. b_{ij} (b_{ji}) is a proportion of intermediate goods sales from i (j) to j (i) in i′s (j′s) total intermediate goods sales. A large value of b_{ij} suggests that industry i depends on industry j as a market for a large proportion in its total intermediate goods sale.

Step 2: Computing the maximum inter-industry linkage matrix E. Based on a_{ij}, a_{ji}, b_{ij} and b_{ji}, we can construct a new matrix E whose elements are e_{ij}:

$$e_{ij} = \max[a_{ij}, a_{ji}, b_{ij}, b_{ji}]$$
$$e_{ij} = 0 \text{ for } i = j \qquad (2)$$

Obviously, E is a symmetric matrix. The information contained in matrix E allows us to focus on the intermediate demands and intermediate inputs, and to identify the maximum linkages that exist between any two industries.

Step 3: Selecting the core industry of a cluster. There are many ways to choose the core industry, such as proportions of GDP, location quotient (LQ), influence coefficient, sensitivity coefficient and so on. The number of core industries will be determined according to the actual situation, and generally, each cluster corresponds to 1 core industry. Undoubtedly, the aircraft industry is the core industry in this research.

Step 4: Searching for other industries of the cluster. The core industry is assumed to be the first industry of the cluster. Then the one with the highest value in column vector corresponding to the first industry of E is added to the cluster as the second industry. The sum of column vectors in E corresponding to the first and the second industries is the basis for identifying the third industry of the cluster. The criterion is again the highest value of the linkages. Then the sum of column vectors in E corresponding to those three industries is the basis for identifying the fourth industry. The rest may be deduced by analogy.

Step 5: Identifying the cluster end. We use $\bar{e}_m$ as a stopping criterion: once its value starts to decrease as one industry becomes a part of the cluster, the procedure is ended. And the formula is:

$$\bar{e}_m = \sum_{i=1}^{m} \sum_{j=1}^{m} e_{ij} / m \qquad (i,\ j = 1, 2,\ \ldots, m) \qquad (3)$$

where i (j) is the industries already included in the cluster and m is the total number of these industries. Clearly, $\bar{e}_m$ represents the mean value of linkages between these industries already included in the cluster.

3 Results and Analyses

3.1 Industry composition

The industries included in the aircraft industry clusters, and e_{ij} (elements in matrix E), the maximum linkages between the core industry and the other industries in the clusters of China and USA are presented in Table 1 and Table 2.

China′s aircraft industry cluster is composed of 17 industries (Table 1). Besides the core industry (C1), the other 16 industries could be roughly sorted into 2 main kinds: one is metal making and products manufacturing industry (C4, C5, C6, C7, C8, C11, C12), and the other is machinery and equipment industry (C2, C3, C13, C14, C15, C16, C17).

According to Table 2, 38 industries, 21 more than China′s, constitute USA′s aircraft industry cluster. It is worthy to mention that there are 53 manufacturing industries altogether in USA while 72 industries in China. Just like China, USA′s aircraft industry cluster also contains a core industry (A1), metal making and products manufacturing industry (A9, A11, A12, A13, A15, A16, A19, A34), and machinery and equipment industry (A4, A10, A14, A17, A18, A20, A21, A27, A38). However, besides the similarities, USA′s aircraft industry cluster comprises much more industries than China′s, which could be crudely grouped into 4 kinds: electronics industry (A2, A3, A5), automobile industry (A6, A7), material industry (A8, A22, A24, A25, A26, A36) and others.

Table 1 Industry composition of aircraft industry cluster in China

Code	Industry	e_{ij}	Code	Industry	e_{ij}
C1	Aircraft manufacturing		C10	Discarded resources & waste materials	0.0005
C2	Turbine & power transmission equipment	0.1863	C11	Nonferrous metal smelting	0.0102
C3	Other general purpose machinery	0.1468	C12	Nonferrous metal pressing	0.0047
C4	Steel pressing	0.0834	C13	Electrical equipment	0.0047
C5	Steel smelting	0.0024	C14	Other special purpose equipment	0.0084
C6	Iron smelting	0.0009	C15	Other electrical equipment	0.0250
C7	Ferroalloy smelting	0.0094	C16	Metalworking machinery	0.0136
C8	Metal products	0.0498	C17	Ship & floating device	0.0135
C9	Coking	0.0020			

Note: Names of industries are abbreviated for convenience, not exactly same as the GB/T 4754-2002

Table 2 Industry composition of aircraft industry cluster in USA

Code	Industry	e_{ij}	Code	Industry	e_{ij}
A1	Aircraft manufacturing		A20	Electrical equipment	0.0003
A2	Electronic instruments	0.1895	A21	Other electrical equipment & components	0.0230
A3	Semiconductors & electronic components	0.0259	A22	Plastics & rubber products	0.0164
A4	Communications equipment	0.0614	A23	Household appliances	0.0000
A5	Computer & peripheral equipment	0.0001	A24	Resins, rubber, & artificial fibers	0.0001
A6	Motor vehicles	0.0000	A25	Basic chemicals	0.0017
A7	Motor vehicle components & parts	0.0090	A26	Paints, coatings, & adhesives	0.0047
A8	Leather & allied products	0.0000	A27	Industrial machinery	0.0000
A9	Metal casting products	0.0203	A28	Non apparel textile products	0.0163
A10	Turbine & power transmission equipment	0.0000	A29	Textile mill products	0.0000
A11	Other fabricated metal products	0.0451	A30	Food products	0.0000
A12	Forgings & stampings	0.0394	A31	Beverage products	0.0000
A13	Primary ferrous metal products	0.0157	A32	Wood products	0.0025
A14	Agriculture, construction & mining machinery	0.0000	A33	Pulp, paper, & paperboard	0.0008
A15	Architectural & structural metal products	0.0114	A34	Metal tool manufacturing	0.0048
A16	Primary nonferrous metal products	0.0167	A35	Other miscellaneous manufacturing	0.0034
A17	Metalworking machinery	0.0119	A36	Other chemical products	0.0073
A18	Other general purpose machinery	0.0329	A37	Printed products	0.0000
A19	Boilers, tanks, & shipping containers	0.0025	A38	HVAC & refrigeration equipment	0.0002

Note: Names of industries are abbreviated for convenience, not exactly same as the NAICS

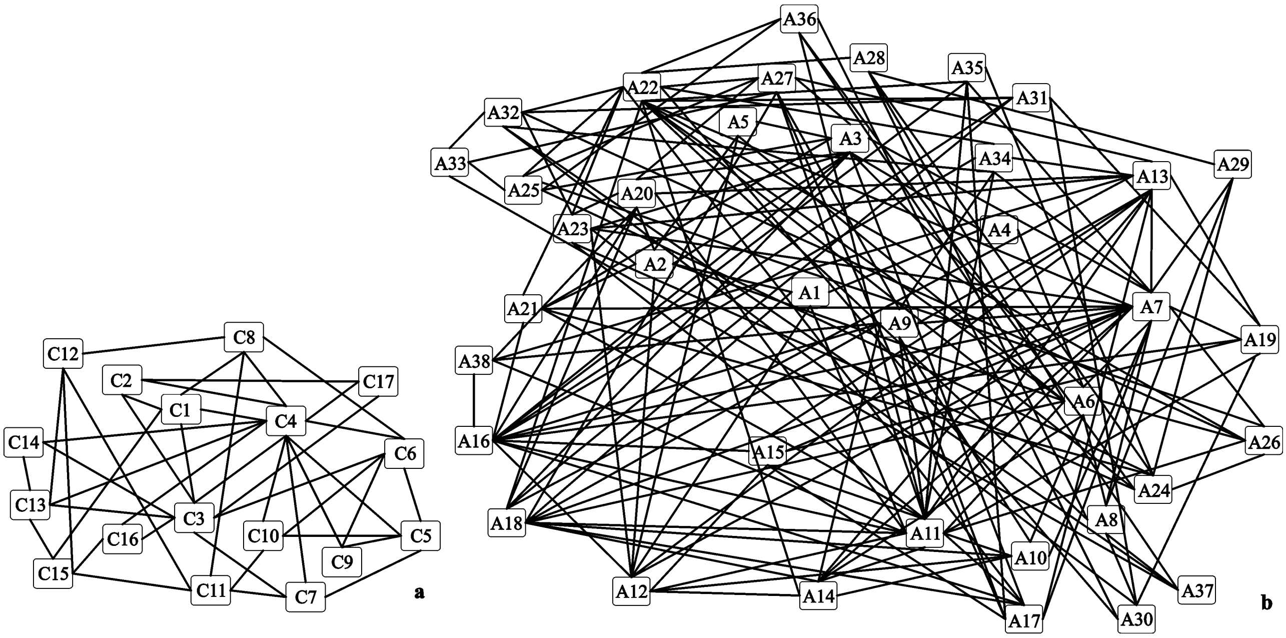
In addition, Berk and Associates (2004) suggested the framework of Seattle′s aircraft industry cluster by field research. There are two major parts in the cluster. One is the core activities, including Boeing, small aircraft industry, and aircraft maintenance and overhaul, which are equivalent to the core industry (A1). The other is related industries, including electronics, electrical equipment manufacturing, engineering, information technology, mechanical, plastics and so on, which basically match the industries (except A1) in USA′s aircraft industry cluster in Table 2, although the names are not exactly the same. In a certain sense, it demonstrates that our identification results of cluster with Czamanski′s method embody a geographical meaning, and the method bears good practicality and applicability.

3.2 Industry linkages

Network maps of the two clusters are drawn on the basis of the maximum inter-industry linkage matrix E (Table 1, Table 2, Fig. 1). As is shown above, the network of the aircraft industry cluster in USA is much more complex than that in China, which corresponds very well to the reality. Taking account of the high level of economic development and the mature industrial system of USA, the identification results of the aircraft industry cluster there are typical. Unquestionably, USA′s aircraft industry cluster has already been in the mature stage (MacPherson and Pritchard, 2003), and is of high structure integrity definitely. Therefore, the gap in industry linkages between two countries′ aircraft industry clusters will be understood clearly by contrast.

There is something in common in the aircraft industry clusters of China and USA. Since aircrafts which are the final goods of aircraft manufacturing industry are mostly made of metal, the identification results both in USA and in China contain metal making and products manufacturing industry, and machinery and equipment industry. In fact, during World War I and World War II, the two industries manufactures were entrusted by the military with most fighter production besides the automobile industry.

There is also difference between the aircraft industry clusters in USA and in China. The aircraft industry cluster in USA includes not only mental manufacturing industry and machinery and equipment industry but also automobiles, materials, and electronics industries. First, there is a strong industry linkage between the aircraft industry and automobile industry, which is of both historical origins and reality basis. At the beginning, the aircraft industry directly relied on the techniques from automobile industry, and many of today′s famous aircraft industry companies have been or are still automobile manufacturers, such as the well-known GE (General Electric), R-R (Rolls-Royce) and so on. And nowadays,



Line from i to j is drawn only when e_{ij} is above mean value of cluster

Fig. 1 Main intra-cluster linkages of aircraft industry cluster ((a) China; (b) USA) there are still positive interaction and cooperation between two industries, such as technique sharing which promotes each other′s technique alternately (Shi, 2008). Second, nonmetallic materials, especially high-tech materials, are now widely used in the aircraft industry (Schatzberg, 2002), which explains very well why the material industries can be included in the aircraft industry cluster. Last but not the least, as the mainstream technologies of aerodynamic configuration and structural intensity have been applied in aircraft industry, the promotion of the performance of aircraft highly depends on the avionics′ upgrade. Therefore, the proportion of avionics in the total cost of an aircraft is increasing continuously (Fig. 2). And this is the reason why almost all of electronic industries are firstly chosen into the cluster in the identification process.

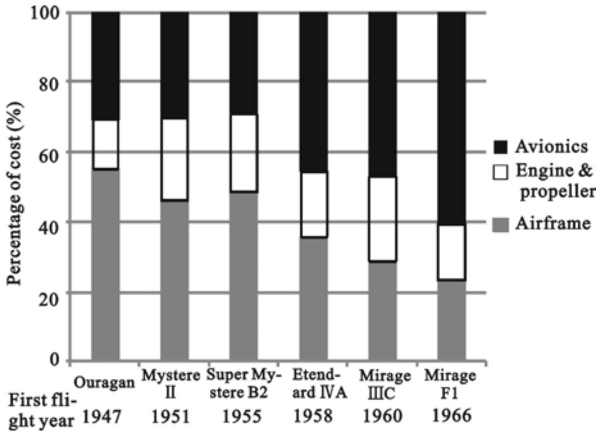


Fig. 2 Cost structure of airplane

In China, the aircraft enterprises entirely belong to the Commission of Science, Technology and Industry for National Defense (COSTIND, which has been now incorporated into the Ministry of Industry and Information Technology), and have a closed development model by which the business management is too cautious and passive to carry out external linkage with others out of the system and lead to a weak industry collaboration. On the contrary, the market level of aircraft industry, even the entire defense industry, is very high in USA. The interrelated industries′ cooperation and interaction are frequent, and the establishment and operation of the entire defense industry′s security system are almost perfect. The huge difference between the development ideas and models in China and in USA resulted in that the aircraft industry cluster in China is simpler and more incomplete than the cluster in USA.

3.3 Economic performance

First of all, in view of the development of the core industry in aircraft industry cluster, China′s aircraft industry cluster is inefficient and disadvantaged. In 2005, the gross industrial output value of USA′s aircraft industry added up to US\$$170\times10^9$, while only US\$$9.3\times10^9$ in China. According to a survey from Flight International, in the ′Aerospace Top 100′ in 2006, 47 corporations belong to USA, and the number of the 47 corporations′ employees, sales and profits accounted respectively for 53.56%, 60.32% and 63.79% in the ′Aerospace Top 100′. At the enterprise level, in 2000, although China Aviation Industry Corporation (AVIC) was the main body of aircraft industry in China, the total sales amount was less than 1/10 of Boeing′s, 1/5 of Lockheed Martin′s, while the total employment was closed to 450×10^3, which was 2.25 times much more than that in Boeing, 3.54 times that of Lockheed Martin (Table 3). Nolan and Zhang (2003) indicated that it just needed 1 200 employees to produce the aircraft engine in China, if the manufacturer is an independent production company and is in accordance with the staffing standards of Rolls-Royce.

Table 3 Relative sizes of selected aerospace companies in 1997 and 2000

	1997				2000			
	Asset ($\times10^9$ US\$)	Revenue ($\times10^9$ US\$)	Profit ($\times10^6$ US\$)	Employee ($\times10^3$)	Asset ($\times10^9$ US\$)	Revenue ($\times10^9$ US\$)	Profit ($\times10^6$ US\$)	Employee ($\times10^3$)
Boeing	38.0	45.8	–178	239	42.0	51.3	2.1	198
Northrop Grumman	9.7	9.2	407	47	10.1	8.3	608	39
Lockheed Martin	28.4	28.1	1300	190	30.4	25.3	–519	126
AVIC	7.1	3.1	72	560				
AVIC Ⅰ					4.2	2.52		236
AVIC Ⅱ					3.8	2.35		210

Note: AVIC (China Aviation Industry Corporation) was reorganized into AVIC Ⅰ and AVIC Ⅱ in 1999
Source: PricewaterhouseCoopers, 2006

Then, considering the development of the entire aircraft industry cluster, USA′s aircraft industry cluster is more competitive. As is shown in Table 4, when it comes to the proportion in the total output of manufacturing industries, the aircraft industry cluster in USA is lower than that in China. On the other hand, the value-added of USA′s aircraft industry cluster accounts for 73.38% of the manufacturing industries′ value-added, which is much higher than that of China (9.37%), and so does export. There is a good explanation for this situation: to allocate resources better and seek more profits, USA′s aircraft enterprises that are holding kernel technologies, primarily focus on the industry with high value-added of the production chain, which are design, assembly and custom services. At the same time, the production of airplane′s components and parts is dispersed to other countries with lower production cost, for instance, China (MacPherson and Pritchard, 2003). Or, we can say that the ′smile curve′ works.

Table 4 Performance comparison of aircraft industry cluster/manufacturing industries between China and USA (%)

	China	USA
Total output	24.74	15.11
Value-added	9.37	73.38
Exports	21.04	46.57

In short, the competitiveness of USA′s aircraft industry and industry cluster is so great that China needs to make immense efforts to catch up, especially in R&D investments in aero technology.

3.4 Spatial organization

USA′s industrialization began in the northeastern region, so did the aircraft industry. The early aircraft industry center concentrated in the northeast industrial area in which almost 80% of the aircraft industries were located before 1933. The saturation of the northeast industrial area resulted in lots of social and environmental problems. Therefore, almost all of the enterprises were after new space to prosper at that time. The industrialization began a process of southward and westward spatial expansion, among which the two westward expansions were more important for the spatial patterns formation of national economic activities. In the diffusion process, the new aircraft industry center was developed in the Pacific coastal states with location advantages, which resulted from the aviation manufacturing enterprises′ nature to pursue a profit. At the same time, under the promptings of both the defense program and the government policy of reducing regional disparities, a military and general oriented aircraft industry cluster was formed in central and southern USA. The northeastern industrial district did not decay, even though the aircraft industry drifted to the southward and westward. It is always the key distribution area, where still there is a large proportion of the aircraft industry employees. Although the proportion of airframe production declined, the aircraft engine, propeller and electronic instruments are still important. There are three aircraft industry clusters including the western, northeastern, and south central clusters. This pattern continues to today (Table 5 and Table 6), and the major centers or local clusters of aircraft industry are located in the areas including Southern California Area, Seattle, the BosWash Megalopolis, Wichita, Kansas City and so on.

From a historical perspective, the spatial evolution of USA′s aircraft industry primarily reflects the common features of general economic activity. Although the de-

Table 5 Distribution of USA′s aircraft industry in 1950

Region	State	Employee share (%)
Western USA		39.3
	CA	30.4
	WA	8.9
Northeastern USA		29.3
	NY	9.0
	NJ	5.6
	CT	8.8
	MD	5.9
South Central USA		16.6
	TX	10.9
	KS	5.7

Table 6 Primary regional aircraft industry cluster of USA in 2000

Order	Cluster	Region	Direct employee
1	Los Angeles, CA	Western USA	107500
2	Seattle, WA	Western USA	95500
3	Washington, DC	Northeastern USA	45500
4	Wichita, KS	South Central USA	40000
5	New York, NY	Northeastern USA	33500
6	Dallas, TX	South Central USA	24500
7	Boston, MA	Northeastern USA	20500
8	Philadelphia, PA	Western USA	19500
9	San Francisco, CA	Western USA	19500

Note: Data only include businesses with 100 employees or more
Source: PricewaterhouseCoopers, 2006

fense strategy and regional policy have a definite impact, resulted from the market rationality, there is a high degree of spatial coherence between the spatial evolution of the USA aircraft industry and the spatial diffusion of the nation′s industrialization.

Look into the development of China′s aircraft industry. On the one hand, the distribution is too scattered. At the beginning, the aircraft industry was set up in Shenyang with the replication factory model under the aid of the Former Soviet Union in 1951. But since the late 1960s, the emphasis on the decision, to locate some production projects in the mountains and conceal some in caves, resulted in the dispersing of both the production capacity and the research capacity of the aircraft industry. There have been a large number of repeatedly-built factories and departments, which have a stiff competition. The facilities and the imported equipment, software and technology cannot be used efficiently. On the other hand, the distribution is inconsistent. The fuselage manufacturers (or engine manufacturers) and their related enterprises scattered in different areas with a distance of thousands of miles, and it is difficult to develop exchange and cooperation. Many areas where the aviation manufacturing enterprises are located are so poor that it is difficult to use local social and economic infrastructure and exert the technology spillover effects of aircraft industry. There have been a lot of inefficient technical isolated island.

As the emphasis on the national defense strategy, the distribution of aircraft industry was extremely irrational, and there has not been an independently aircraft industry center with international competitiveness in China. At present, most aviation manufacturing enterprises have a development mode with a factory and a research institute. The business was too small to achieve the economies of scale and develop a cluster with industrial competitiveness.

4 Conclusions and Discussion

The identification of cluster is a key foundation of carrying out cluster researches. Utilizing Czamanski′s method and based on I-O data, the aircraft industry clusters in China and USA have been identified quantitatively in this paper. Moreover, the results have been analyzed in several aspects, such as industry composition, industry linkages, economic performance and spatial organization. The conclusions can be drawn as follows:

Firstly, on the basis of the identification results, especially USA′s, it can be concluded that, a mature aircraft industry cluster would be generally composed of 7 subgroups, including aircraft industry, metal making and products manufacturing industry, machinery and equipment industry, electronics industry, automobile industry, material industry and others. And since avionics′ improvement is crucial to modern aero technology, the electronics industrial subgroup will play a more and more important role in the aircraft industry cluster in the future.

Secondly, a comparison between aircraft industry cluster in USA and China shows that there is quite a large gap between them apparently. The research findings tell us that, China′s aircraft industry cluster only includes three main subgroups, which are aircraft industry, metal manufacturing and product industries, and machinery and equipment industries. And the network of intra-cluster linkages of China′s aircraft industry cluster is much less complex than that of USA′s. The economic performance analyses also show that, the competitiveness of USA′s aircraft industry and industry cluster is very great. To narrow the gap, without question, China should shoulder extremely heavy responsibilities.

Finally, unlike the traditional viewpoint that the location behaviors of aircraft industry are considered unconventional for its military background, at a national level, the aircraft industry centers mainly exhibit the commonness as a general economic activity, and their spatial evolution is just a part of the nation′s industrialization diffusion. And it is implied that the market forces, i.e. enterprises′ nature of profit-seeking weigh much more against non-market ones, i.e. consideration of national defense.

Compared with MC methods and PCA methods, Czamanki′s method has advantages of defining the interrelations among industries in a certain cluster, both complementary linkages and vertical ones. In terms of economic logic, additionally, Czamanski′s method is highly consistent with the cluster theory. In the future, it is absolutely necessary and valuable to use this method in researches concerning other industries or other countries, which is affirmatively conducive to the method′s perfection. Besides, it is suggested to integrate the method with spatial data and spatial analysis, which is likely to get some breakthrough in methodology.

Lots of activities were held in China, which revealed China′s determination to develop its own competitive aviation industry. However, in general, the development of China′s aviation industry in the past was not very satisfactory. Because of special historical reasons, a lot of airplane plants are located in inland provinces and the spatial evolution of aircraft industry is exactly in reverse with the diffusion of industrialization in China. Although the arrangement achieved the strategic objects in the special period, it is one of the main retarding forces for the rise of China′s aircraft industry now. The experience of US shows that, to develop a mighty aircraft industry, besides increasing R&D investments, China should employ institutional innovation, and should be market-oriented. In particular, China should abandon the traditional pattern of closed-development, and strengthen the interaction and collaboration between aircraft industry and related industries, especially the electronics industry. On the other hand, China should rectify and perfect its spatial development planning of aircraft industry. In the future, for the R&D of commercial airplane, it is necessary to integrate the resources of capital, talents and technology in the superior regions, like the Changjiang (Yangtze) River Delta, the Zhujiang (Pearl) River Delta and the Beijing-Tianjin-Hebei area, where there are convenient accesses to the international market, which will be beneficial for the cooperation with other countries.

Acknowledgements

The authors would like to express our sincere appreciation to Professor Morris M Kleiner, University of Minnesota for his helpful comments and data.

References

Aguilera C M, Castanedo A, Guerrero F, 2006. Past, present and future of the Andalusian aeronautical cluster. In: Camarinlia-Matos L *et al.* (eds.). *IFIP International Federation for Information Processing*. Boston: Springer, 583–590.

Beaudry C, 2001. Entry, growth and patenting in industrial clusters: A study of the aerospace industry in the UK. *International Journal of the Economics of Business*, 8(3): 405–436. DOI: 10.1080/13571510110079000

Bergman E, Feser E, Sweeney S, 1996. Targeting North Carolina manufacturing: Understanding the state′s economy through industrial cluster analysis. Chapel Hill: Institute for Economic Development.

Berk and Associates, 2004. Basic industries cluster analysis study. Seattle: the City of Seattle Office of Economic Development.

Cunningham W G, 1951. *The Aircraft Industry*: *A Study in Industrial Location*. Los Angeles: Lorrin L Morrison.

Czamanski S, 1974. Study of clustering of industries, spatial organization of industries. Halifax, Nova Scotia, Canada: Institute of Public Affairs, Dalhousie University.

Feser E J, Bergman E M, 2000. National industry cluster templates: A framework for applied regional cluster analysis. *Regional Studies*, 34(1): 1–19. DOI: 10.1080/00343400050-005844

Fichtmüller P, 1999. Aerospace industry propelled upwards by European momentum and strong performance. *Air & Space Europe*, 1(4): 18–23. DOI: 10.1016/S1290-0958(00)87114-2

Frenken K, 2000. A complexity approach to innovation networks: The case of the aircraft industry 1909–1997. *Research Policy*, 29(2): 257–272. DOI: 10.1016/S0048-7333(99)0006-4-5

Goldstein A, 2005. The political economy of industrial policy in China: The case of aircraft manufacturing. *Journal of Chinese Economic and Business Studies*, 4(3): 259–273. DOI: 10.1080/14765280600991628

Kaufman L, Rousseeuw P, 1990. *Finding Groups in Data*. New York: Wiley.

Li Yanhua, Liu Jie, 2008. Study on rearing of industry cluster about Tianjin aviation industry based on the intention of industry interaction and rooting. *Soft Science*, 22(12): 97–101. (in Chinese)

Liang Jinshe, He Canfei, Zhang Hua, 2005. Changes in the economic functions of Beijing, 1992–2002: Based on the inter-industrial linkage and economic base theory. *Acta Geographica Sinica*, 60(4): 577–586. (in Chinese)

Libby J E, 1992. To build wings for the angels: Los Angeles and its aircraft industry, 1890–1936. *Business and Economic History*, 21(2): 22–25.

Lin Zuoming, 2008. The aviation industry and the great power′s status. *Economic Research of the Aviation Industry*, (1): 4–16. (in Chinese)

MacPherson A, Pritchard D, 2003. The international decentralisation of US commercial aircraft production: Implications for US employment and trade. *Futures*, 35(3): 221–238. DOI: 10.1016/S0016-3287(02)00055-1

Morris F A, 2003. *Boeing and Beyond: Seattle in the Global Economy*. Los Angeles, CA: Pacific Council on International Policy.

Niosi J, Zhegu M, 2005. Aerospace clusters: Local or global knowledge spillovers? *Industry and Innovation*, 12(1): 1–25. DOI: 10.1080/1366271042000339049

Nolan P, Zhang J, 2003. Globalization challenge for large firms from developing countries: China's oil and aerospace industries. *European Management Journal*, 21(3): 285–299. DOI: 10.1016/S0263-2373(03)00047-1

Porter M, 1998. Clusters and the new economics of competition. *Harvard Business Review*, 76(6): 77–90. DOI:10.1225/98609

PricewaterhouseCoopers, 2006. Flight international top 100, 2006. http://www.pwc.co.uk/eng/publications/flight_international_top_100_2006.html, 200609/200905.

Rey S, Mattheis D, 2000. Identifying regional industrial clusters in California. Sacramento: The California Employment Development Department.

Schatzberg E M, 2002. Materials and the development of aircraft: Wood-aluminium-composites. In: Coen Vermeeren (ed.). *Around Glare: A New Aircraft Material in Context*. Springer.

Scott A J, Mattingly D J, 1989. The aircraft and parts Industry in Southern California: Continuity and change from the Inter-War Years to the 1990s. *Economic Geography*, 65(1): 48–71.

Shi Donghui, 2008. *The Global Market Structure and Competition of Large Commercial Airplane Industry*. Hubei: Hubei Education Press. (in Chinese)

Slater P B, 1977. The determination of groups of functionally integrated industries in the United States using a 1967 interindustry flow table. *Empirical Economics*, 2(1): 1–9. DOI: 10.1007/BF 01764717