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# Identification of Agricultural Industrial Chains Based on Average Propagation Lengths and Minimal Spanning Tree

## --Taking Jilin Province as an Example

Anning Ye*, Min Zhang

School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Bengbu, China.

*yeanning@sohu.com

## Abstract

**On the basis of inter-industry linkages, the theory of economic distance and minimum spanning tree is used to identify the agricultural industry chain in Jilin Province. There are products trading among industries, indicating the degree of interdependence between industries. Economic distance means the number of steps it takes when exogenous changes in one industry effect another industry, which can judge the direct and indirect impact. Minimal spanning tree can make complex networks simple and clear. Combining the linkages, distance and minimal spanning tree among industries, the information of industrial chain will be presented in more dimensions. Finally, this method is used to study the agricultural industry chain in Jilin Province.**

## Keywords

**Agriculture; Linkages; Chains of Industry; Average Length of Propagation; Minimal Spanning Tree.**

## 1. Introduction

As an important province of agricultural production, Jilin Province can not only be satisfied with the production of primary agricultural products, but must turn to the whole industrial chain production, otherwise it will affect the overall economic development of Jilin Province. From the perspective of industrial chain, agriculture, upstream and downstream industries are interdependent, and the development of agriculture will affect the development of related industries. An important prerequisite for the development of agricultural industrial chain is to identify the agricultural industrial chain. This paper outlines the agricultural industrial chain through the input-output model and the minimum spanning tree theory in graph theory.

Agricultural industrial chain refers to the network structure with industrial dependence on the production of agricultural products, and the input-output table can well describe this network structure. Some of the products produced by an industry are used to meet the final demand, but other of them are used in the form of intermediate products. In this way, a product will flow through various industries before reaching the final goal, that is, the final demand. At each stage, value will be added to the product. This from the initial stage of production to the final demand stage is called the industrial chain.

Triangulation method is used to judge the distance of an industry from the final demand in the industrial chain. The purpose of establishing a triangular input-output table is to show the hierarchy of sectors, that is, to establish a triangular structure module from the top final product to the bottom primary product. The idea of this method is to re label each sector (rearrange rows and columns), so that the sector providing output to the final demand is at the top, and the sector providing products to other sectors is at the bottom. If there is no circular

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flow, this input-output table will be triangular and zero on the other side of the main diagonal. Although the triangulation problem is simple, it is extremely difficult to establish its algorithm, which is generally classified as NP problem.

The triangulation method can judge the position of the industry in the whole economic system, However, it can not measure the size of industrial linkages. There is a lot of literature on how to properly measure interdependence. Technical methods range from simple to highly complex. In addition to the common input coefficient matrix method, Leontief inverse matrix method, Hypothetical extraction method, it also includes qualitative input-output analysis, inverse of important coefficients, field of influence, eigenvector, graph theory and other methods.

The above measure of dependency often refers to the total impact, which is not measured the distance betweeen industries. Dietzenbacher, Romero and Bosma used “average propagation length” (APL) to measure the average step number of the impact of an exogenous variable, and used APL to measure the industrial chain of Andalucia, Spain [1]. The large APL indicates that the indirect impact is dominant in the total impact, that meaning the distance is far away, and the small APL indicates that the direct impact is dominant, that meaning the distance is near. Chen proposed generalized average propagation length (GAPL), which can measure the distance between two types of industrial clusters [2].

In the field of agricultural industry association, Jiang pointed out that agricultural industry clusters include service before, during and after the production process. [3] Xue and Li used the input-output table to measure agricultural forward integration industry and agricultural backward integration industry.[4] Geng and Zhou found the importance of China's agricultural related industry system by using China's input-output table in 2007. [5] Li analyzed the evolution of agricultural related networks in Jiangsu province using complex network theory.[6]

To sum up, foreign research on agricultural industrial chain mainly focuses on different industrial lingages measurement methods, propagation distance, triangulation and other technical aspects, while domestic research mainly focuses on the industrial linkages level, and there are few cases to identify the whole agricultural industrial chain by means of “economic distance” and minimum spanning tree. This paper will build a complete agricultural industry chain in Jilin province from the perspective of average propgation distance, industrial linkages and the minimum spanning tree method in graph theory, combined with the input-output table of Jilin province in 2012, in order to provide valuable opinions and suggestions for the better development of agricultural industry chain in Jilin province.

The structure of the article is as follows: the second part introduces two input-output models, and discusses the use of input-output models to measure industrial linkages and average propgation distance. The third part applies this method to the agriculture of Jilin province, and constructs the agricultural industry chain of Jilin province by using the input-output model and the minimum spanning tree theory in graph theory. The fourth part is the conclusion of this paper.

## 2. Models and Data

### 2.1. Models

Leontief model can be obtained from total output and final use.

$$X = (I - A)^{-1} f \tag{1}$$

Where X is the total output column vector, A is the input coefficient matrix, f is the final demand column vector, $(I - A)^{-1} = I + A + A^2 + A^3 + \cdots$is Leontief inverse matrix,denoted L.

The Ghosh model can be obtained from the total output and initial input.

$$X' = V(I - B)^{-1} \tag{2}$$

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Where V is the initial input row vector, $(I-B)^{-1}=I+B+B^2+B^3+\cdots$ Is the Ghosh inverse matrix, denoted G.

Define the average propagation distance matrix V:

$$V=G(G-I)/(G-I) \tag{3}$$

I is the unit matrix. The ij element of V represents the average impact distance from the cost promotion of industry i to industry j. The total impact between sectors is divided into direct impact and indirect impact. A high impact distance indicates that the impact between the two sectors is dominated by indirect impact, while a low impact distance indicates that the impact between the two sectors is dominated by direct impact.

The L matrix can also be used to define V:

$$V=L(L-I)/(L-I) \tag{4}$$

It can be proved that V defined in (3) and (4) is equivalent. The ij element of V represents the average impact distance (step length) of the final use of industry j by one unit on the total output of industry I.

The industrial linkages of the two sectors has two dimensions, one represents the size of the industrial linkages, and the other represents whether the sectors linkages is dominated by direct linkages or indirect linkages. Here, an sectors linkages matrix is established, and the elements of the matrix measure sizes of the sectors linkages:

$$F=\frac{1}{2}[(L-I)+(G-I)] \tag{5}$$

The F matrix includes L and G, and the elements of F are expressed as the size of the linkages between the two sectors. If the value of this ij element is very small, the linkages between sector i and sector j can be ignored. A new matrix S is constructed by using distance matrix V and linkage matrix F.

$$S_{ij}=\begin{cases}\text{int}(v_{\text{ij}}) & \text{f}_{\text{ij}}\geq a\\ 0 & \text{f}_{\text{ij}}<a\end{cases} \tag{6}$$

Where int is the rounding symbol and $a$ is the threshold value. S is a matrix consisting of 0 and positive integers.

### 2.2. Data

In the empirical part, the data used are input-output table of 42 sectors and input-output tableof 7 sectors in Jilin province in 2012. The input-output table of 7 sectors is used to analyze the linkages and economic distance between 7 sectors in Jilin province; 42 department table is used to analyze the current situation and characteristics of agricultural industry chain in the economic system of Jilin province.

The focus of this study is the agricultural industrial chain in Jilin province. The intermediate transaction only includes the product flow produced in Jilin province, excluding the products produced outside the region. In order to estimate the product flow in the region, it is necessary to estimate the transfer in (import) matrix outside the region, and then subtract the transfer in matrix from the intermediate transaction matrix.

## 3. Empirical Results

### 3.1. Linkages of 7 sectors and APLS

Table 1 lists the linkages indicators of seven sectors. The forward linkage of agriculture is 1.09 and the backward linkage is 0.57, and the ratio of the two is 1.92. This value is greater than 1, indicating that agriculture is a driving sector, and its driving effect on the economy is stronger than that of pulling the economy. Other corresponding driving industries are mining, transportation, posts and telecommunications and commerce and catering, and their forward

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linkages are stronger than backward linkages. Manufacturing and construction is a industry of pulling effect, which has a stronger pulling effect on the economy than driving operation, that is, the backward linkages are greater than the forward linkages. It is worth noting that the forward linkages and backward linkages of other service industries are similar, and the difference between the driving effect and pulling effect can be ignored.

Table 1. Linkages of 7 sectors

| | AGR | MI | MNF | CON | TPC | CC | OSV | sum | Row sum / colum sum |
|---|---|---|---|---|---|---|---|---|---|
| AGR | 0.22 | 0.05 | 0.56 | 0.08 | 0.02 | 0.11 | 0.05 | 1.09 | 1.92 |
| MI | 0.03 | 0.15 | 0.61 | 0.10 | 0.02 | 0.03 | 0.06 | 0.99 1.76 | |
| MNF | 0.22 | 0.25 | 0.76 | 0.48 | 0.23 | 0.19 | 0.26 | 2.39 | 0.82 |
| CON | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.03 | 0.04 |
| TPC | 0.03 | 0.04 | 0.42 | 0.09 | 0.11 | 0.04 | 0.11 | 0.85 | 1.68 |
| CC | 0.04 | 0.03 | 0.30 | 0.07 | 0.03 | 0.05 | 0.09 | 0.61 | 1.25 |
| OSV | 0.04 | 0.04 | 0.26 | 0.08 | 0.08 | 0.07 | 0.14 | 0.71 | 1.00 |
| sum | 0.57 | 0.56 | 2.92 | 0.91 | 0.50 | 0.49 | 0.72 | | |

Data source: calculated by using the input-output table of 42 departments in Jilin Province in 2012, the same below. Industry abbreviation: AGR, Agriculture, MI, Mining, MNF, manufacturing, CON, construction TPC, transportation, post and communication CC, Commerce and catering OSV, Other services.

As far as individual sectors are concerned, the forward related sectors of agriculture are manufacturing, agriculture and commerce and catering, and the backward related sectors are manufacturing and agriculture. Therefore, there is a two-way linkages between agriculture and manufacturing, but the industrial linkages of agriculture is dominated by the forward linkages.

When analyzing the data of APLs, it should be noted that each APL has two meanings. For example, $\nu_{13}$=2.11, represents the average cost driving impact steps of agriculture on manufacturing industry, and also represents the average demand pulling impact steps of manufacturing industry on agriculture. Therefore, each value in the table has two explanations. In order to avoid confusion, it is called forward or backward average propgation distance.

Table 2 lists the average propagation length (APL) for each sector. These APLS have the following characteristics: first, most of the lower APLS are on the diagonal, which mean that the self dependence of the industry is direct, indicating that within the same industry, enterprises buy products from each other. At this time, there is direct dependence within the industry, but the feedback effect of enterprises purchasing products from other industries on the industry is limited. Second, there are 9 APLS among the tertiary industries, and only 1 APL greater than 2, accounting for 11%, indicating that the feedback effect between the tertiary industries is lower. Thirdly, there are 9 backward APLS from the secondary industry to the tertiary industry, all of which are greater than 2, indicating that the pulling effect of the secondary industry on the tertiary industry is mainly reflected in the indirect pulling effect.

Table 2. APLS of 7 sectors

| | AGR | MI | MNF | CON | TPC | CC | OSV | Average |
|---|---|---|---|---|---|---|---|---|
| AGR | 1.49 | 2.57 | 2.11 | 2.91 | 3.29 | 1.71 | 3.20 | 2.47 |
| MI | 3.24 | 1.44 | 2.01 | 2.39 | 2.98 | 2.95 | 2.68 | 2.53 |
| MNF | 2.11 | 2.09 | 1.99 | 1.94 | 2.11 | 2.12 | 2.07 | 2.06 |
| CON | 3.23 | 2.55 | 2.60 | 1.28 | 1.76 | 1.62 | 1.27 | 2.05 |
| TPC | 2.57 | 2.01 | 2.12 | 2.08 | 1.35 | 1.97 | 1.81 | 1.99 |
| CC | 2.11 | 2.15 | 2.07 | 2.12 | 2.05 | 1.70 | 1.69 | 1.98 |
| OSV | 2.24 | 2.17 | 2.14 | 2.18 | 1.63 | 1.72 | 1.56 | 1.95 |
| Average | 2.43 | 2.14 | 2.15 | 2.13 | 2.17 | 1.97 | 2.04 | |

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For different thresholds tested repeatedly, the S matrix is obtained from the average propgation distance matrix, as shown in Table 3. At this time, the threshold a is (1/7).

Fig. 1 is a graphical representation of matrix S. The solid arrow indicates that APL is 1, and the dotted arrow indicates that APL is 2. There are two explanations for the arrow pointing. For example, the arrow pointing from industry i to industry j can indicate both the forward APL of industry i to industry j and the backward APL of industry j to industry i.

Table 3. Matrix S of 7 sectors

| | AGR | MI | MNF | CON | TPC | CC | OSV |
|---|---|---|---|---|---|---|---|
| AGR | 1 | 0 | 2 | 0 | 0 | 0 | 0 |
| MI | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| MNF | 2 | 2 | 1 | 1 | 2 | 2 | 2 |
| CON | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TPC | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| CC | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| OSV | 0 | 0 | 2 | 0 | 0 | 0 | 0 |

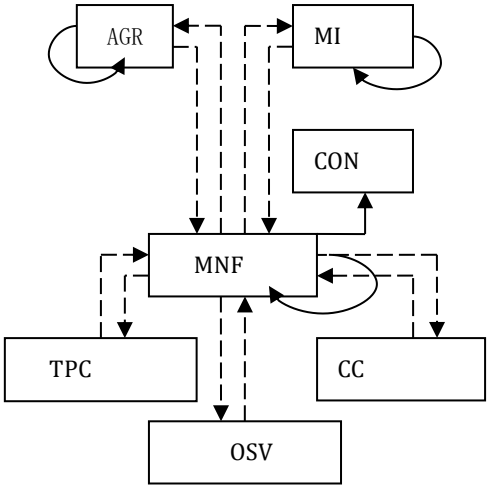


Figure 1. Network of 7 sectors in Jilin province

At this time, figure 1 shows the industrial chain of 7 sectors, which has the following characteristics. First, focus on manufacturing. There are strong industrial linkages between manufacturing and other sectors, which can be forward or backward. There are some two-way dependencies between manufacturing and most sectors. Second, the status of the construction industry is relatively special. In addition to the backward dependence of the construction industry on the manufacturing industry, this dependence is a one-step dependence; The construction industry is in the final demand stage, and there is no important forward linkages from the construction industry, so the construction industry is at the end of the industrial chain. Third, agriculture, mining and manufacturing industries have an economic distance of less than 2 intra these industries, which reflects that direct transactions in these industries are easier and the geographical agglomeration effect is obvious.

## 3.2. APLS analysis of agricultural industrial chain

As mentioned earlier, it is difficult to study the essence of the whole economic map because of too many sectors, so we choose to pay attention to the agricultural sector and its linkages, and no longer consider all sectors. Firstly, the linkages matrix and distance matrix are calculated through the input-output table of 42 sectors, and different thresholds are selected repeatedly. Finally, the matrix S is obtained. At this time, the threshold a =3/42. Since agriculture is the first

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sector in the input-output table, the first row and column of matrix s are selected, and the j elements of this row and column are respectively $s_{1j}$ and $s_{j1}$. If $s_{1j} = s_{j1} = 0$, It indicates that agriculture and sector j are weakly related. Delete row j and column j in table S, otherwise retain sector j. The last remaining sectors are agriculture (AGR), food and tobacco (FT), clothing, shoes and hats (CSH), wood processing and furniture manufacturing (WF), chemical industry (CHM), transportation equipment (TRE), gas (GAS), wholesale and retail (WR), accommodation and catering (AC), social services (SSV). Draw the corresponding industrial chain diagram of the deleted matrix S, as shown in Figure 2.

Figure 2 shows the industrial chain of agriculture in Jilin province. In order not to be affected by the linkages between other sectors, only the pointing and pointed arrows of agriculture are marked here. It should be emphasized that the position of agriculture in Figure 2 is similar to that in Figure 1. When it comes to the whole economic system of Jilin, there is an interdependence between agriculture and manufacturing, which shows that both agriculture and manufacturing have arrows pointing to each other; When the system is divided in more detail, the manufacturing industry is still related to agriculture. However, the detailed division will produce some inconsistencies, which is expected. If there is a dependency relationship between the two sectors, it does not necessarily lead to greater collective dependency, and the thresholds of the two cases are not consistent.

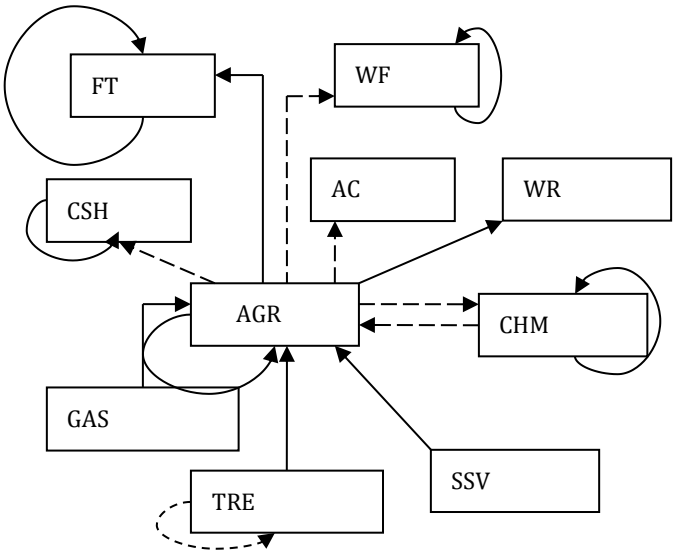


Figure 2. Schematic diagram of agricultural industry chain in Jilin province

## 3.3. Minimum spanning tree of agricultural industry chain

The industrial chain obtained in Figure 2 is centered on agriculture, and examines the interdependence between the input and output of agriculture and other industries. However, the position of other industries in the agricultural industrial chain is difficult to investigate. In order to clarify the position of other industries in the agricultural industrial chain, the minimum spanning tree in graph theory will be used to build a complete agricultural industrial chain. First, the submatrix of the obtained F matrix is recorded as $\bar{F}$, and then calculated $\tilde{F} = \bar{F} + \bar{F}'$. At this time, $\tilde{F}$ is a symmetric matrix. And the ij element in the matrix represents the dependence between sector i and sector j. Since there is undirected graph here, the forward or backward dependence are no longer distinguished. It can represent the driving of i to j sector, the pulling of i to j, the driving of j to i sector, the pulling of j to i, or any combination of the above four situations. Then, the algorithm of minimum spanning tree in undirected graph can be used,

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which can use loop breaking method or loop avoiding method. Here, the minimum spanning tree is obtained by using the circle avoidance method.

Figure 3 shows the central position of agriculture (AGR) and food and tobacco (FT) in the agricultural industry chain. Through the linkages of food and tobacco to accommodation and catering, the agricultural industrial chain is extended; Similarly, the agricultural industry chain can be expanded through the food and tobacco-transportation equipment-wholesale and retail.

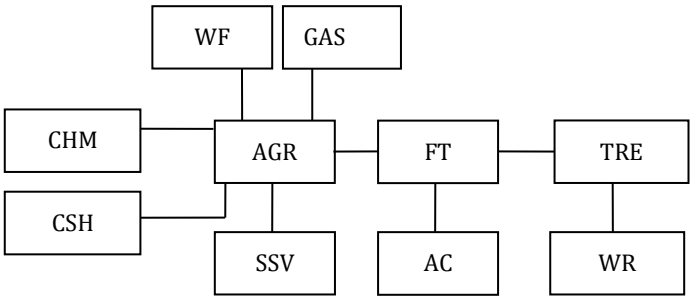


Figure 3. Minimum spanning tree of agricultural industry chain

## 4. Conclusion

In order to display the agricultural production chain as a whole, this paper analyzes the input-output table of 7 sectors in Jilin province in 2012, and the results show the central position of manufacturing industry; In addition to the construction industry, the association between manufacturing and other industries includes backward linkages and forward linkages. The economic distance is more than two steps, that is, indirect influence is the main.

If only agriculture is analyzed, there are great differences in the direction, degree and distance of agricultural industry linkages. The forward dependance of agriculture include food and tobacco, accommodation and catering, wholesale and retail, clothing, shoes and hats, wood processing and furniture manufacturing. The one step depends on wholesale and retail, food and tobacco, and the two steps depend on accommodation and catering, clothing, shoes and hats, wood processing and furniture manufacturing. As the upstream industry of the above five industries, agriculture can effectively promote the development of these industries. The backward dependent industries of agriculture are gas, transportation equipment, social services and other industries. These backward dependent industries are one-step dependence. Gas provides power source for agriculture, which can not be neglected in agricultural production; The characteristics of agriculture and agricultural products, transportation equipment to ensure the efficiency of agricultural production and trade; Social service is an inevitable requirement for the professional and intensive development of modern agriculture. Chemical industry and agriculture are interdependent, and the dependence distance is two-step dependence. On the one hand, agriculture provides raw materials to the chemical industry. On the other hand, pesticides and chemical fertilizers in the chemical industry are important intermediate inputs to agriculture. The development of the two industries restricts and promotes each other.

From the retained six intra industry communication paths, most of the communication steps are 1. The intra industry transmission step of agriculture, clothing, shoes and hats, food and tobacco, wood processing and furniture manufacturing and chemical industry is 1, while the intra industry transmission step of transportation equipment is 2. The transmission step length is 1, indicating that the impact of the final demand of the industry on the industry is mainly realized through the mutual purchase channels within the industry, rather than through the

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channels indirectly affected by other industries. Transportation equipment is a special industry in Jilin province. This industry has a wide impact on the whole economic system of Jilin province. It not only plays an important role in agricultural production, but also maintains close economic and technological ties with other industries. Therefore, the impact of the final demand for transportation equipment on the output of the industry is complex, which is reflected not only in the mutual purchase of products within the industry, but also in the further expansion of the impact of the final demand on the output of the industry through the feedback effect of other industries.

The minimum spanning tree shows the key role of food and tobacco industry in the agricultural industry chain. The food and tobacco industry has strong economic and technological linkages with accommodation and catering, transportation equipment, wholesale and retail. On the one hand, this connection shows that the agricultural industry chain is more forward dependent on the food and tobacco industry, on the other hand, it shows that the food and tobacco industry has extended or expanded the agricultural industry chain.

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