Analysis on the Spatiotemporal Changes and Correlation of the National Industrial Chain
Taking 30 Provinces and Cities in China as Examples

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ABSTRACT
The internal connection between industrial sectors is an important part of the current global production and trade network relationship. The degree of industrial sector connection is usually measured in terms of length and strength. The study took 30 provinces and cities in China as the object, combined with the GAPL method to estimate the specific positions of 30 provinces and cities in the national industrial chain, and used the regional industry influence coefficient and the response coefficient to measure the strength of industry links and leading industry links between the upper and middle reach and downstream provinces in the national industrial chain. The results show that from 2007 to 2012, Hebei, Shandong, Shanxi, Henan, and Inner Mongolia were in the upstream position of the national industrial chain, and Guangdong, Guangxi, Chongqing, and Yunnan were in the downstream position of the national industrial chain, and provinces in the midstream and middle and lower reaches of the industrial chain varied greatly. The upstream and downstream provinces were spatially adjacent, and the upstream spatial scope of the industrial chain was gradually expanding, and the downstream spatial scope was gradually shrinking; in the national industrial chain structure of upstream and downstream provinces, industry played a role of strong radiation and weak pulling function, and the construction industry played a role of strong pulling and weak radiation function; moreover, the pulling and restricting effects of transportation and warehousing gradually weakened, and the pulling and restricting effects of wholesale and retail industry gradually increased.

Keywords: *average propagation length (APL), influence coefficient, response coefficient, industrial chain*

I. INTRODUCTION

In the report of the 19th National Congress of the Communist Party of China, General Secretary Xi Jinping clearly pointed out that "China's economy has shifted from a stage of rapid growth to a stage of high-quality development". China is a large country with a vast territory, and there are large differences between provinces in the high-quality development stage. The industrial chain is mainly a regional cooperation carrier based on regional differences in various regions, focusing on giving play to regional comparative advantages, relying on the regional market to coordinate the contradiction between specialized division of labor and multi-dimensional needs, and taking industrial cooperation as the realization form and content [1]. Clarifying the roles and positions of various provinces in the process of national economic production is of great importance to promote the division of labor among regions and coordinated development.

The input-output model is currently one of the powerful and more popular tools used for important research issues in the industrial chain to connect with the industrial sector [2]. From the perspective of methods study, Inomata applied a new indicator based on APL model to measure the degree of division of labor in the empirical research in the Asian-Pacific region [3]. Antràs et al. proposed the "upstream degree" index for the relative position measurement of the industrial chain based on the input model against the background of production fragmentation. This index is very similar to APL and is a variant of APL [4]. Oosterhaven and Bouwmeester further discussed and determined the APL concept and its scope of application through different industry levels [5]. Lu Xiaoling and Xu Jian compared the APLs matrix of 1997 and 2002, and explained the change of APL matrix from the perspective of direct input coefficient

[6]. Chen Quanrun proposed extended GAPL on the basis of APL and used it in the analysis of the global industrial chain [7]. From the perspective of the role and status of a country or region in the industry chain, Dietzenbacher and romero used the APL model to visualize the production structure of six European countries based on the European regional input-output table, and accurately located the role of each country in this system [8]. Yu et al. combined the APL model and the vulnerability index to determine the priority of industrial sectors that need to be supported and restored after a disaster [9]. Miller and Temurshoev conducted in-depth research on the "upstream degree" indicator and applied it to the identification of countries in the global industrial chain position [10]. Ju Jiandong et al. used the index of "upstream degree" to study the position of various industries and regions at the micro level in the Chinese industrial chain [11]. From the perspective of identifying important industrial chains in the economic system, based on the APL model, Deng Zhiguo, Chen Xikang and others studied inter-sectoral industrial chain relationships and their evolutionary trends [12],[13]. Zhao Suping et al. introduced the APL model to calculate the economic distance between industrial sectors, and tracked China's major industrial chains based on input-output improvement influence coefficients and response coefficients [14]. From the perspective of studying specific industrial sectors, Tang Zhipeng and others introduced input-output correlation and APL model to study the industrial chain and sector correlation of the electric power thermal industry [15]. Li et al. combined the input-output correlation degree and APL and other methods and used the input-output table to analyze the evolution of Chinese coal industry chain from a macro perspectives [16].

In general, Chinese and foreign scholars' research on the industrial chain is mostly based on the APL index to measure regional industrial associations, and there is no research on the industrial chain relationship and spatial position between different regions and provinces. And their researches pay more attention to the relative position of China in the global industrial chain and the role of division of labor in the industrial chain, and there is a lack of systematic research on the status of inter-provincial industrial division in China. As a result, they have insufficient understanding when evaluating the current status of regional industrial development in China, and it is difficult to integrate the industrial chains among different regions of China into a unified whole to measure the degree of coordinated development among Chinese provinces. Based on this, the study uses the APL — GAPL (Generalized APL) model applicable between the two groups of industrial sectors as the main research method and calculates the GAPL value of each province in China in combination with the input-output table of Chinese regions; besides, it combines the influence coefficient and the response coefficient model to analyze the position of each province in the national industrial chain and the industrial correlation strength and internal structure of the upstream and downstream cities in the position. Through research, it's hoped to understand and measure the spatial pattern relations of regional division of labor in different provinces from a new perspective, and provide theoretical foundation and practical reference for the sustainable development of regional industries.

II. RESEARCH METHODS

A. Traditional average propagation length (APL)

Dietzenbacher et al. constructed the APL indicator based on the input-output model for the first time and used it in the analysis of the industrial chain [17]. APL measures the average number of steps required by the change in the final demand of sector i to affect the total output of sector j throughout the production process. The larger this value is, the more steps are experienced, and the longer the correlation between sector i and sector j is [18][19]. The APL formula is shown below:

$$APL_{ij}=\begin{cases}1\times\frac{a_{ij}}{l_{ij}}+2\times\frac{\sum_k a_{ik}a_{kj}}{l_{ij}}+3\times\frac{\sum_k\sum_s a_{ik}a_{ks}a_{sj}}{l_{ij}}+\ldots & i\neq j\\ 1\times\frac{a_{ij}}{l_{ij}-1}+2\times\frac{\sum_k a_{ik}a_{kj}}{l_{ij}-1}+3\times\frac{\sum_k\sum_s a_{ik}a_{ks}a_{sj}}{l_{ij}-1}+\ldots & i=j\end{cases} \tag{1}$$

The APL is expressed in matrix form as:

$$\mathrm{v}=\frac{1\times\mathbf{A}+2\times\mathbf{A}^2+3\times\mathbf{A}^3+}{\mathbf{L}-\mathbf{I}}=\frac{\mathbf{L}(\mathbf{L}-\mathbf{I})}{\mathbf{L}-\mathbf{I}} \tag{2}$$

In the formula: A is the direct input coefficient matrix, the $\mathbf{L}=(\mathbf{I}-\mathbf{A})^{-1}$ is Leontief inverse matrix, and the $\mathbf{I}$ is the identity matrix.

B. Improved APL

The traditional APL didn't consider the initial effect "1" in the construction of the entire production process, which means that the average number of steps required for sectors to influence each other is ignored. On the one hand, although the initial effect has zero steps through the sector itself, the influence of the initial effect can't be ignored. On the other hand, the change in the final demand growth of this sector has a significant impact on its own sector, so the initial effect should be taken into account to calculate the weight of each step. Then the improved APL formula becomes:

$$APL = \frac{0\times\mathbf{I}+1\times\mathbf{A}+2\times\mathbf{A}^2+3\times\mathbf{A}^3+\ldots}{\mathbf{L}} = \frac{\mathbf{L}(\mathbf{L}-\mathbf{I})}{\mathbf{L}} \quad (3)$$

The APL_{ij} in the matrix satisfies:

$$APL_{ij} = \frac{\sum_{k\neq j} l_{ij}l_{kj} + l_{ij}(l_{jj}-1)}{l_{ij}} \quad (4)$$

The improved APL index, on the one hand, in the industry chain of the final product of a particular sector, the sector and its own APL are the smallest. In other words, the sector itself is the closest to the final demand of a particular sector; and the sector itself is affected by the changes in the final demand of the department and will be propagated to the sector in the fewest steps. Therefore, in the specific product industry chain, there is no need to compare the sector's own APL with other APL, which can prevent people from thinking that APL in sectors themselves is meaninglessly compared with other sectors' APL [20]. On the other hand, the APL_{ij} is the number of times the total output of sector i is repeatedly calculated in the industrial chain of the final product of sector j.

C. GAPL — extension of APL model

It can be known from the formula derivation that the APL is the same as the calculation repetition times [21]. Therefore, the repetition calculation times can replace the APL when the APL calculation is complicated. This method of recalculating the number of times is relatively simple, and it is easier to explain the application of APL in other problems. Based on the angle of repeated calculations, APL is easier to expand into a generalized APL — namely GAPL.

The traditional APL portrays the distance between sectors and sectors. GAPL measures the economic distance between groups and groups. A group contains multiple economic entities. Because in the final demand product production process of multiple sectors in a group of economic entities, the total output of multiple sectors of another group of economic entities that is completely needed will require more and more complicated paths to achieve. Comparing the calculation of APL between individual sectors, the calculation of two groups of economic entities is more complicated. Therefore, the APL between groups will be considered from the perspective of repeated calculations, and the calculation of GAPL will become simple and clear.

Assuming that the I and the J represent two groups of sectors, the total output of the "sector group J " required for the production of the "sector group I " final product is the $\mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{f}_{\mathrm{J}}$. Among them, the $\mathbf{i}'_{\mathrm{I}}$ is a sum vector, the corresponding element of the I of the sector group is 1, and the other elements are 0; the $\mathbf{f}_{\mathrm{J}}$ is a final demand vector containing only the sector group J , and the rest of the other sectors are all 0. In the production process of the final product of the sector group J , the total output of the sector group I implied in the total output of all the participating sectors is $\mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{L}\mathbf{f}_{\mathrm{J}}$. The repetitive computation numbers of total output of sector group I counted in the production process of $\mathbf{f}_{\mathrm{J}}$ are:

$$\frac{\mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{L}\mathbf{f}_{\mathrm{J}} - \mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{f}_{\mathrm{J}}}{\mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{f}_{\mathrm{J}}} = \frac{\mathbf{i}'_{\mathrm{I}}\mathbf{L}(\mathbf{L}-\mathbf{I})\mathbf{f}_{\mathrm{J}}}{\mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{f}_{\mathrm{J}}} \quad (5)$$

The generalized APL formula between the I group sector and the J group sector is:

$$APL_{IJ} = \frac{\mathbf{i}'_{\mathrm{I}}\mathbf{L}(\mathbf{L}-\mathbf{I})\mathbf{f}_{\mathrm{J}}}{\mathbf{i}'_{\mathrm{I}}\mathbf{L}\mathbf{f}_{\mathrm{J}}} = \frac{\mathbf{i}'_{\mathrm{I}}\mathbf{L}(\mathbf{L}-\mathbf{I})\bar{\mathbf{f}}_{\mathrm{J}}}{\mathbf{i}'_{\mathrm{I}}\mathbf{L}\bar{\mathbf{f}}_{\mathrm{J}}} \quad (6)$$

In the formula: $\bar{\mathbf{f}}_{\mathrm{J}}$ is a standardized vector of $\mathbf{f}_{\mathrm{J}}$; its element is the proportion of the final demand of each sector in sector group J to the total demand of sector group J .When the I group contains only one sector namely sector i, the J group also contains only one sector, namely sector j, and the APL_{IJ} is equal to the APL_{ij} .

$$APL_{ij} = \frac{\sum_{k\neq j} l_{ik}l_{kj} + l_{ij}(l_{ij}-1)}{l_{ij}} \quad (7)$$

It can be seen that the GAPL indicator is called the generalized APL indicator, and the APL indicator is just a special case of the GAPL indicator. The larger the GAPL value is, the more intermediate product links need to be passed to reach the final demand side.

D. Influence coefficient and response coefficient

1) Regional industry influence coefficient: The influence between each other and the relation affected in the production process is called the correlation between industries, and the influence coefficient and the response coefficient can measure this index. In the inter-regional input-output analysis, the regional influence coefficient reflects the impact of demand on other sectors of the national economy when an industry increases the final use of a unit in a certain region. The greater the index value of the regional influence coefficient, the greater the role of the industry in pulling production.

$$\mathrm{F}_j^s = \frac{\sum_r \sum_i b_{ij}^{rs}}{\frac{1}{m \times n} \sum_r \sum_s \sum_i \sum_j b_{ij}^{rs}} \quad (8)$$

In the formula: the F_j^s is the regional influence coefficient of the j industry in the s area; b_{ij}^{rs} is the total consumption matrix of the i sector in the r area for the j industry in the s area (ie, Leontief inverse coefficient). The m is the number of regions; n is the number of industries, $m = 30$, $n = 6$.

2) Regional industry response coefficient: In the inter-regional input-output analysis, the regional industry response coefficient reflects the impact of all demand on a certain sector in the region when each sector in the national economy adds one unit of final use (that is, the amount of output required by the sector for all sectors). The larger the index value of the coefficient, the greater the dependence of other sectors on the industry's demand.

$$\mathrm{E}_j^r = \frac{\sum_s \sum_j b_{ij}^{rs}}{\frac{1}{m \times n} \sum_r \sum_s \sum_i \sum_j b_{ij}^{rs}} \quad (9)$$

In the formula: the E_j^s is the regional industry response coefficient of the i industry in the r area. b_{ij}^{rs} is the total consumption matrix of the i sector in the r area for the j industry in the s area (ie Leontief inverse coefficient). The m and n have the same meaning as the above formula.

E. Data sources

The research data is based on the "2007 Inter-regional Input-output Table of 6 Sectors of 30 Provinces and Cities in China" and "2012 Inter-regional Input-output Table of 8 Sectors of 31 Provinces and Cities in China" jointly prepared by the Accounting Department of State Statistics Bureau and the Institute of Geographical Sciences and Natural Resources Research of the Chinese Academy of Sciences [22]. Due to the lack of Tibet data in the 2007 input-output table, in order to keep the data consistent between the two years, the 2012 Tibet data was not included in the analysis. At the same time, in order to facilitate comparative analysis, the 8 sectors of 31 provinces and cities were merged into the table of 6 sectors of 30 provinces and cities in 2012. Based on formula (6), where the I is composed of 6 industries in a specific province, and the J is composed of 30*6, the GAPLs between the total output of each province and the national final demand in 2007 and 2012 were calculated respectively.

III. Analysis of the Changes in the Spatial Location of the National Industrial Chain in 30 Provinces and Cities in China

A. Division of location levels

In the production process of products, it has become a common phenomenon that the production process is cut into several relatively independent production links and is matched and reorganized in enterprises, industries, trans-provincial and even the world [23]. The GAPL index was adopted to examine the position of China's 30 provinces and cities in the national industrial chain, and the ranking of China's 30 provinces and cities in the national industrial chain in 2007 and 2012 was obtained (see "Table I"). If the total output of a province passes through many sectors in the national final product production process (that is, the greater the GAPL value), then the province is considered to be closer to the "upstream" position of the regional industry, otherwise it is closer to the "downstream". In general , from 2007 to 2012, the number of upstream provinces and upper and middle reach provinces increased, while the number of downstream provinces decreased. Among the provinces located in the downstream of the national industrial chain between 2007 and 2012, Guangdong, Guangxi, Chongqing and Yunnan were always at the first level (0.5~1.3), mainly engaging in the production activities of supplying final products; the ranks of the second and third levels provinces changed greatly and were unstable, and the provinces in these two levels in 2012 were mainly the downstream provinces in 2007; the second-level provinces engaging in intermediate input production activities were less than the end-use production activities; the third-level provinces engaging in intermediate input production activities were more than the end-use production activities; the fourth-level provinces were located in the upper reaches of the national industrial chain; in 2007 and 2012, Hebei, Shandong, Shanxi, Henan and Inner Mongolia were always in the fourth level, and these provinces were mainly engaged in intermediate input production activities, and were far from the national production final product market.

TABLE I. GRADE CLASSIFICATION TABLE OF CHINA'S 30 PROVINCES AND CITIES IN THE NATIONAL INDUSTRIAL CHAIN IN 2007 AND 2012

Grade	Year	Major provinces and cities
First level	2007	Yunnan, Guangxi, Guangdong, Chongqing, Sichuan, Zhejiang, Hunan, Qinghai, Hubei, Gansu, Fujian, Shanghai, Hainan, Beijing
0.5~1.3	2012	Yunnan, Guangxi, Guangdong, Chongqing
Second level	2007	Guizhou, Shaanxi, Jiangsu, Jilin, Jiangxi, Ningxia, Anhui, Tianjin
1.3~1.5	2012	Hunan, Hubei, Fujian, Shanghai, Hainan, Xinjiang, Heilongjiang, Jiangsu
Third level	2007	Heilongjiang, Xinjiang, Liaoning
1.5~1.7	2012	Guizhou, Sichuan, Zhejiang, Qinghai, Beijing, Jilin, Anhui
Fourth level	2007	Shanxi, Hebei, Henan, Shandong, Inner Mongolia
1.7~2.0	2012	Shanxi, Hebei, Henan, Shandong, Inner Mongolia, Jiangxi, Ningxia, Shaanxi, Liaoning, Gansu, Tianjin

B. Time scale evolution

According to the calculation results of the GAPL model, the corresponding provinces and cities with large GAPL values in 2007 are sorted in descending order. In 2012, the ranking was based on the ranking of provinces and cities in 2007 and then the change trend of 30 provinces and cities in the national industrial chain was obtained (see "Fig. 1"). At the same time, according to the above ranking list, the ranking table of China's 30 provinces and cities in 2007 and 2012 (see "Table II") is made to analyze the provinces with the largest ranking changes in the national industrial chain. On the whole, the rankings of upstream and downstream provinces in 2007 and 2012 are relatively stable in the national industrial chain, and the rankings of provinces in the middle and lower reaches and middle and upper reaches have relatively large changes. From a partial perspective, the position of Gansu and Beijing in the national industrial chain has moved up with time, from 25th and 29th positions in 2007 to 10th and 12th positions in 2012 respectively; Gansu and Beijing moved from the lower reaches of the national industrial chain to the upper and middle reaches. For example, the positions of Heilongjiang and Xinjiang in the national industrial chain moved down with time, from the 6th and 7th positions in 2007 to the 20th and 23rd positions in 2012 respectively; Heilongjiang and Xinjiang moved down from the middle and upper reaches of the national industrial chain to the middle and lower reaches.

TABLE II. RANKING TABLE OF CHINA'S 30 PROVINCES AND CITIES IN 2007 AND 2012

Province	Ranking (2007)	Ranking (2012)	Province	Ranking (2007)	Ranking (2012)
Shanxi	1	3	Tianjin	16	11
Hebei	2	2	Yunnan	17	28
Henan	3	4	Guangxi	18	27
Shandong	4	1	Sichuan	19	16
Inner Mongolia	5	5	Zhejiang	20	17
Heilongjiang	6	20	Hunan	21	21
Xinjiang	7	23	Qinghai	22	14
Liaoning	8	9	Hubei	23	22
Guizhou	9	18	Chongqing	24	30
Shaanxi	10	8	Gansu	25	10
Jiangsu	11	19	Fujian	26	26
Jilin	12	15	Shanghai	27	25
Jiangxi	13	6	Hainan	28	24
Ningxia	14	7	Beijing	29	12
Anhui	15	13	Guangdong	30	29

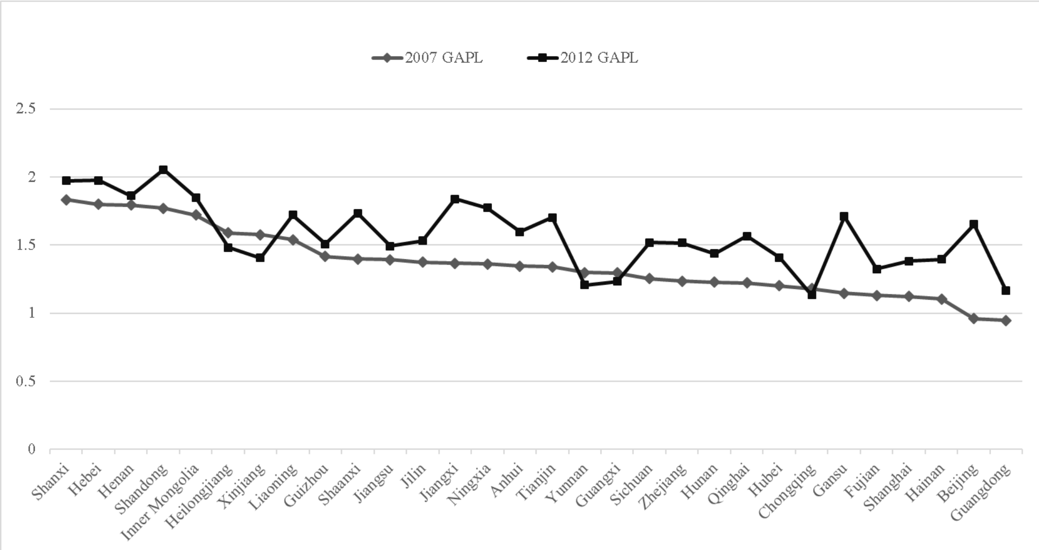

Fig. 1. The position of China's 30 provinces and cities in the national industrial chain in 2007 and 2012.

C. Spatial scale evolution

The author uses the Arcgis 10.3 symbolization function to analyze the spatial position of China's 30 provinces and cities in the national industrial chain, and discusses the spatial evolution law of provinces and cities located in different positions of the industrial chain from 2007 to 2012. The results are shown in "Fig. 2". In general, provinces and cities of the same level are basically neighboring provinces, such as upstream Inner Mongolia, Shandong, Shanxi, Hebei, Henan, etc., and downstream provinces Guangxi, Guangdong, Yunnan, etc.; from 2007 to 2012, the spatial position of the upstream provinces showed a trend of developing in the shape of "人" from the "Hu Line" from east to west; the spatial scope of upstream provinces continues to expand, extending westwards to Gansu, Ningxia, Shaanxi and other provinces and eastwards to Jiangxi; the spatial scope of downstream provinces continues to shrink, including Yunnan, Guangdong, Guangxi and other provinces. The role of resource-based cities represented by upstream provinces in the entire industrial chain is becoming increasingly important. From a partial perspective, from 2007 to 2012, Xinjiang moved down from the middle and upper reaches to the middle and lower reaches, indicating that Xinjiang increased the activities of final production in the entire industrial chain, Xinjiang's regional resources, transportation infrastructure, and technological innovation were significantly improved, and Xinjiang's regional economy and industrial structure gradually showed the characteristics of a healthy balance and sustainable development. Neighboring Qinghai, Sichuan and Guizhou moved up to the middle and upper reaches of the industrial chain; Gansu, Ningxia and Shaanxi moved up to the middle and upper reaches of the industrial chain. The regional advantages of the economic hinterland in the central and western regions in the entire industrial chain gradually emerge.

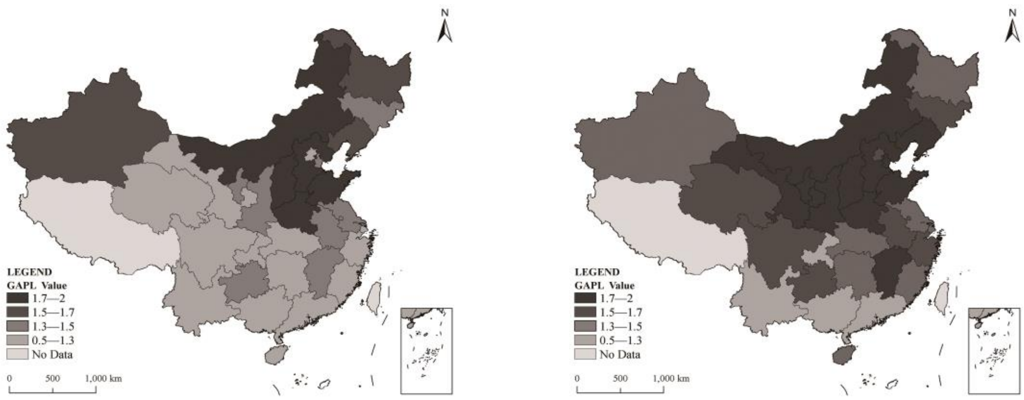

Fig. 2. The position of China's 30 provinces and cities in the national industrial chain in 2007 (left) and 2012 (right).

IV. INDUSTRY ASSOCIATION ANALYSIS OF UPSTREAM AND DOWNSTREAM PROVINCES

In summary, the provinces located at both ends of the industrial chain are relatively stable; comparatively speaking, the changes in the provinces located in the middle and upper reaches and the middle and lower reaches are unstable, and are not typical in the entire industry chain. To further clarify the leading industries that contribute to the economic system in provinces that are mainly engaged in intermediate product input and final product activities in the entire industrial chain, with various calculation models based on Chinese inter-regional input-output table compilation research related data [24] and various input and output table economic structure calculation models, the author calculates the total output of each province by industry sector in 2007 and 2012 in the production process of upstream and downstream provinces and their influence coefficient and response coefficient.

A. Industry relevance analysis

Ignoring the influence of specific departments, the calculation results of the average influence and response coefficient of upstream and downstream provinces are shown in "Table III"; the results show that the influence and sensitivity of upstream provinces are generally greater than those of downstream provinces. From 2007 to 2012, the influence coefficient and sensitivity of Hebei and Shandong were both greater than 1, while among the provinces located downstream of the industrial chain, there were no provinces with influence and response coefficients greater than 1. It shows that the provinces in the upstream of the industrial chain have a strong economic driving and restricting effect on the whole industrial chain, and accordingly, the downstream has a weak driving and restricting effect on the industrial chain. From the point of view of the difference coefficient, the influence of the upstream provinces of Hebei and Shandong gradually declined from 2007 to 2012, and the influence of Shanxi and Inner Mongolia gradually increased, indicating that the central and western regions have increased the role of pulling the economy in the industrial chain. The sensitivity of all provinces except Shandong declined, with the most obvious decline trend in Hebei. The influence of downstream provinces except Guangdong is weakening. Among them, the weakening trend of Chongqing's influence is most obvious, and its effect on economic development is weakening. In addition, the response coefficients are decreasing and Guangdong has the largest decrease, indicating that Guangdong's role in restricting economic development has gradually weakened. On the whole, the influence and sensitivity of the upstream provinces are relatively large. The contribution of upstream provinces to the entire industrial chain is becoming more and more important, its role of restricting demand in other regions is gradually strengthened, and it will have a more profound impact on future economic development.

TABLE III. THE AVERAGE INFLUENCE AND RESPONSE COEFFICIENT OF UPSTREAM AND DOWNSTREAM PROVINCES

	Upstream provinces				**Downstream provinces**			
	Hebei	Shanxi	Inner Mongolia	Shandong	Guangdong	Guangxi	Chongqing	Yunnan
Average influence of 2007	1.0379	0.9585	0.9711	1.1464	0.9192	0.9456	1.0133	0.9773
Average influence of 2012	1.0051	0.9653	0.9787	1.0524	0.9329	0.8984	0.9225	0.9632
Coefficient of difference	-0.0328	0.0067	0.0076	-0.0940	0.0137	-0.0472	-0.0908	-0.0141
Average sensitivity of 2007	1.4199	0.9711	0.9843	1.4883	1.3789	0.8593	0.8318	0.8170
Average sensitivity of 2012	1.2221	0.9249	0.9826	1.6052	1.2562	0.8454	0.7676	0.7839
Coefficient of difference	-0.1978	-0.0461	-0.0017	0.1169	-0.1227	-0.0139	-0.0642	-0.0331

The influence and response coefficients of the industrial sectors of the upstream and downstream provinces in 2007 and 2012 were analyzed (see "Fig. 3" and "Fig. 4"). From an industrial perspective, the most sensitive upstream and downstream provinces from 2007 to 2012 are the industrial sectors; industry provides basic support and resource guarantees for the development of the national economy, so it has strong constraints. It can be seen from "Fig. 3" and "Fig. 4" that Hebei, Shandong, and Guangdong have the highest sensitivity; in addition, the influence coefficient of the construction sector in the upstream and downstream provinces is relatively high, but the response coefficient is low, indicating that the construction industry plays a role of strongly pulling and weak radiation in the industry chain. The influence and response coefficient of industry and construction can reflect that China's economic structure is still dominated by the secondary industry. From 2007 to 2012, the influence coefficient and response coefficient of agriculture, forestry, animal husbandry, fishing, transportation and warehousing industries in upstream and downstream provinces basically showed a decreasing or flat trend. On the one hand, it shows that the contribution and restriction of the primary industry to the economy in the industrial chain system has weakened, and on the other hand, it shows that with the passage of time and the progress of economy and technology, the limiting role of geographical distance or time in economic development is gradually weakened. From 2007 to 2012, the influence and response coefficient of the wholesale and retail industry in upstream and downstream provinces increased with time; the service industry of wholesale and retail has gradually increased its driving and restricting role in the industrial chain, and especially in the downstream cities, the increase is more obvious.

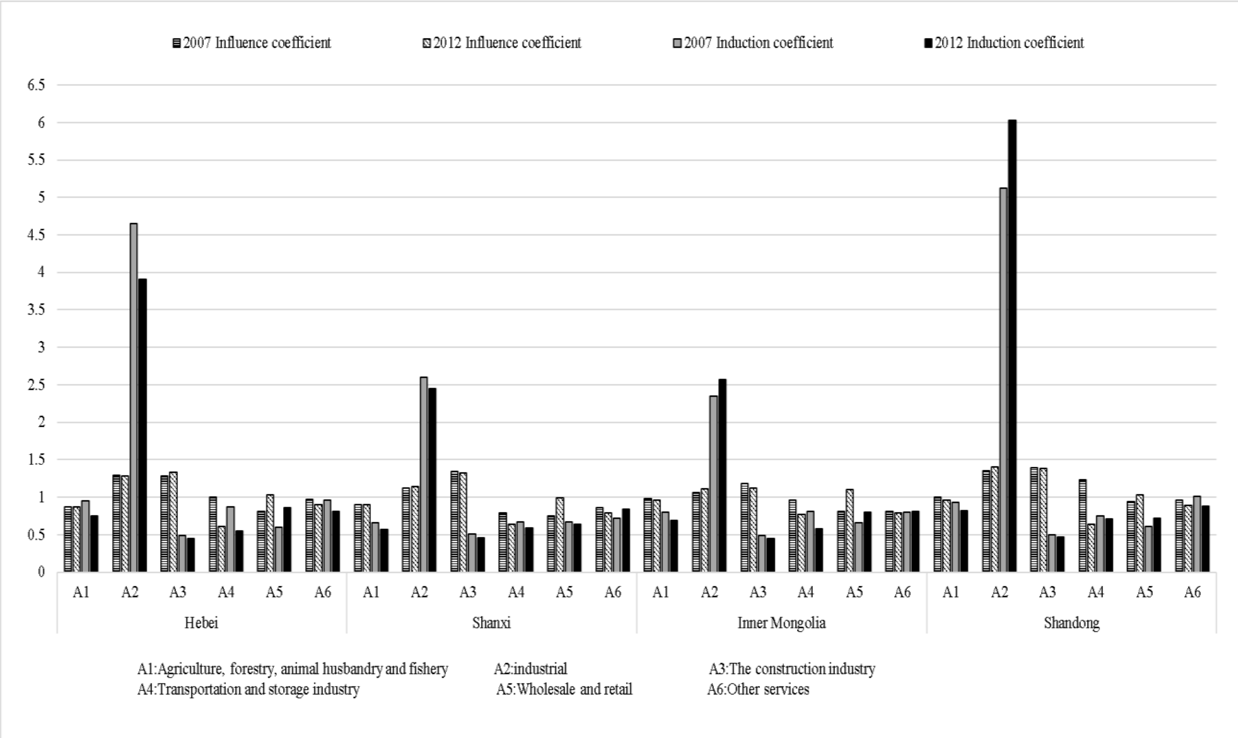

Fig. 3. Influence coefficient and response coefficient of major upstream cities in 2007 and 2012.

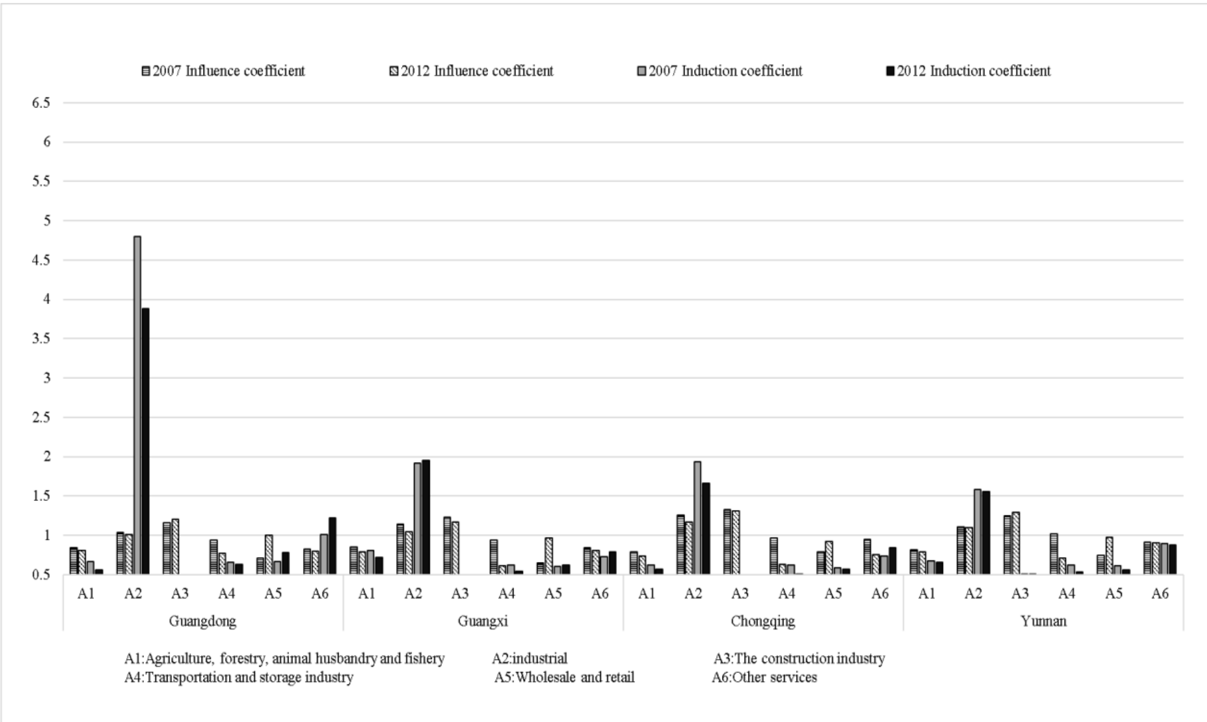

Fig. 4. Influence coefficient and response coefficient of major downstream cities in 2007 and 2012.

B. Industrial structure analysis

According to industry correlation analysis, the influence and sensitivity of Hebei and Shandong in the upstream provinces from 2007 to 2012 are both greater than 1; the influence and sensitivity coefficients of Guangdong and Chongqing in the downstream provinces vary greatly; therefore, the four provinces are regarded as typical of upstream and downstream provinces to analyze their internal industrial structure. The proportion table of total output demand in Hebei, Shandong, Guangdong, and Chongqing is drawn as follows(see "Table IV"). From 2007 to 2012, the most productive activities in upstream and downstream provinces were industry and other service industries. The production activities of agriculture, forestry, animal husbandry and fishery in the upstream provinces of Shandong and Hebei were gradually decreasing after industry and other service industries. The production activities of the downstream provinces Guangdong and Chongqing were after the industry and other service industries, especially the production activities of the Chongqing construction industry were 2 to 3 times that of Guangdong. From the perspective of the proportion of intermediate and final products, from 2007 to 2012, the construction industry of upstream and downstream provinces was basically used for the production of final products; industry, transportation, storage and wholesale and retail trade were engaged in the production of intermediate products. From a partial analysis, the upstream provinces of Hebei and Shandong also had more agricultural, forestry, animal husbandry and fishery production activities, and used more than 70% for intermediate inputs. Nearly 65% of production activities in Hebei and more than 70% of Shandong occurred in industry, and nearly 80% was spent on intermediate products. The production activities of 66% of the downstream provinces in Guangdong and 55% of Chongqing took place in the industrial sector, but only about 50% of their input was used as intermediate products. At the same time, Chongqing's production activities in the construction sector averaged around 13%, and almost all of them were used as intermediate inputs. It can be seen that Hebei and Shandong rely more on the advantages of local resources, and the industrial characteristics of Shandong and Hebei that mainly provide intermediate inputs determine their position in the national industrial chain.

TABLE IV. PROPORTION OF TOTAL OUTPUT DEMAND IN 2007 AND 2012

Industry	Hebei		Shandong		Guangdong		Chongqing	
	2007	2012	2007	2012	2007	2012	2007	2012
Agriculture, animal, husbandry and fishery	7.34%	6.86%	5.74%	4.56%	2.88%	2.70%	6.53%	4.83%
Industry	65.36%	64.75%	69.68%	71.48%	70.29%	65.87%	55.22%	56.48%
Construction industry	5.59%	7.15%	5.17%	5.81%	4.46%	5.07%	12.03%	14.89%
Transportation and warehousing	5.73%	3.19%	3.71%	4.70%	2.71%	4.64%	4.45%	3.83%
Wholesale and retail industry	2.73%	6.20%	2.98%	2.80%	3.41%	3.54%	4.80%	3.41%
Other service industry	13.25%	11.85%	12.71%	10.66%	16.26%	18.19%	16.97%	16.56%

V. CONCLUSION

The calculation result shows:

The provinces located upstream of the industrial chain are basically cities that rely on resources for development. Their industrial structure and excellent resource conditions basically determine its position in the national industrial chain. The provinces such as Guangdong, Guangxi, and Chongqing located downstream of the national industrial chain have been affected by market changes for a shorter period of time than the provinces such as Hebei, Shanxi, and Shandong, which are more sensitive to market shocks;

Upstream and downstream provinces present the characteristics of neighboring provinces. The corresponding position of each province in the industrial chain is obviously affected by the region, and the spatial position of the upstream provinces shows a trend of developing in the shape of "人" from the "Hu Line" from east to west; the geographical advantages of the economic hinterland in the central and western regions in the entire industrial chain gradually emerge;

From the perspective of the influence coefficient and the response coefficient, industry plays a role of strong radiation and weak pulling in the development of the industrial chain; the construction industry plays a role of strong pulling and weak radiation; the industry has great constraints on the demand of the industry chain, followed by the construction industry, and the pulling and restricting effects of transportation and storage are gradually weakening, and the pulling and restricting effects of wholesale and retail industry are gradually increasing;

With the exception of Chongqing, the remaining three provinces in the downstream have little effect on the pulling effect and demand restriction of the entire industrial chain. The downstream city has a weak driving role in radiation. Chongqing is located in the middle of other provinces and this geographical feature determines its scattered radiation, so Chongqing has a strong role in promoting and restricting the industrial chain.

Generally speaking, the downstream provinces of the industrial chain are far away. In the development of the industrial chain, the downstream provinces have not exerted their economic advantages to a great extent in the industrial chain, which is also inconsistent with their economic development and is mostly related to the resource-based provinces in the industrial chain. Therefore, the upstream radiation of the industrial chain has a strong driving effect. So, in the future development, it's needed to increase the investment in knowledge-based industries in the middle and upper as well as middle and lower reaches of provinces, strengthen the leading role of knowledge-based industries, take into account the rational layout of the industrial structure of each province and give full play to the advantages of each province.

The inter-region input-output table is compiled according to the regional planning industry. This feature will provide a systematic and comprehensive data support for studying the relationship between regions and industries. Expanding APL from the perspective of repeated calculation of sectional flows in total output and proposing a GAPL model that measures the economic distance between two sets of industrial sectors that include multiple economies can provide a new perspective for the interpretation of spatial production linkages between industries in the region. After combining the two, it's possible to see the position of each province in the national industrial chain from a national perspective. The research measures the industrial relevance of different provinces at both ends of the national industrial chain, and analyzes the status and spatial pattern of inter-provincial industrial division in China to provide a certain reference for promoting the coordinated development of regional and inter-provincial in China. However, due to the hysteresis quality of the input-output table and the immature research method of the industrial economic distance model, the analysis results exist flaw to a certain extent. In the future, the close attention will be paid to the timeliness analysis of the input-output table and other related content.

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