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# Using input–output methods to assess ripple effect and induced effect of high-tech service industry in national economy

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**Abstract.** High-tech service industry(HTSI) is the high-end part of modern service. It can support the development of other related industries. This paper uses an input–output model to quantify the socioeconomic impact of high-tech service industry in China. Using the relevant data of China in 2016, the input-output table was integrated into a simple table. The ripple and induced effects of the service industry on other industries were analyzed. Results indicate that the high-tech service industry depends on manufacturing industry at a highest level, then traditional service industry,high-tech service industry and infrastructure. It depends on agriculture at the lowest level. High-tech service industry has a large extent of promotion and radiation function in national economy, after manufacturing industry and infrastructure industry. Final demand items have a low induced effect on products of high-tech service industry, but consumption and investment promote the high-tech service industry obviously.HTSI has a strong connection with manufacture and infrastructure.

**Key words.** High-tech service industry,input–output motheds,rippleeffect,induced effect.

## 1. Introduction

High-tech service industry(HTSI) is the high-end part of modern service. That activity is of economic relevance in countries driven by industrial economies[1].Its character of high-end leading, universality and high value increment, have a large multiplier effect in national economy. It will highly improve the development of national economy in the future.

The basic idea of measuring inter-industry relationships goes back at least to the time of Quesnay's tableau ?conomique, and appears in a more modern form

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in Leontief (1936)[2]. Technology appears in this framework as the coef?cients of production expressing the input and output relations between industries.

When assessing the effects of institutional measures from a socioeconomic perspective, common practice is to use methodologies based on input–output (IO) analysis [3-5]. Input–output analysis provides a way to measure the interdependence of the national production system, as well as its interdependence in the global economy in Lundvall [6-8].

However, as currently envisaged, on the one hand, academic community is lack of relevant studies on HTSI's status and influences towards development of national economy and HTSI's mechanism of action on other industries; on the other hand, HTSI was still in the early stage of development, and there are many prominent problems in China. Therefore, the problems to be solved is how to promote its development quickly and optimize its structure reasonably. Based on this situation, the study used HTSI as research object and based on input-output table in China in 2016. IO methods, Ripple effect and Induced effect had been applied for two purposes: assessing the status and influences of HTSI towards development of national economy, analysing the relations between HTSI and other industries.

## 2. Foundation of input-output table of HTSI

Input-output methods was applied to have quantitative analysis for economic problems. Input-output table is a schedule recording the procedure of manufacturing, earning, allocation and using. By vertically and horizontally interlacing the input source and money spending in manufacturing of national economy, it was made into a balanced schedule like a chessboard, in order to explain the quantitative relation of interdependence and mutual restriction between various departments.The index matrix of direct consumption was used to figure out the coefficient of production interdependence and production restriction of one industry, in order to analyze how this industry influences all kinds of production directly and how it reacts to the demand of all departments' manufacture.

Input-output table focused on the subdivision of all inner industries. Based on this characteristics of input-output table, and through a study of relevant quantity features between HTSI and other industries, the input-output table adopted in this paper was highly integrated. HTSI, as an important component of the third industry, has difficulties to show its characteristics. Thus, in this paper HTSI was peeled out from the third industry for further study, which can stick out its characteristics and mechanism of action. That includes information transporting, software and information technology service industry, financial industry, business service industry, scientific research and technical service industry. Meantime, HTSI, as the product of modern service industry and high and new technical service industry, will have a tight connection with and other industries. In order to study the connection between HTSI and other industries, the service industry, expect for HTSI, was studied as a whole industry called traditional service industry(TSI).

The increasing industrialization of China accelerates inner demand of HTSI, while development of industrialization was exactly shown in great development of manu-

facture industry in China. And there exists a relationship of supplement and mutual promotion between HTSI and manufacture industry. Therefore, in this paper manufacture industry was peeled out from manufacture to study the connection with HTSI. Other industries, including mining industry, production and supplement industry of electricity heating power fuel gas and water, building industry, provides common material conditions for social production and residents' lives, such as railways, highway, water, electricity, gas, etc. These are called infrastructure.

Agriculture is the basis of national economy and provides important materials and board markets for the development of manufacture and service industry. At the same time, rapid development of service industry is good for increasing potential power of agricultural production and promote socialization and specialization of agriculture and manufacture. Therefore, planting industry, forestry, animal husbandry and fishery are called by agriculture in this paper.

In conclusion, the input-output table of HTSI in China was highly integrated of five departments, which includes agriculture, infrastructure, manufacture, TSI and HTSI.

## 3. The explanation of main referent coefficients

The use of input-output table for economic analysis, need to figure out various of coefficients of input-output table. There are many coefficients in input-output table, of which the most common and the most basic coefficients are direct consumption coefficient, complete consumption coefficient, Leontief inverse coefficient, influence coefficient and response coefficient, based on these coefficients, the final demand induced coefficient and productions' final demand induced dependence can be calculated to discover how different departments and demands effect and drive national economy and relevant departments. Influence coefficient and response coefficient regard final consumption as a whole; while the analysis of production induced volume and induced dependence of final consumption can be distinguished which mainly drove different departments, consumption, investment or exporting.

### *3.1. Direct consumption coefficiente*

Direct consumption coefficient refers to the quantity of productions or services that a product department(such as the j department) consumes directly in the production and operation of each product unit(e,gi department). Its calculation basis is the ratio of direct consumption of other industries to total input of one industry. The mathematical calculation formula is as follow:

$$a_{ij} = \frac{x_{ij}}{X_j}(i, j = 1, 2, \cdots, n) \tag{1}$$

In this formula, $a_{ij}$ is jth department's direct consumption coefficient to ith department. The explanation of $x_{ij}$ and $X_j$ are the same as its explanantions of input-output table.

$a_{ij}$, direct consumption coefficient, reflects jth department's direct dependence

and technical and economic relations to ith department. The bigger coefficient value is, the higher jth department's direct dependence to ith department is. On the contrary, the smaller coefficient value is, the lower jth department's direct dependence to ith department is. If the value of direct consumption coefficient is 0, the matrix $A(a_{ij})_{n\times n}$,made of all direct consumption coefficients of each industry, is direct consumption coefficient matrix, which can reflects the relation between technology and economy and between products of industries.

### *3.2. Complete consumption coefficient and complete demand coefficient*

The relation of industries in national economy includes direct relation of consumption and being consumed, and complicate and multi-level indirect relation of consumption and being consumed. Quantitative studies of relation between direct consumption and all indirect consumption have a great meaning. Complete consumption coefficient $b_{ij}$ refers to the numbers of $i$ product of direct consumption all indirect consumption in order to produce a unit of final product $j$. In other words, the computational formula to calculate the sum of direct consumption coefficient and indirect consumption coefficient is as follow:

$$b_{ij} = a_{ij} + \sum_{k=1}^{n} b_{ik}a_{kj}(i, j = 1, 2, \cdots, n) \tag{2}$$

In this formula, $b_{ij}$ shows the$j$th department's complete consumption to $i$th department, and $k$ is the number of intermediate product departments. $\sum_{k=1}^{n} b_{ik}a_{kj}$is, to produce a unit of $j$ product, all consumption of $i$ products by using $k$ kinds of intermediate products.

### *3.3. Influence coefficient and response coefficient*

Influence coefficient refers to the influence that one industry's increasing a unit of final product effects on other departments' demand. The bigger coefficient is, the more impetus the development of national economy has. The industry having a big influence coefficient is more important for promoting development of national economy. Therefore, these industries ought to be treated as the dominant industries in national economy.

The computational formula of influence coefficient is as follow:

$$\lambda_j = \frac{\sum_{i=1}^{n} \bar{b}_{ij}}{\frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n} \bar{b}_{ij}}(j = 1, 2, \cdots, n) \tag{3}$$

In this formula, $\lambda_j$is influence coefficient of $j$th department, and $\bar{b}_{ij}$ is complete demand coefficient.

Response coefficient reflects this department's response extent which effects by other departments' demand. The department having a big response coefficient has a higher demand response of other departments, and national economy has a bigger

pull effect on it.Computationalformula of response coefficient is as follow:

$$\delta_i = \frac{\sum_{j=1}^{n} \bar{b}_{ij}}{\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \bar{b}_{ij}} (i = 1, 2, \cdots, n) \tag{4}$$

In this formula, $\delta_i$ is response coefficient of $i$th industry, $\bar{b}_{ij}$ is complete demand coefficient.

### *3.4. Product induced coefficient and dependence coefficient*

The product induced coefficient refers to the capacity of each industry induced by a unit of final demand, which indicates how each demand project influences production in each department. The bigger product induced coefficient of each demand indicates that it has larger production ripple effect on production department.

Then, the capacity of each industry, induced by each final demand project, is final demand induced capacity.

$$X_i^s = \sum_{k=1}^{n} C_{ik} Y_k^s (i = 1, 2, \cdots, n; s = 1, 2, 3) \tag{5}$$

In this formula, $X_i^s$ is ith industry's capacity induced by s items of final demands. $C_{ik}$ is component of matrix $(I\text{-}A)^{-1}$; $Y_k^s$ is final demand of $s$th item in $i$th industry; among the formula, s=l,2,3 is on behalf of three final demand projects of investment, consumption and exporting.

The induced capacity of final demand project of ith industry was divided by the sum of relevant final demand project, then product induced coefficient of final demand project of each industry was figured out. Its computational formula is as follow:

$$W_i^s = \frac{\sum_{k=1}^{n} C_{ik} Y_k^s}{\sum_{k=1}^{n} Y_k^s} \tag{6}$$

In this formula, $W_i^s$ is product induced coefficient of $s$th final demand of $i$th industry; $\sum_{k=1}^{n} Y_k^s$ is the sum of$s$th final demand of each industry.

Product induced capacity of each final demand project in this industry was diveded by the sum of product induced capacity of each final demand project, then this industry's dependence coefficient to each final demand project was figured out. Its computational formula is as follow:

$$Z_i^s = \frac{X_i^s}{\sum_{s=1}^{3} X_i^s} (i = 1, 2, \cdots, n) \tag{7}$$

In this formula, $Z_i^s$ is ith industry's dependence coefficient to $s$th final demand projects; $Z_i^s$ is the product induced capacity of $s$th final demand project in$i$th industry; $\sum_{s=1}^{3} X_i^s$ is sum of product induced capacity of each final demand project in$i$thindustry.

## 4. Analysis of industry correlation of HTSI

### *4.1. Industry correlation of HTSI*

A production process of one industry is also a consumption of other industries' mediate product. In this procedure, there are not only relations oof this industry and other industries, but also indirect relation with other industries by relations of industries. In this paper, direct consumption coefficient and Leontief inverse matrix were used to reflect industry correlations within economic system.

Table 1. Direct consumption coefficient of each industry in 2016

| | Agriculture | Infrastructure | Manufacture | TSI | HTSI |
|---|---|---|---|---|---|
| Agriculture | 0.1330 | 0.0031 | 0.0587 | 0.0180 | **0.0025** |
| Infrastructure | 0.0113 | 0.1851 | 0.1029 | 0.0253 | **0.0166** |
| Manufacture | 0.2064 | 0.3683 | 0.5465 | 0.2207 | **0.1893** |
| TSI | 0.0427 | 0.0954 | 0.0598 | 0.1117 | **0.1395** |
| HTSI | **0.0219** | **0.0418** | **0.0351** | **0.0626** | **0.1307** |

According to table 1, HTSI has the highest dependence on manufacture, then TSI, HTSI itself and infrastructure, and the least is agriculture. Thus it can be seen that the development of HTSI was highly effected by manufacture, for in manufacture majority of this industry provide hardware environment and technical supports. In other industries' direct dependence on HTSI, high-tech service itself is at the highest level, then TSI, infrastructure and manufacture, and the least is agriculture. Therefore it can be seen that the development of HTSI and TSI was highly affected by HTSI.

### *4.2. Analysis of ripple effect of HTSI*

In national economic system, the ability of one industry's influence and induction to other industries is different from each others. For this, this paper use the influence coefficient and response coefficient of each industry to illustrate.

The ripple effect of industries includes pull effect and push effect. Pull effect is, when one industry added a unit of final demand, the change of demand value that each direct and indirect relevant industries had. And influence coefficient($r_j$) is direct reflection of this effect. Push effect is the reaction or response that one industry showed direct and indirect relevant industries' demand, when each department in national economic system was added a unit of final demand. And it was used to measure response coefficient($s_i$).

Table 2. Influence coefficient and response coefficient of each department

| | Response coefficient | Response coefficient |
|---|---|---|
| Agriculture | 0.80173 | 0.58287 |
| Infrastructure | 1.17859 | 0.76666 |
| Manufacture | 1.32730 | 2.28825 |
| TSI | 0.83768 | 0.75727 |
| HTSI | **0.85469** | **0.60495** |

According to table 2, the response coefficient of manufacture(1.32730) is the largest, then infrastructure(1.17859), HTSI(0.85469), and TSI(0.83768), and the least is agriculture(0.80173). That indicates, It is in the process of development of industrialization. The industry and construction industry have a large pull effect on national economy. The influence of HTSI is higher than TSI's. Thus in the process of developing service industries, HTSI's development should have a priority. The influence of HTSI was lower than infrastructure's and manufacture's due to its characteristics. It is mediate product industry which directly serves the field of production but not provides direct products. That indicates its impetus is lower than infrastructure's and manufacture's, but higher than TSI's.

### *4.3. The ripple effect of value and price of HTSI*

Studies on macro-economic perspective, connection between economy and techniques of one industry was shown by the influence that the chages of its value and price had on other industries. The value of HTSI was supplied to increase by $y_5$so the value of other industries is going to change according to the linking mechanism of departments' input and output. The changed value is calculated by following:

$$\begin{bmatrix} \Delta y_1 \\ \Delta y_2 \\ \Delta y_3 \\ \Delta y_4 \end{bmatrix} = \begin{bmatrix} \bar{b}_{15} \\ \bar{b}_{25} \\ \bar{b}_{35} \\ \bar{b}_{45} \end{bmatrix} \times \frac{\Delta y_5}{\bar{b}_{55}} = \begin{bmatrix} 0.0610 \\ 0.1298 \\ 0.7626 \\ 0.2578 \end{bmatrix} \times \frac{\Delta y_5}{1.2074} = \begin{bmatrix} 0.0505 \\ 0.1075 \\ 0.6316 \\ 0.2135 \end{bmatrix} \times \Delta y_5 \qquad (8)$$

In this formula, $y_i$(i=1,2,3,4,5) is on behalf of changed capacity of five departments in this paper. $\bar{b}_{ij}$is column matrix of HTSI in complete demand matrix. When HTSI's value increases a unit, the result is that agriculture's value increases by 0.0505 unit, infrastructure's 0.1075 unit, manufacture's 0.6316 unit and TSI 0.2135 unit. Thus it can be seen that increasing of HTSI's value has a large ripple effect on manufacture's value, then TSI and infrastructure, the least is agriculture.

According to Watras's general equilibrium theory, any product's balanced price was decided by the level of all kinds' products in the whole economic system. One change of a departments; products; price will results in the changes of other departments' products' prices. Supposing that the level of HTSI's price changed due to some reasons, so the changes of other departments' prices can be calculated by the

following formula:

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \end{bmatrix} = \begin{bmatrix} \bar{b}_{51} \\ \bar{b}_{52} \\ \bar{b}_{53} \\ \bar{b}_{54} \end{bmatrix} \times \frac{\Delta P_5}{\bar{b}_{55}} = \begin{bmatrix} 0.0753 \\ 0.1467 \\ 0.1535 \\ 0.1289 \end{bmatrix} \times \frac{\Delta P_5}{1.2074} = \begin{bmatrix} 0.0624 \\ 0.1215 \\ 0.1271 \\ 0.1068 \end{bmatrix} \times \Delta P_5 \quad (9)$$

in this formula, $\Delta P_i$(i=1,2,3,4,5) is on behalf of change extent of these five departments' price. $\bar{b}_{ij}$is the line coefficient of HTSI in complete demand matrix. When HTSI's price increases a unit, the result is that agriculture's price increases 0.0624 units, infrastructure's 0.1215units, manufacture's 0.1271 units, and TSI's 0.1068units.changes of HTSI's price have a big ripple effect on manufacture's and infrastructure's, then TSI's and the least is agriculture.

### *4.4. The induced effect of final demand to HTSI*

The influence coefficient showed the degree of induction each department, and the response coefficient showed the degree of demand of production, but it had limitation. Both of these partly reflect the total change of final consumption, and it can't reflect the movement trend of final consumption stucture. In order to distinguish which were the dominant factors affecting different departments, consumption, investment or exporting, product induced coefficient of final demand is to be analyzed.

Other than providing mediate products for process of each industry, the products of each industry in national economy provide products for each demand, including three parts: consumption, investment or exporting. According to final use structure coefficient oh HTSI, coefficient of final use structure of consumption of HTSI in 2016 is 63.729%, which is far larger than other two final uses. Final use structure coefficient of total investment is 14.334%. And final use structure coefficient of exporting is 21.937%.

Meantime, product induced coefficient and dependence coefficient canbetter show the extent of influence that final demand had on HTSI. Product induced coefficient of each final demand refers to the departments' capacity induced by increasing a unit of final demand. That discovered extent of final demand's effects on each departments' production, and explained which demand effects the industry. It also showed the fundamental direction of stimulating consumption, investment or exporting to effect on industrial structure. The bigger production induced coefficient is, the more ripple effect of its production is.

Table 4. Production induced coefficient of each department in 2016

| | Rural residents consumption | City residents consumption | Government consumption | Final consumption | Total investment | Exporting |
|---|---|---|---|---|---|---|
| Agriculture | 0.0538 | 0.1079 | 0.0238 | 0.1856 | 0.1608 | 0.0075 |
| Infrastructure | 0.0431 | 0.1629 | 0.0374 | 0.2435 | 0.8709 | 0.0143 |
| Manufacture | 0.2659 | 0.9083 | 0.2106 | 1.3848 | 1.8885 | 0.8243 |
| TSI | 0.0918 | 0.3697 | 0.3063 | 0.7677 | 0.3222 | 0.1070 |
| HTSI | 0.0326 | 0.1356 | 0.0486 | 0.2168 | 0.1658 | 0.0469 |

According to above data, in these three demands, consumption has the largest product induced effect on HTSI and the majority are city residents consumption. Then investment, and the least is exporting. Telecommunication, television and internet have already become essential and fundamental supplement in people's daily lives, while governments' scientific researches and technical studies have an increase year by year, which promotes the development of scientific researches and technical studies industry. So consumption became the most obvious final demand of product induced effect in HTSI. The diversified development of financial institution brought lots of opportunities and challenges for investment marketing, and enlarged investment in many aspects and promoted the development of financial industry in HTSI.

## 5. Conclusion

The objective of this paper was to introduce a way to assess the ripple and induced effects of the service industry on other industries. This measure was then used to identify the relation between five different industries. HTSI has a big pull effect and radiation effect on national economy, just less than manufacture and infrastructure; on the contrary, national economy's influence on HTSI is not obvious. These results allowed us to describe the influence in the ?ve industries included in this paper. The results provided a greater understanding of the linkages outlined in the taxonomy provided by Lundvall.

This study shows that the HTSI has provided supports of manufacture's and TSI's development and had a strong connection with manufacture and infrastructure. When HTSI's value and price changed, manufacture was highly effected, then TSI and infrastructure, but agriculture is more stabile comparing with HTSI's value and price.

One weakness of this study is that the infrastructure data used includes only providing social production and living conditions of the general material.It lacks data of network infrastructure.

Future research can probe into the new problems in the current research framework. In addition, future research can explore new research areas relevant to Internet Industry.

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