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Construction of Measurement Indicators for the Integrated Development of Logistics and Manufacturing Industries in China

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Abstract: According to data released by the China Federation of Logistics and Purchasing, the total logistics volume in China in 2022 was 34.76 trillion yuan, of which the total logistics volume of industrial products accounted for 88.95%, and the added value of manufacturing accounted for over 70% of the industrial added value. From this data, it can be seen that the logistics industry, as a productive service industry, has the closest relationship with the manufacturing industry. This article constructs measurement indicators for the degree of integration between the two industries from the perspectives of nodes and networks, focusing on the integration of logistics industry into manufacturing industry and manufacturing industry into logistics industry.

1. Background

Under the new pattern of economic globalization and dual circular economy development, industrial integration is no longer an internal issue within a province (city), but more of a regional, national, and even global network problem. Studying the integration and development of the two industries from a single regional perspective is clearly not in line with the actual situation of industrial integration. Therefore, this article constructs indicators from both node and network levels to measure the degree of integration between the two industries. The main basis for dividing the fusion degree of two different directions in this article is based on the input-output table. From an investment perspective, the penetration of the logistics industry into the manufacturing industry is manifested as the logistics industry being used as an intermediate product in the production of the manufacturing industry[1];Similarly, the penetration of manufacturing into the logistics industry is manifested as a large number of manufacturing products being put into the logistics industry as intermediate products. From an output perspective, the penetration of the logistics industry into the manufacturing industry is manifested as the portion of the unit output of the manufacturing industry that is consumed by the logistics industry, while the penetration of the manufacturing industry into the logistics industry is manifested as the portion of the unit output of the logistics industry that is consumed by the manufacturing industry. The calculation at the node level adopts the input-output table published by each province (city), representing the degree of integration between logistics and manufacturing industries within each province (city)[2],This reflects the internal integration capability of the logistics industry (manufacturing industry). The calculation at the network level adopts the inter regional input-output table, which represents the integration of the logistics industry (manufacturing industry) of each province (city) into the manufacturing industry (logistics industry) of other provinces (cities), reflects the external integration ability of the logistics industry (manufacturing industry), and the status and role of each province (city) in the two industry integration network. The research results of nodes and networks comprehensively and deeply reflect the degree of integration and development between China's logistics industry and manufacturing industry from both internal and external perspectives[3].

There is a problem of integration direction in the development of logistics and manufacturing industries. Currently, the scale of China's manufacturing industry is large, which plays a significant driving role in the business volume of the logistics industry. However, the structure is not good, and coupled with the low level of development of China's logistics industry, the development of the logistics industry has not effectively promoted the transformation of the manufacturing industry[4].Therefore, for measuring the degree of integration between the two industries, different integration directions should be distinguished to more comprehensively and deeply depict the current situation and driving factors of the integration of the two industries[5].

2. Measurement indicators at the node level

The input-output table is a model constructed based on the quantitative relationship between inputs and outputs within the system, used to describe the sources, intermediate inputs, and output relationships of products in various industries. It can well reflect the input structure, output, and usage direction of products in the production process. In empirical research on industrial integration, intermediate input rate and influence coefficient are commonly used as indicators to measure the degree of industrial integration[6]. However, the intermediate input rate and influence coefficient did not exclude the influence of other industries in the calculation process, which cannot well reflect the degree of mutual penetration between the logistics industry and the manufacturing industry. This article refers to the research of Peng Hui and Kuang Xianming (2019) to construct three indicators: one-way integration degree (logistics industry integrated into manufacturing industry, manufacturing industry integrated into logistics industry), comprehensive integration degree, and industry integration degree, in order to eliminate interference from other industrial sectors in the input-output table[7].

(1) Unidirectional fusion degree

Unidirectional integration degree is the calculation of the proportion of input (consumption) of another industry as an intermediate product in the production of a certain industry, excluding other departments from the input-output table. This article uses this indicator to measure the degree of mutual penetration between the logistics industry and the manufacturing industry, which is divided into manufacturing input (the proportion of manufacturing as an intermediate product in logistics production) and logistics input (the proportion of logistics as an intermediate product in manufacturing production)[8], manufacturing demand rate (the proportion of manufacturing consumed by logistics industry to total manufacturing output), and logistics demand rate (the proportion of logistics consumed by manufacturing industry to total logistics output). The range of values for one-way fusion degree is (0,1), and the larger the value, the deeper the fusion degree[9].

① Integration of logistics industry into manufacturing industry

Logistics industry investment T_1: In the production process of unit manufacturing products, 2 (2 in 2002 and 2007, 1 in 2012 and 2017) logistics sub industries as a whole account for the proportion of total investment in 17 (17 in 2002 and 2007, 19 in 2012, and 18 in 2017) manufacturing sub industries. The higher the input value of the logistics industry, the better it is integrated into the production process of the manufacturing industry. The calculation formula is shown in equation (1.1).

$$T_1 = \frac{\sum_{j=1}^{17}\sum_{i=1}^{2} x_{ij}}{\sum_{j=1}^{17} X_j} \tag{1.1}$$

In equation (1.1), represents the intermediate input value of logistics sub industry i to manufacturing sub industry j, and $\sum_{j=1}^{17} X_j$ represents the total input of manufacturing industry.

Manufacturing demand rate X_m: The proportion of unit manufacturing output consumed by the logistics industry to the total output of the manufacturing sector, as shown in equation (1.2):

$$X_m = \frac{\sum_{i=1}^{17}\sum_{j=1}^{17} X_{ji}}{\sum_{i=1}^{17} X_i} \tag{1.2}$$

② Integrating manufacturing into logistics industry

Manufacturing input ratio T_m: In the production process of unit logistics products, 17 (17 in 2002 and 2007, 19 in 2012, and 18 in 2017) manufacturing sub industries are treated as a whole as intermediate inputs, accounting for the proportion of total input in 2 (2 in 2002 and 2007, and 1 in 2012 and 2017) logistics sub industries. The calculation formula is shown in equation (1.3).

$$T_m = \frac{\sum_{j=1}^{2}\sum_{i=1}^{17} x_{ij}}{\sum_{j=1}^{2} X_j} \tag{1.3}$$

In equation (1.3), T_m is the input degree of manufacturing industry in logistics industry, i represents the row vector of input-output table, and j represents the column vector of input-output table. The greater the investment in the manufacturing industry, the more it indicates that the logistics industry mainly relies on intermediate inputs from the manufacturing industry, and services are relatively low-end. Then it represents the intermediate input value of the i-th manufacturing sub industry in the logistics industry j industry (the logistics industry in the input-output table consists of two sub industries: transportation and warehousing (ministry, postal industry)). Represents the total investment in the logistics industry.

Logistics industry demand rate X_i: the proportion of the output of the logistics industry consumed by the manufacturing industry to the total output of the logistics industry, as shown in equation (1.4):

$$X_i = \frac{\sum_{i=1}^{1}\sum_{j=1}^{17} x_{ji}}{\sum_{i=1}^{2} X_i} \tag{1.4}$$

(2) Comprehensive integration degree

The degree of one-way integration can only indicate the degree of integration between the logistics industry and the manufacturing industry, and cannot well reflect the overall integration of the two industries. This article is based on the one-way integration degree and constructs a comprehensive integration degree index to measure the degree of mutual integration between the logistics industry and the manufacturing industry from a macro perspective of the entire industry. The higher the comprehensive integration degree, the greater the degree of mutual influence between the logistics industry and the manufacturing industry. The calculation formulas are shown in equations (1.5) and (1.6).

$$Z_1 = \frac{T_l}{T_m} \tag{1.5}$$

$$Z_2 = \frac{X_l}{X_m} \tag{1.6}$$

Z_1 represents the comprehensive integration degree of the two industries from the perspective of input, also known as input equilibrium degree, and represents the comprehensive integration degree of the two industries from the perspective of demand, also known as demand equilibrium degree. The range of values for the comprehensive integration degree is also (0,1), and the larger the value, the higher the balance of the mutual influence between the logistics industry and the manufacturing industry.

(3) Industry integration degree

There are many sub industries involved in the manufacturing industry. In order to analyze the integration of the manufacturing and logistics industries more deeply, referring to the formula of influence coefficient, the industry integration degree is constructed to reflect the degree of driving force of the j sub industries under the manufacturing industry on the logistics industry.

$$T_{mj} = \frac{\sum_{i=1}^{2} A_{ij}}{\frac{1}{17}\sum_{j=1}^{n}\sum_{i=1}^{2} A_{ij}} \tag{1.7}$$

In equation (1.7), T_{mj} represents the degree of industry integration between manufacturing sub industry j and logistics industry, which is the value of logistics industry i and manufacturing sub industry j in the Leontief inverse matrix. The larger the value T_{mj}, the stronger the driving effect of the manufacturing sub industry on the logistics industry.

In the analysis of one-way fusion degree, this article refers to the existing literature's classification standards for fusion degree (Li Wei, Chen Zhen, 2014;Huang Sai and Zhang Yanhui, 2015; Zhang Xiaofen and Yang Zhen (2021) divided the degree of fusion into the following levels, as shown in Table 1.1.

In order to vertically compare the one-way fusion degree of each year, using the most recent year (2017) as a reference value, the one-way fusion degree values of each year are divided into the following levels according to the standards in Table 1.2, as shown in Table 1.2. The average and standard deviation in the table are the values of 2017.

Tab. 1.1 The integration grade division of absolute value

Confluence	Fusion level
0<Confluence<0.1	for the first time
0.1<Confluence<0.2	moderate fusion
0.2<Confluence<0.3	medium to high degree integration
0.3<Confluence<0.5	deep integration
0.5<Confluence<1	symbiotic integration

Tab. 1.2 The integration grade division of relative value

Confluence	Fusion level
0<Confluence<(average value-standard deviation)	medium low
(average value-standard deviation)<Confluence<(average value)	low
(average value)<Confluence<(average value+standard deviation)	medium high
(average value+standard deviation)<Confluence<maximum value	high

3 Network level measurement indicators

(1) Network construction

Whether there is a fusion relationship between the logistics industry and the manufacturing industry between two regions, according to the criteria for distinguishing the integration development within the region, it can be considered that the output of the logistics industry (manufacturing industry) in one province (city) is used as an intermediate input for the manufacturing industry (logistics industry) in another province (city), and the two industries have a fusion relationship. The depth of integration can be further compared and analyzed from the actual value of the number of manufacturing sub industries and investment[10].

This paper takes provinces as nodes, uses the inter regional input-output tables of 31 provinces (cities) in China (in 2002, 2007, 2010, 2012, 2015 and 2017 respectively), and takes the industrial integration relationship between logistics industry and manufacturing industry in 30 provinces (cities) in China (excluding Xizang) as the edge to build the integrated development network of two industries. Due to the directionality of the integration of the two industries, the network is further divided into a fusion network of manufacturing industry integrated into logistics industry (input of manufacturing industry in logistics industry) and a fusion network of logistics industry integrated into manufacturing industry (input of logistics industry in manufacturing industry). Social network analysis method is used for network feature analysis. Social networks can usually be divided into undirected networks and directed networks. Referring to Jiang Han's (2021) research, this article constructs an undirected network for the integrated development of the two industries to represent the breadth of the integrated development of the two industries, while the depth of the integrated development of the two industries is represented by a directed network. It should be noted that the networks constructed in this article all include the logistics industry of node i integrated into the manufacturing industry of node i, that is, the logistics industry of a certain province (city) integrated into the manufacturing industry of other provinces (cities), including the logistics industry of that province (city) integrated into its own manufacturing industry [11]. Similarly, the integration of manufacturing into the logistics industry's network is no exception.

Two industry integration undirected network: Construct a 30 * 30 0-1 matrix to represent the undirected network of two industry integration during period t. Each unit in the matrix represents whether there is a two industry integration relationship between node i province (city) and node j province (city). According to the research content of this article, the integration of two industries in an undirected network can be divided into undirected network A, where manufacturing is integrated into logistics, and undirected network B, where logistics is integrated into manufacturing. Each element in the matrix of undirected network A and B is represented by a_{ij} and b_{ij}, respectively, corresponding to the input-output table. a_{ij} represents the value of manufacturing input from province (city) i into logistics input from province (city) j in the input-output table. If a_{ij} is greater than 0, the value is 1, otherwise it is 0. B_{ij} represents the intermediate input value from the logistics industry of province (city) i to the manufacturing industry of province (city) j in the input-output table. If b_{ij} is greater than 0, the value is 1, otherwise it is 0.

A directed network for the integration of two industries: Similarly, a 30 * 30 directed network for the integration of two industries is constructed, which is divided into a directed network A for the integration of manufacturing and logistics industries, and a directed network B for the integration of logistics and manufacturing industries. Due to the numerous sub industries included in the manufacturing industry, in the integration relationship between the two industries, on the one hand, the more sub industries the logistics industry integrates into the manufacturing industry (or the more sub industries of the manufacturing industry integrate into the logistics industry), the deeper the degree of integration between the two industries. On the other hand, the larger the value of intermediate input between the logistics industry and the manufacturing industry (or the larger the value of intermediate input between the manufacturing industry and the logistics industry), the deeper the degree of integration between the two industries. Therefore, directed networks can be further divided into directed networks AM and AN, and directed networks BM and BN. The element AM_{ij} in directed network AM corresponds to the number of manufacturing sub industries in province (city) i that are invested in the logistics industry in province (city) j in the input-output table. The element AN_{ij} in the directed network AN corresponds to the actual value of manufacturing inputs from province (city) i to logistics inputs from province (city) j in the input-output table. The element BM_{ij} in the directed network BM corresponds to the number of sub industries in the manufacturing industry of province (city) j that are invested in the logistics industry of province (city) i in the input-output table. The element BN_{ij} in the directed network BN corresponds to the actual value of the logistics industry input from province (city) i to the manufacturing industry of province (city) j in the input-output table.

(2) Measurement indicators

① Overall network metrics

Node count: The number of participating nodes in the network, which in this article refers to the number of provinces participating in the network.

Edge count: The number of connections formed by the interaction between two nodes in a network.

Average path length: The average distance between nodes in a network.

Network density: The degree of interconnectedness between behavioral entities in a network, which is the ratio of the actual number of relationships to the maximum possible theoretical number of relationships.

Maximum output: The maximum number of relationships emitted from that point.

Maximum in degree: The maximum number of relationships that enter the point.

Agglomeration index: indicates the degree of interconnectivity among nodes in a network, applicable only to undirected networks.

Reciprocity index: The ratio of the number of relationships with bidirectional cooperative relationships in a network to the total correlation coefficient.

Network centrality: It reflects whether the nodes in the network are in a central position and can be used to measure the status and role of each node in the network. The more central the nodes are, the greater their influence. This article uses the node's degree network center potential to represent the network center potential of the entire network.

② Node centrality index

Node strength: The degree of a node in the network is represented by its output, which indicates the number of nodes directly related to the node and reflects its position in the network.

Node diversity: used to represent the diversity of nodes in the network, that is, whether the status of each node in the network is equal.

This article uses the strength (logarithmic) of each node to estimate the kernel density and obtain a kernel density distribution map to analyze the network

Differences in nodes within.

4 Data Explanation

The input-output table in our country is released every five years. So far (since 1987), there have been a total of seven official input-output tables released, and on this basis, extended tables for some years have been compiled. The statistical caliber of input-output tables for different years is not completely consistent in terms of industry division. To ensure comparability between different years, this article chooses the input-output table of 42 departments. As the number of departments was 33 before 2002, 40 in 1997, and relatively stable at 42 after 2002, the research period of this article is set from 2002 to 2017. The node level adopts the input-output table of each province (city), and the currently published years are 2002, 2007, 2012, and 2017. At the network level, a multi regional input-output table is used, and the currently published years are 2002, 2007, 2012, 2015, and 2017. Based on this, the research years at the node level in this article are 2002, 2007, 2012, and 2017, while at the network level they are 2002, 2007, 2012, 2015, and 2017.

In terms of industry statistics, the logistics industry was composed of transportation and warehousing industry (department code 27) and postal industry (department code 28) in the input-output tables of each province (city) in 2002 and 2007. The manufacturing industry was defined according to the "National Economic Industry Classification" and corresponding to the input-output table, consisting of 17 departments including food manufacturing, tobacco processing industry, textile industry, etc. (department codes 06-22). In the input-output tables of each province (city) in 2012, the previously independent transportation and warehousing industry and postal industry (department codes 27 and 28) were merged into transportation, warehousing, and postal industry (department code 30). The manufacturing sector has increased to 19 departments, with local changes as follows: the general equipment and specialized equipment manufacturing industry (department code 16) has been split into general equipment (department code 16) and specialized equipment (department code 17), and metal products, machinery, and equipment repair services (department code 24) have been added. In 2017, the number of manufacturing sectors in the input-output tables of each province (city) was adjusted to 18, with the specific change being the merger of other manufacturing products (department code 22) and waste materials (department code 23) into other manufacturing products and waste materials (department code 22). Although there are slight differences in the number of logistics and manufacturing sectors in the input-output tables for 2002, 2007, 2012, and 2017, the included industries have not undergone significant changes and are comparable.

5. Summary

This article constructs one-way integration degree indicators, comprehensive integration degree indicators, and industry integration degree indicators to measure and analyze the integration degree of logistics and manufacturing industries in each province (city) at the node level. Construct undirected network, directed network M, and directed network N, and study the degree of integration between the two industries at the network level from two aspects: overall network characteristics and cohesive subgroups.

Node level: Firstly, the measurement results of the degree of integration of logistics industry into manufacturing industry show that China's manufacturing industry has a low dependence on logistics industry demand, and the contribution of logistics investment to manufacturing industry is not high. The absolute integration level of logistics industry into manufacturing industry is basically in the initial stage of integration. In terms of spatial distribution, the integration of logistics and manufacturing industries in the three major regions is at the initial level of integration. The spatial differentiation phenomenon in the east-west direction is gradually slowing down, while the spatial differentiation phenomenon from the perspective of logistics industry investment in the north-south direction is showing an increasing trend, and the perspective of manufacturing demand rate is showing a slowing trend. The agglomeration characteristics of high-value and sub high value areas where the logistics industry is integrated into the manufacturing industry are weakening, while the agglomeration characteristics of low value and sub low value areas are showing an increasing trend, indicating a negative spatial spillover effect of the integration of the logistics industry into the manufacturing industry. Secondly, China's logistics industry has a high dependence on manufacturing, and the development of manufacturing has a strong driving force on the demand for logistics industry. The fusion levels are mostly medium to high and moderate fusion. In terms of spatial distribution, the eastern region is dominated by deep integration and moderate to high integration levels, while the central and western regions are dominated by moderate to high integration levels. The overall spatial clustering characteristics are weakening. High value areas have obvious spatial clustering characteristics in the early stage, and are dispersed in the later stage. The spatial clustering characteristics of the second highest value areas are gradually increasing. Again, the balance of the integration degree between the two industries is weak, and the dependence of the logistics industry on the manufacturing industry is significantly higher than that of the manufacturing industry on the logistics industry, and this degree of asymmetry is increasing. The overall integration level of logistics and manufacturing industries in China is relatively low, and their spatial distribution is also very scattered, without spatial agglomeration characteristics. The results of industry integration indicate that the logistics industry has the highest interaction with capital intensive manufacturing industries and the lowest interaction with labor-intensive industries.

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