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The construction of network model for industrial linkage of IT industry on the Campbell theory

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Abstract: **Industrial linkage is the objective existence in economy. Relational and spatial structure of multi-regional industrial linkage is not only a major factor in determining multi-regional disequilibrium strategy, but also an important source to obtain competitive advantages. This paper, by applying the Campbell theory, intends to construct network model for multi-regional industrial linkage of IT industry and conduct an empirical study using an inter-industry input-output table.**

Keywords: Industrial linkage; IT industry; Campbell theory

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1. Introduction

Along with the rapid development of information technology, based on the industrial /product linkage, making strategies from the perspective of globalization has become the main form for nations, regions, and enterprises to participate in the competition. At the national and regional level, on the basis of industrial linkage, it is mainly manifested in giving priority to the development of key industries or key industrial clusters (chains) to form leading industries or industrial clusters, and consequently to enhance its competitiveness and realize sustainable development. At the enterprise level, to maintain a competitive advantage, they also mainly base on the industrial linkage, through strategic alliance or integration strategy to form the value chains (global value chains). There is no doubt that the industrial/product linkage of the information age will create more new strategic models, business models, and trade patterns.

Industrial structure, as a resource, plays an important role in determining key industries, industrial clusters, and making regional development strategies. Industrial network is not only adopted for research on the industrial linkage as well as its characteristics, but also is applied to work on the relationship between some specific structures (such as circles, spanning trees, etc.) and key industries and industrial clusters. In the industrial network perspective, for some hot issues from the current theory and practice such as supply chain management, industrial clusters, integration strategy, and industrial upgrading, their essence is the optimization and reconstruction of industrial network. Therefore, the industrial network theory based on industrial linkage, and focused on the structure of industrial linkage, is having more and more important theoretical and practical significance.

The information industry, as a new economic form, is playing an increasingly critical part in obtaining a regional competitive advantage and driving regional economic development. On this ground, having a knowledge of the industrial linkage as well as industrial structure of information industry in the region will be of great importance for leading and promoting regional development. In this paper, taking the information industry as the research object, the author analyzes the important influence of information industry on the regional industrial structure through establishing the regional industrial network model guided by Campbell theory.

2. Industrial Linkage and Industrial Network Model

2.1. Development of Industrial Linkage and its Connotation

The ideology of industrial linkage can be traced back to the Economic Table (l785) studying on trade relations between industries by the French economist Quesnay; Leontiefpublished in 1936 the multisectoral American industrial linkage table taking the US economy in 1919 as the sample, which made a quantitative description of the linkage between industries, and the input-output model he founded had become the basic method of measuring industrial linkage; industrial linkage to which was paid great attention in academic circles, was derived from the research by Hirschman. In order to study economic development strategy and non-balanced development strategy, Hirschman (1958)[1] , from the perspective of industrial linkage, clearly put forward the concept of backward and forward linkages, and more importantly, he made research on the key industries from the two dimensions of backward and forward linkages and for the first time applied industrial linkage to the research of regional economic strategy. To define the key industrial sectors and economic development strategy on the fundamental basis of backward and forward linkages is known as the “Hirschman criterion” of selecting leading industries. Interdependence among sectors,interindustry/inter-industry linkages, sectors’ linkages, industry linkages, industrial interdependence, intersectoral linkages, inter-relationships between sectors.

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Based on different perspectives, the international academic circles make different descriptions of the term "industrial linkage". At different stages of the studies on industrial linkage, there used to be terms one after another like interdependence among sectors, interindustry/inter-industry linkages, sectors' linkages, industry linkages, industrial interdependence, intersectoral linkages, and inter-relationships between sectors, which reflects the foreign scholars' deepening understanding of industrial linkage, and in the meantime reflects the rich connotation of industrial linkage.

With the help of the description method based on graph theory, the strict definition of industrial linkage can be as follows:

Suppose $S=\{1,2,3\cdots n\}$ is a collection consisting of "n"industries, with regard to $i,j\in S$, if and only if $\langle i,j\rangle \in R\bigcup IR$, there is a linkage between industry i and industry j.

To calculate the linkage between industry i and industry j, the steps are as follows:

(1) To determine the critical value matrix

(2) To calculate the industrial direct linkage matrix L

(3) To determine the indirect linkage on the basis of L

The core of industrial network theory targeted at studying on industrial linkage and industrial structure is how to simulate and describe the linkage between industries, which has contributed to the various industrial network modeling approaches.

Industry linkage has three levels of meaning. The first level mainly refers to the relationship between industries, which is the basis of describing industrial linkage; the second level refers to the relationship between a single industry and the entire industry system (or industry subsystem) , signifying the influence of a single industry on the whole industry system (or industry subsystem) and depicting the status as well as influence of a certain industry in the industry system, and in fact, the linkage at the first level can be regarded as a special case of that at the second level; the third level refers to the relationship structure of industries, describing the overall characteristics and nature of the relationship between industries, including the characteristics of the industry subsystem and the total interactive relationship between industry subsystems. Industrial network modeling is the most appropriate method of making quantitative research on industrial linkage at the second and third levels.

2.2. Industrial Network Theory and Its Modeling

Industrial network has two meanings. First, ontological significance, that is to say, industrial network is an objective phenomenon: from the product perspective, manifested as the sum of the linkage between products; from the organization perspective, manifested as the sum of the behavioral relationship between various subjects related to the product group. Second, the importance of methodology, namely, industrial network is the model and method describing the linkage between industries, where models describing the relationship between products are called the industrial linkage network, and models describing the behavioral relationship between various subjects related to the product group are known as industrial organization network. The industrial network is actually a complex network coupled by the industrial linkage network and industrial organization network.

The research on industrial network model began in the 1970s. The basic idea is to regard the entire industry as an interconnected system, and to build a model by using graphs and network as the tool with the help of input-output model and based on the linkage between industries. When modeling, the industries (products) in the industry system are corresponding to the vertexes of the network, and whether or not there is an edge (arc) between the vertexes is determined by mutual influence between industries. Therefore, the key to building the industrial network model is to determine the edge (arc) rule of the vertexes in accordance with industrial linkage. Some scholars equate industrial linkage with the input-output relationship, and believe that there will be a linkage between industries if the correlation value of input-output is greater than 0, while some scholars believe that only the correlation value of input-output reaches a certain critical value will there be a linkage between industries. Some scholars take into account only the direct linkage between industries, and some scholars believe that industrial linkage also include indirect linkage between industrial structures.

There are many methods to build industrial network model. Holub[4] believed that the establishment of a network based on industrial linkage, not only required to consider the direct linkage between industries, but also needed to consider the indirect linkage formed by structural factors, and further he put forward the calculation method of indirect linkage. Schnabl[5] proposed that a minimum flow could be determined as the critical value through taking endogenous approaches. When the flow from industry i to industry j is greater than the critical value, there is linkage between industry i and industry j. Unless to build a directed arc from industry i to industry in the industrial network, or else there will be no arc connecting the two industries[6,7]. This method is known as the Minimum Flow Analysis (MFA), resulting in a significant impact on the research development of industrial network model. Aroche-Reyes [8] proposed that the linkage between industries could be determined on the basis of the important coefficient, and it was practicable to build the industrial network model by the method of Important Coefficient Analysis (ICA). Schnabl [9] held

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the opinion that the Elasticity Coefficient Analysis (ECA) would be more general which covered the concept of Important Coefficient Analysis[11-12]. In the research on industrial network model, the method of using the adjacency matrix of network obtained on the foundation of the input-output model to establish the industrial network is defined as Qualitative Input-Output Analysis (QIOA). Morillas [12] put forward that industrial network model could be established under the guidance of the fuzzy theory, to be specific, it was based on the input-output model, and to identify the industrial linkage through finding the α-cut-set of the fuzzy sets, building the fuzzy directed graph of the industry system. However, among all the methods of building industrial network model, Campbell Model is one of the most classic models, and also is the most widely used by many scholars[13].

3. Campbell Model

Early network models for multi-regional industrial linkage are all limited to a certain area, which are generally based on the input-output model. In the model, every vertex represents each industrial sector, and the rule of joining the vertices can be fixed according to the matrix of input-output value. Here is the rule if the value is larger than zero, the two corresponding vertices can be connected by an edge, or there is no edge present between the vertices. Thus, the model can be completed in this way.

In 1970, Campbell was the first man to study industrial linkage with directed graphs, and use some concepts in it, such as block, degree and hadron graph to describe the structural features of industrial linkage. Campbell-model established by some scholars represented by Campbell is the early network model using graphs and networks as tools to do research on industrial linkage.

Campbell (1972) believes that a directed graph can show structural features of a system, so it can be applied to industry systems. That is to say, an industry can design a directed graph as linkage structural model based on inter-industry input-output relationship, in which the structural features of industrial linkage will be reflected clearly using the related concepts in the directed graph. As the research constantly goes deeper and the research purposes vary, some scholars have pursued further studies about the edge rule of industrial network and eventually drawn a conclusion that when the input-output value goes beyond a certain tipping point, inter-industry linkage or the edge will exist, otherwise there is no linkage.

4. Theory and Method of Model-Building

The general conception of model-building is based on the inter-industry input-output relationship to divide the incidence relation of industry systems into two types: industrial linkage which does exist and industrial linkage which doesn't exist. Furthermore, the final purpose is to construct network model and study the structure and linkage of industry systems using some related concepts in digraph. The specific modeling steps are as follows:

4.1. Identify the collections of factors of industry system

The factors of industry system refer to industry (product) and department divided on certain principles, which usually can be determined using the input-output table, and can also be merged in a certain way.

4.2. Choose the basis of industrial linkage

In the input-output table, trade flow matrix X can tell us the inter-industry investment for a set amount of time. When $x_{ij} > 0$, it means that Industry i has made an investment in Industry j, otherwise there is no investment. In this way, Campbell-model depends on the analysis of the inter-industry investment to confirm inter-industry linkage relationship.

4.3. Rank the linkage of industrial factors

In fact, the inter-industry direct trade flows can help to rank industrial linkages through turning the trade flow matrix X to the industrial linkage relationship matrix $L = (l_{ij})$ with the rules as follows:

Table1. Rules for confirming the level of industrial linkage in Campbell-model

Input-output flow	Linkage relationship	Coefficient of Rank Correlation
$x_{ij} > 0$	yes	$l_{ij} = 1$
$x_{ij} = 0$	no	$l_{ij} = 0$

Because those studies of industrial linkage only focus on the inter-industry relationship but no consideration about their inside situations. Therefore, all the factors of main diagonal lines in the industrial linkage relationship matrix are set into 0 to avoid circles turning up in the directed graph.

4.4. Construct the digraph D

Suppose the industrial cluster is $\{1, 2, \cdots, n\}$ and directed graph $D = (V(D), A(D))$ with $V(D) = \{1, 2, \cdots, n\}$. So for i, $j \in V(D)$,

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$\vec{ij} \in A(D) \Leftrightarrow l_{ij} = 1,\ 1 \le i, j \le n$, the direction of the arc shows where the inter-industry products have moved.

5. Calculation examples

Table 2 states the value deal flows of IT industry system. In the table, the number 1-5 represent five IT industries: internet, network, communication, intelligence and service industry related to IT. The intersections show the deal flows of inter-industry investment. Taking the first row, second column for example, the number 12 refers to the investment that IT industry 1 has made in IT industry 2.

Table 2. Inter-industry input-output flow statement of IT industry X

IT industry	*1*	*2*	*3*	*4*	*5*
1	8	12	0	16	0
2	11	0	10	9	0
3	12	16	4	14	6
4	0	0	0	0	0
5	0	0	0	11	0

Here are the steps to construct network model of IT industry.

First of all, the industrial linkage relationship matrix L should be constructed on the basis of the new input –output trade flow matrix after the transformation. If $x_{ij} = 12 > 0$, we can get $l_{12} = 1$; if $x_{13} = 0$, so $l_{13} = 0$. And the factors of main diagonal lines in the industrial linkage relationship matrix L are set into 0, which can be seen in Table 3.

Table 3. IT industrial linkage level matrix L

Industry	1	2	3	4	5
1	0	1	0	1	0
2	1	0	1	1	0
3	1	1	0	1	1
4	0	0	0	0	0
5	0	0	0	1	0

The second step is to draw the directed graph. For instance, when $l_{12} = 1$, the node 1and node 2 can be linked together with an arc starting from node1 to 2. It proves that the product or service flows do exist between IT industry 1 and IT industry 2. Similarly, the rest of arcs will be got in the graph.

Finally, the reverse graph should be drawn to describe the payment currency flow of product and service, as shown in Figure1(a).

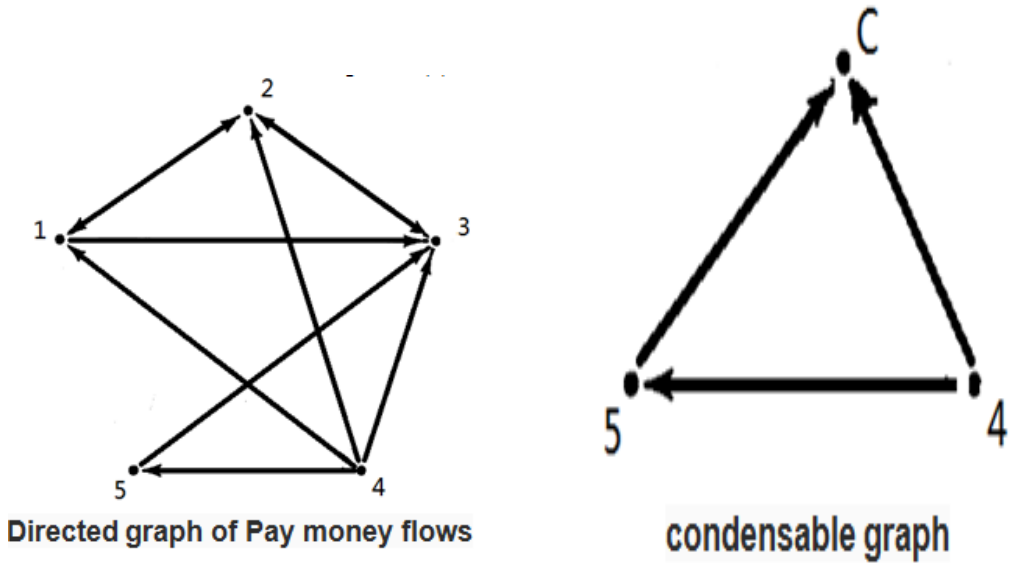

Figure 1. Directed graph and condensation graph.

According to Figure 1(a), they are accessible to each other among the three industries, which turns to the hadron graph. To clearly embody the IT industrial linkage structure, we can see the hadron graph as a condensation point C to get the condensation graph shown in Figure1(b).

With the help of the above modeling method, this paper tries to use the IT industrial input-output data of Shandong province in 2012 to study the IT industrial linkage directed graph. Because the IT manufacturing department is regarded as the main research object, thus the resources department and non-commercial department are respectively combined to be one. Then we have the input-output flow matrix X of 19 departments, which can be transformed to the linkage relationship matrix L shown in Table 4.

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Table 4. IT-related industrial input-output linkage relationship matrix of Shandong in 2012

Ind. no.	19	7	6	20	5	10	21	8	15	1–4	16	12	9	14	18	17	11	22–27	13	δ^+
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
7	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	4
6	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	4
20	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	1	5
5	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	5
10	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	6
21	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1	1	1	8
8	1	1	0	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	0	9
15	1	0	0	1	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	11
1–4	0	1	1	0	1	1	0	1	1	0	1	0	1	1	0	0	1	1	1	12
16	1	0	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	12
12	1	1	1	1	0	1	0	0	0	1	1	0	1	1	1	0	1	1	1	13
9	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	1	15
14	1	1	1	1	1	1	0	0	1	1	1	0	1	0	1	1	1	1	1	15
18	1	1	1	1	0	1	1	0	1	1	1	0	1	1	0	1	1	1	1	15
17	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	16
11	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	17
22–27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	18
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	18
δ^-	13	12	11	13	9	8	9	5	8	15	10	5	13	11	10	8	13	18	14	

We can see from Table 4 above that it is likely to have 19×18=342 linkage relationships among 19 departments. However, in fact there are only 205, accounting for 59.5%. Then the directed graph 2 comes after the linkage relationship matrix. On the basis of the model, Campbell makes further analysis of some related indicators, such as the linkage percentage, the relative centricity and so on, to do research on the structure features of industrial linkage. P.S. Node 22 refers to the combination of Node 22-27.

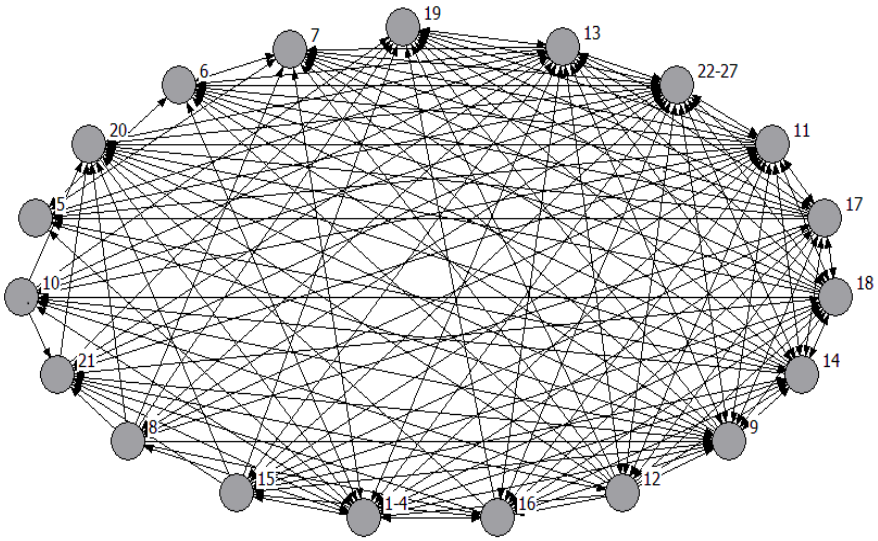

Figure 2. Directed graph[3].

6. Conclusion

That Campbell-model uses graph theory to study industrial linkage is a major breakthrough in thought. In the following studies of industry system, it can clearly show the binary relation between industries and describe the linkage structure with some concepts of the graph, such as degree, connectivity, block, hadron graph and so on. In this way, the study of industrial linkage will be preliminarily extended from the binary relation to its structure to realize the macroscopic analysis of industrial linkage structure.

As can be seen from the model, the development of any industry has a dual function, on the one hand, it increases the supply, to promote the development of other industries. On the other hand, it stimulates an

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increase in demand, drives the development of other industries. The development of the industrial clusters in any industry can promote and stimulate the development of industrial clusters in the development of other industries. Industrial clusters in every industry in industrial clusters external industry a strong boost. Basis on the directed graph, it can determine the industry's leading industry and promote industry sets, fully reflect the dual role of industry development.

However, the construction and application of Campbell-model is so new and preliminary that it still has some obvious shortcomings, which can be mainly reflected in two aspects. First, in the original model, the un-obvious input-output relationship between industries has been put into the consideration. The results in the fact that the industrial relationships become too various to tell the industrial linkage structure features. And in the later and improved model, it is subjective to use the average value as threshold. Second, in the process of model-building, it ignores considering the influence of structure factors on industrial linkage and the indirect linkage among industries, which leads to the incomplete description of the industrial linkage.

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