EE482 Industrialization: Role of Public and Private Sectors (Section 046401)

Academic Year 1/2023

Chapter 5

Introduction to Input-Output Analysis

Assoc. Prof. Dr. Nattapong Puttanapong

Faculty of Economics, Thammasat University

4.1 Introduction

The content of the previous chapter introduced the historical development of the economy and emphasized the importance of industrial development. In the case of countries like Japan and South Korea, the government has played a pivotal role in selecting target industries and providing support for their development, focusing on exports and enhancing the international competitiveness of these industries.

In addition to studying policy directions, this chapter presents an approach to analyze economic development projects. This method involves quantitative tools, with a specific emphasis on the application of Input-Output Tables and the use of multipliers. This approach is suitable for industrial policy analysis because it allows for a detailed examination at the sectoral level and demonstrates the interconnections among different industrial branches, as well as the links between various sectors within the economic system.

Furthermore, it enables the calculation of the value of impact pass-through, which is beneficial for studying the consequences of expansion within each industry on the overall economic system. It can also be used as a guideline for prioritizing target industries for selection. The World Bank and international research have applied this method to study the impacts of industrial policies in various cases, such as South Korea, clearly showing that government support for target industries with high multipliers can significantly stimulate economic growth.

4.2 Background of Input-Output Table

Prof. Wassily Leontief (1906-1999) pioneered the "Input-Output" (IO) technique, a tool for assessing economic effects and tracking circular flows in an economy. This innovation was a significant factor in his being awarded the Nobel Prize in 1973. The IO model offers insights into economic dynamics by capturing the interplay between various industries and sectors. A prime strength of this model is its capacity to illustrate the ripple or multiplier effects evident in inter-industry transactions. This provides an avenue to scrutinize how shifts or events in one sector can influence others by tracing the money flow between them.

Central to the IO model is the concept of inter-industry transactions. This suggests that industries rely on the outputs of other industries as inputs for their own production. A practical example of this is the automobile industry, which requires materials such as steel, glass, rubber, and plastic to manufacture cars. Thus, a surge in automobile demand inherently increases the demand for these materials.

Input-output analysis is a widely acclaimed and effective analytical method. Its primary merit in economic studies lies in its robust descriptive analytical capabilities. Such tables proficiently consolidate vast data into a coherent and digestible format, offer a comprehensive view of inter-industry relationships, underscore the significance of specific industries, and spotlight avenues for bolstering economic activities and employment growth. In particular, policymakers should be adept at comprehending the framework, presumptions, and data essentials of Input-Output Analysis.

4.3 Structure of Input-Output Table

The actual Input-Output table of Thailand is presented as an example. Specifically, the official Input-Output table for the year 2010 has been adjusted to have a size of three production sectors (unit: million baht). These production sectors include:

(1) Agriculture
(2) Manufacturing
(3) Service

	Agriculture	Manufacturing	Service	Private Consumption	Government Consumption	Fixed Capital Formation	Change in Inventory	Export	Total
Agriculture	167,539.50	1,195,667.65	167,634.60	609,945.88	5,645.33	1,585.19	29,129.75	171,920.76	**2,349,068.67**
Manufacturing	445,125.97	8,581,619.75	2,888,248.57	2,919,975.44	184,648.48	1,733,549.35	405,858.65	6,178,978.84	**23,338,005.02**
Service	62,616.81	950,716.64	1,970,596.99	2,364,876.88	1,507,568.19	858,033.56	96,028.63	785,445.46	**8,595,883.18**
Wages and Salaries	310,362.79	905,287.56	2,287,442.85						
Operating Surplus	757,903.16	1,583,078.02	2,848,190.05						
Depreciation	44,261.12	474,739.46	1,006,208.95						
Indirect Taxes less Subsidies	-450.21	623,898.55	244,004.53						
Import	110,523.14	5,771,094.06	529,181.99						
Import Tax	4,825.33	351,994.91	644.11						
Wholesale Trade Margin	210,042.93	1,386,466.58	-1,596,509.51						
Retail Trade Margin	180,353.71	1,142,452.65	-1,322,806.35						
Transportation Cost	55,964.41	370,989.19	-426,953.60						
Total	**2,349,068.67**	**23,338,005.02**	**8,595,883.18**						

Figure 4.1: An Example of the Structure of Thailand's Input-Output Table (Unit: Million Baht)

Note: Data from the National Economic and Social Development Council (NESDC)

The table above on the left illustrates the relationships among the three sectors in terms of being users of raw materials produced by other sectors. Additionally, the upper right section represents the values of final demand, which indicate the use of goods and services in each sector for consumption. It includes the values of the following activities:

(1) Private Consumption
(2) Government Consumption
(3) Fixed Capital Formation (Investment)
(4) Change in Inventory
(5) Exports

Another significant component of the Input-Output Table (IOT) is value added, which demonstrates the return from the utilization of production factors in the production processes of each sector (including taxes and subsidies by the government). Value added consists of four components:

(1) Wage and Salary
(2) Operating Surplus (Profit)
(3) Depreciation
(4) Indirect taxes and Subsidies

Details of income and expenditure for each production sector as shown in the table, such as in the case of the Agriculture sector, consist of the following expenditure details:

- The purchase cost of raw materials from the Agriculture sector (e.g., seeds, organic fertilizers, etc.) amounts to 167,539.50 million baht.
- The purchase cost of raw materials from the Manufacturing sector (e.g., agricultural machinery, chemicals, etc.) amounts to 445,125.97 million baht.
- Expenditure on services (e.g., banking, insurance, etc.) amounts to 62,616.81 million baht.
- The Agriculture sector employs labor with a total value of 310,362.79 million baht and uses capital, resulting in a total profit of 757,903.16 million baht and depreciation costs of 44,261.12 million baht.
- Additionally, there is the value of indirect taxes and government subsidies, amounting to -450.21 million baht. A negative value indicates receiving more subsidies than paying indirect taxes (e.g., specific business taxes), while a positive value indicates higher indirect tax payments than subsidies.

- Furthermore, there is the value of imports, totaling 110,523.14 million baht, and import taxes of 4,825.33 million baht.
- Lastly, there are details of the value of wholesale and retail trade, amounting to 210,042.93 million baht and 180,353.71 million baht, respectively. There is also the value of transportation costs, totaling 55,964.41 million baht.
- The total expenditure (or total cost) amounts to 2,349,068.67 million baht.

Details of revenue as shown in the data by row in the case of the Agriculture sector.

- The second part of the revenue comes from selling products used for final demand, which includes private consumption and government consumption, amounting to 609,945.88 and 5,645.33 million baht, respectively. Additionally, some products are exported, totaling 171,920.76 million baht.
- Some products are held for future use in the form of capital goods, amounting to 1,585.19 million baht, and there is a change in the inventory of agricultural products within the country, totaling 29,129.75 million baht (a positive value indicates an increase in inventory).
- When you sum up the total value of agricultural product usage (which represents the revenue of the Agriculture sector), it amounts to 2,349,068.67 million baht, which equals the total expenditure. This demonstrates the balance of the matrix account.
- However, even though the revenue matches the expenditure, which is considered normal profit in economics, in business accounting or financial analysis in the agricultural sector of Thailand in 2010, the value of profit generated from agricultural production activities amounts to 757,903.16 million baht.
- Regarding the value added from wholesale trade margin, retail trade margin, and transportation cost, they are considered expenses for both the Agriculture and Manufacturing sectors. Nevertheless, these values are part of the service sector's activities.
- Therefore, these values serve as revenue for the service sector and have negative values. When you sum the values of wholesale trade margin, retail trade margin, and transportation cost for all three production sectors, the result is zero. This demonstrates the offsetting of all entries and ensures accounting balance because the total expenditure for these three types together is recorded as revenue for the service sector.
- The total sum of 210,042.93 + 1,386,466.58 + 180,353.71 + 1,142,452.65 + 55,964.41 + 370,989.19 - 1,596,509.51 - 1,322,806.35 - 426,953.60 represents the value added from wholesale trade margin, retail trade margin, and transportation cost for all sectors.
- "Value added" generated during the one-year period for each sector, which is the sum of wages and salaries, operating surplus, depreciation from machinery

usage throughout the year, and the value of indirect taxes less subsidies from the government.

- In the agricultural sector, the value added is equal to 1,112,076.86 million baht, and in the industrial and service sectors, the value added is equal to 3,587,003.59 million and 6,385,846.38 million baht, respectively.
- When the value added of all production sectors is combined, it results in the Gross Domestic Product (GDP), which has a value of 11,084,926.83 million baht. This GDP is calculated as the sum of value added across the entire economy (value-added approach) and is at prices of the year 2010 (or current price GDP). When used for year-to-year comparisons, it needs to be adjusted for price changes using a price index (such as the GDP deflator) to eliminate the impact of price fluctuations.
- This method is the most convenient way to calculate Gross Domestic Product (GDP) from Input-Output Tables (IOT) factors. In the following section, details of calculating GDP using all three methods will be presented based on the Social Accounting Matrix (SAM) table.

4.4 Calculation of Multipliers

4.4.1 Calculation of Cost Structure Ratios (Matrix A)

This calculation method is considered the simplest. It involves dividing the values in each column by the total in that column. The result obtained represents the proportion of costs by type.

Similar to the previous section, the Input-Output Table (IOT) for the year 2010, which was constructed and published by the National Economic and Social Development Council (NESDC), has been adjusted to include only three sectors (namely, the agricultural sector, industrial sector, and service sector) for the purpose of analysis. This will be used as an example in this section.

	Agri	Manuf	Servc	FinalDmnd	Total
Agri	167,540	1,195,668	167,635	818,227	2,349,069
Manuf	445,126	8,581,620	2,888,249	11,423,011	23,338,005
Servc	62,617	950,717	1,970,597	5,611,953	8,595,883
Value-Added	1,112,077	3,587,004	6,385,846		
Import	115,348	6,123,089	529,826		
Trade & Transport Margin	446,361	2,899,908	-3,346,269		
Total	2,349,069	23,338,005	8,595,883		

Figure 4.2: Main structure of Thailand's Input-Output Table for the year 2010 (3-sector model).

The above Input-Output table can be transformed into the matrix of cost structure ratios (Matrix A) as follows.

$$\boldsymbol{A} = \begin{bmatrix} 0.071 & 0.051 & 0.020 \\ 0.189 & 0.368 & 0.336 \\ 0.027 & 0.041 & 0.229 \end{bmatrix}$$

In the agricultural sector, when each value in the column is divided by the total production cost of the agricultural sector, it provides the proportion of costs for intermediate inputs of each type:

- For this case, the agricultural sector uses intermediate inputs from the agricultural sector itself at 7.1%.
- It uses intermediate inputs from the industrial sector at 18.9%.
- It incurs expenses in the service sector at 2.7%.

The proportion of intermediate input usage in the industrial sector per total production cost has proportions of 5.1%, 36.8%, and 4.1% for intermediate inputs from the agricultural sector, industrial sector, and service sector, respectively (and these values correspond to the second column of Matrix A). When calculating the proportions in the service sector, it is found that intermediate inputs from the agricultural sector, industrial sector, and service sector account for 2.0%, 33.6%, and 22.9% respectively (and these values correspond to the third column of Matrix A).

From the example shown here, organizing data in matrix A allows us to determine the proportions of intermediate resource usage in the production process for every sector within the economic system. Matrix A is also referred to in another form as the Technical Coefficient Matrix (or matrix showing the coefficients of technology). Furthermore, these calculations can also display the proportions of production factors (such as labor and capital) or the proportions of value added per total cost. In the case of Thailand, the results of dividing value added by total production cost show that value added in the agricultural sector accounts for 47.3%, while the industrial and service sectors account for 15.4% and 74.3%, respectively, in descending order.

These calculations reveal that the service sector can generate the highest proportion of value added, while the agricultural sector generates a lower proportion. Meanwhile, the industrial sector can generate the lowest proportion of value added.

	Agri	**Manuf**	**Servc**
Value Added	0.473	0.154	0.743

$$\boldsymbol{V} = [0.473 \quad 0.154 \quad 0.743]$$

Figure 4.3: Table Displaying the Values of Matrix V

	Sector 1	**Sector 2**	**Sector 3**	**Final demand**	**Total output**
Sector 1	Z_{11}	Z_{12}	Z_{13}	f_1	X_1
Sector 2	Z_{21}	Z_{22}	Z_{23}	f_2	X_2
Sector 3	Z_{31}	Z_{32}	Z_{33}	f_3	X_3
Value added	V_1	V_2	V_3		
Total input	X_1	X_2	X_3		

Figure 4.4: Structure of Input-Output Table (Represented by Variable Notation)

In this regard, considering the relationships in each row of the Input-Output Table (IOT), we obtain the following set of equations (1) - (3). It can be observed that in each sector, goods are produced with a total value of X_i and are used as intermediate inputs by other production sectors, with a value of Z_{ij}.

$$X_1 = Z_{11} + Z_{12} + Z_{13} + f_1 \qquad (1)$$

$$X_2 = Z_{21} + Z_{22} + Z_{23} + f_2 \qquad (2)$$

$$X_3 = Z_{31} + Z_{32} + Z_{33} + f_3 \qquad (3)$$

4.4.2 <u>Calculating the Leontief Multipliers</u>

Furthermore, it is possible to simplify the expression into relationships in the form of Technical Coefficients, which have the following format as shown in equations (4) - (7).

$$a_{ij} = \frac{z_{ij}}{x_j} \qquad (4)$$

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + f_1 \qquad (5)$$

$$X_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + f_2 \qquad (6)$$

$$X_3 = a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + f_3 \qquad (7)$$

The format of the set of equations (5) - (7) can be arranged into a matrix as follows:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{13} \\ \vdots & \vdots & \vdots \\ a_{31} & \cdots & a_{33} \end{bmatrix}, \quad X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}, \quad F = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \end{bmatrix}$$

$$X = AX + F$$

The relationships in the above equations can be rearranged by moving the term AX to the same side as X and reformatting the equations using parentheses, resulting in the following equation:

$$X - AX = F$$

$$(I - A)X = F$$

Next, when rearranging the equations once again and placing the term (I-A) on the other side of the equation, we obtain the relationship as shown in the following equation:

$$X = (I - A)^{-1}F$$

This equation is the fundamental form of calculating economic impact using Leontief multipliers (or the matrix value of $(I\text{-}A)^{-1}$). It demonstrates the relationship of the impact that changes in final consumption (such as household consumption, government consumption, investment, and exports) have on the production of each sector. In general, it is found that the value of the multiplier is greater than or equal to 1.00, indicating that an increase in final consumption leads to increased production, subsequently affecting the overall economy and generating a cyclical economic process. The multiplier value illustrates the net impact of this cycle that continues indefinitely.

It can be represented in the mathematical form of a Power series expansion, and it can illustrate the details of the impact on the economic system in the form of additive effects based on the number of rounds of impact. The first round of impact results in an effect equal to A, and the impacts in the second, third, and fourth rounds result in effects equal to A^2, A^3, A^4 respectively

$$(I - A)^{-1} = 1 + A + A^2 + A^3 + A^4 + \dots$$

In the case of the Input-Output Table with 3 sectors, when calculating the values of the Leontief multipliers according to the equations, the results are as follows:

$$(I - A)^{-1} = \begin{bmatrix} 1.098 & 0.093 & 0.068 \\ 0.359 & 1.658 & 0.732 \\ 0.057 & 0.091 & 1.138 \end{bmatrix}$$

The Leontief multiplier matrix reveals that if the final consumption of agricultural products increases by 1 baht, it will have an impact resulting in an increase in agricultural production by 1.098 baht, and an impact leading to an increase in industrial and service sectors' production by 0.359 baht and 0.057 baht, respectively. This adds up to a total impact on the entire economic system of 1.514 baht.

An analysis in the same manner shows that if the final consumption of industrial products increases by 1 baht, it will lead to an impact resulting in an increase in agricultural production by 0.093 baht, industrial production by 1.658 baht, and service sector production by 0.091 baht. This results in a total impact of 1.842 baht on the economic system.

For the case of an increase in the service sector, if the final consumption of the service sector increases by 1 baht, it will have an impact leading to an increase in agricultural, industrial, and service sector production by 0.068 baht, 0.732 baht, and 1.138 baht, respectively. This results in a total impact on the economic system of 2.138 baht.

4.3.3 Calculation of Backward and Forward Multiplier

Backward and Forward Multiplier

	Agriculture	Manufacturing	Service
Agriculture	0.07	0.05	0.02
Manufacturing	0.19	0.37	0.34
Service	0.03	0.04	0.23
Wages and Salaries	0.13	0.04	0.27
Operating Surplus	0.32	0.07	0.33
Depreciation	0.02	0.02	0.12
Indirect Taxes less Subsidies	- 0.00	0.03	0.03
Import	0.05	0.25	0.06
Import Tax	0.00	0.02	0.00

A matrix

Inverse of (I-A) of matrix B

	Agriculture	Manufacturing	Service	*Forward multiplier*
Agriculture	1.097815103	0.093364738	0.068478909	**1.25965875**
Manufacturing	0.359270092	1.657811766	0.731802134	**2.748883992**
Service	0.056956009	0.090850018	1.338482319	**1.486288346**
Backward multiplier	**1.514041204**	**1.842026522**	**2.138763362**	

Figure 4.5: Calculation of Backward and Forward Multiplier

In addition to applying the Leontief multiplier matrix for calculating impacts as presented in the various cases discussed above, the Leontief multiplier matrix (or matrix B = (I-A)^-1) can be used to analyze the role of each production sector in the economic system. This analysis can be accomplished by summing the values of the multipliers for each sector, and the result will indicate the values of the backward multipliers.

Backward multiplier of the sector is denoted as $j = BW_j = \sum_i b_{ij}$

In the case of calculating the values of forward multipliers, which represent the impacts on the downstream, it involves adding the multiplier values along the rows.

Forward multiplier of the sector is denoted as $i = FW_i = \sum_j b_{ij}$

The results indicate that if a production sector, which is in the downstream as mentioned, increases its production, it will have an impact on the upstream sectors. This enables the upstream sectors to utilize the increased production as intermediate inputs or products to expand their own production. Therefore, the forward multiplier values show the roles of each production sector in another dimension, apart from the backward multiplier values that indicate the impact on the upstream.

Both forward and backward multipliers can be transformed into linkage indices known as the **Backward Linkage Index (BLI_i)** and **Forward Linkage Index (FLI_i).** These indices adjust the multiplier values to indicate the size in comparison to the average of all multipliers. The equations for calculating both indices are as follows:

$$\mathrm{BLI_j} = \frac{\sum_i b_{ij}}{\frac{1}{n} \sum_j \sum_i b_{ij}}$$

$$\mathrm{FLI}_i = \frac{\sum_j b_{ij}}{\frac{1}{n} \sum_i \sum_j b_{ij}}$$

<u>Interpreting the Meaning of Backward and Forward Multiplier Values</u>

If a production sector has a higher value of the backward multiplier compared to the forward multiplier, it indicates that such production activity has a greater impact on connecting with other industries upstream. This is because the length of a backward path is longer, implying that this sector can generate more impact in such a direction[1]. In this case, it suggests that the production activity is likely to be situated at the end of the supply chain (or in the final stages of production, close to delivery to consumers).

Conversely, if a production sector has a higher value of the forward multiplier compared to the backward multiplier, it indicates that the sector has a greater impact

[1] In simple terms, if a production sector has a higher backward multiplier than the forward one, it means it has more influence on industries that come before it in the production process. Think of it like a product being close to the final stages before reaching customers. On the other hand, if the forward multiplier is higher, it means the sector affects industries that come after it more. This is like being at the start of making something, like producing raw materials or initial steps. By comparing these multipliers, we can figure out where an industry stands in the whole production process.

downstream in the supply chain. This value suggests that the production activity is likely to be among the first stages of the supply chain, involved in raw material production or initial processing.

Notably, the comparison of backward and forward multipliers can be used to determine the position of each industry in the supply chain. As depicted in Figure 4.6, in the case where the forward multiplier is greater than the backward multiplier, it indicates that Production Sector Y is closer to the beginning of the supply chain (or Sector Y is the upstream production activity).

Figure 4.6: Sector Y Operating as the Upstream Production Activity

On the other hand, as shown in Figure 4.7, in the case where the forward multiplier is less than the backward multiplier, it indicates that Production Sector Z is closer to the downstream part of the supply chain (or Sector Z is the downstream production activity).

Figure 4.7: Sector Z Operating as the Downstream Production Activity

Figure 4.8 demonstrates that when the multipliers, which can be calculated as both Backward Linkage Index (BLI) and Forward Linkage Index (FLI), are arranged as pairs, it provides a clear picture of the role of industries in a quadrant format. Upstream industries are located in the quadrant with high Forward Linkage Index (FLI) and low Backward Linkage Index (BLI), while downstream industries are in the quadrant with low Forward Linkage Index (FLI) and high Backward Linkage Index (BLI). Furthermore, comparing the multipliers from two different time periods can illustrate changes in the supply chain roles of each industry.

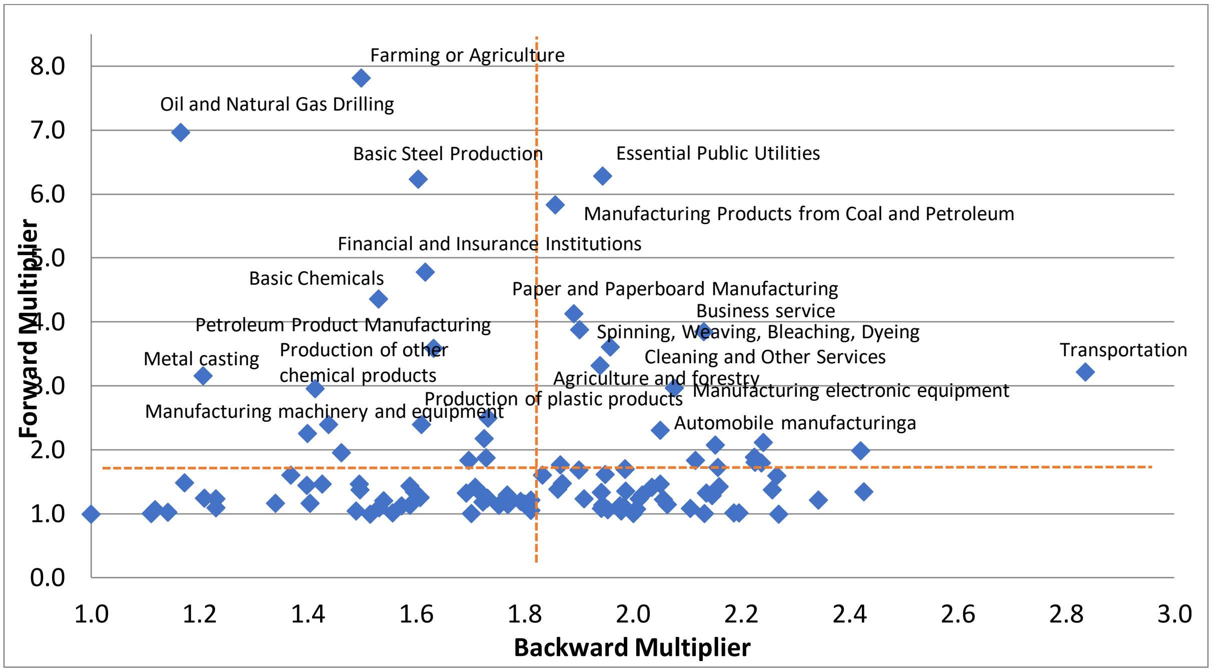

Figure 4.8: Characteristics of the Production Sectors based on the Values of Backward Multiplier and Forward Multiplier (using data from Thailand's Input-Output Tables)

The format of quadrant analysis shown in Figure 4.8 can be extended to visualize the intertemporal changes of backward and forward multipliers by incorporating the multipliers computed from two Input-Output tables. Based on this approach, Figure 4.9 illustrates the changes in five key export sectors of Thailand between the years 2001 and 2011. Most of them remain in the same quadrant except for the electronics sector, which shifted to the quadrant in the lower right corner. This result indicates that the electronics sector has changed its role, especially its position on the supply chain.

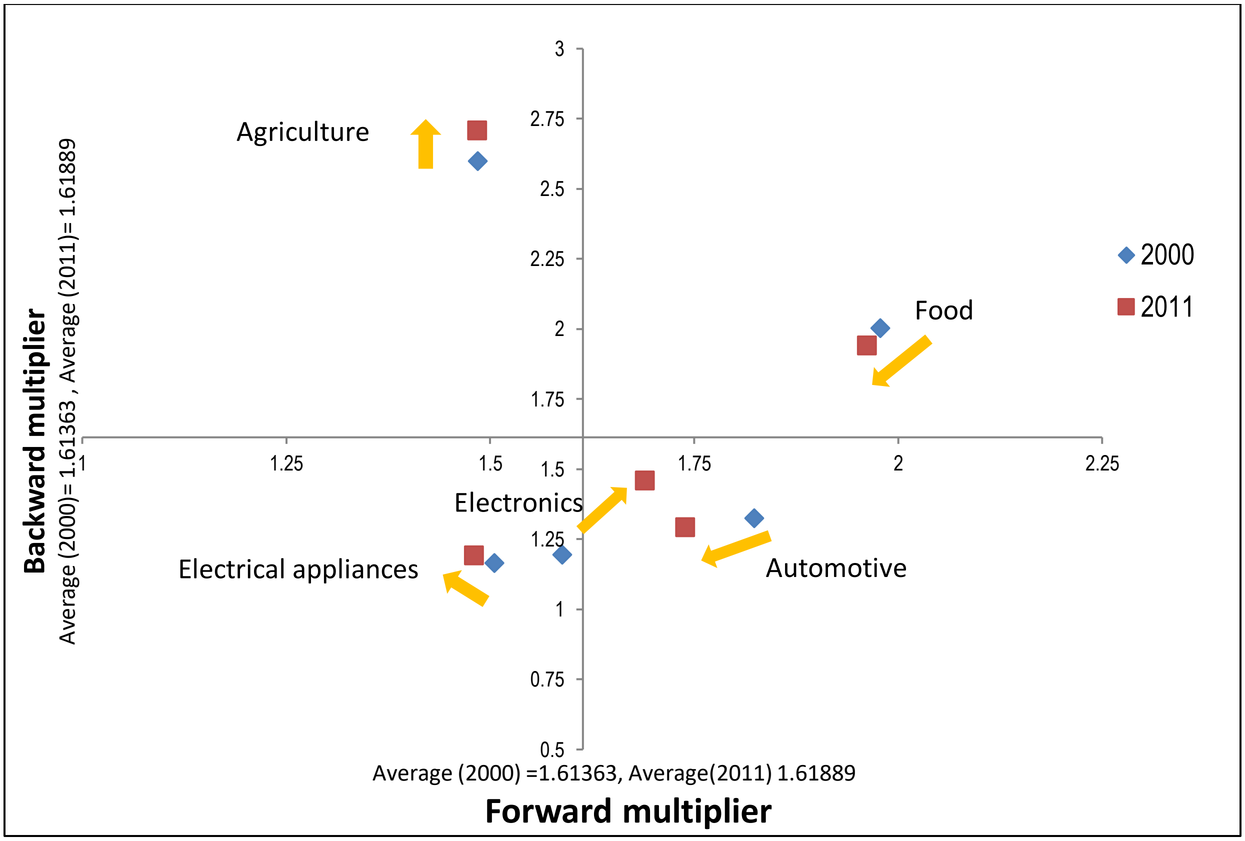

Figure 4.9: Characteristics of the Production Sectors Based on the values of Backward Multiplier and Forward Multiplier, using data from Thailand's Input-Output Tables (IOT) for the years 2000 and 2011

Summary

The analysis of industrial policies necessitates quantitative tools to help understand and demonstrate the value of economic impact resulting from the expansion or contraction of each industry. This chapter introduced the Input-Output Tables (IOT), which provide a comprehensive system of data illustrating the interconnections between different sectors of the economy and the linkage between industrial sectors. Moreover, it presented methods to calculate the economic impact using multipliers, which are both the Backward Linkage Index (BLI) and the Forward Linkage Index (FLI). These multipliers can calculate the impact of each industry in detail, showing the size of the ripple effects of each sector. The Backward Linkage Index (BLI) reflects the ability to expand production, leading to increased purchases of intermediate goods and raw materials, benefiting the upstream industries. Conversely, the Forward Linkage Index (FLI) reveals that increasing production in a particular industry leads to more production in downstream industries. Thus, the upstream industries benefit from expansion. Furthermore, comparing the values of both types of multipliers can demonstrate the roles of each industry in the supply chain. Industries with high FLI and low BLI are considered upstream industries, while those with low FLI and high BLI are downstream industries.

In Figure 4.10, the quadrant format provides a clear illustration of each industry's role in the economy. This method also allows for comparisons between different time periods to understand changes in the supply chain roles of industries. Finally, the application of these tools is crucial for policymakers to make informed decisions and understand the structure of the economy and the importance of each industry. These quantitative tools facilitate the evaluation of the economic impact of industrial policies and help identify the key industries in the supply chain.

	Primary metal	Chemical	Machinery and equipment	Construction	Transport equipment	Precision industry
Impact coefficient (Backward linkage effect)	1.282	1.106	1.220	1.177	1.278	1.092
Sensitivity coefficient (Forward linkage effect)	1.988	1.945	0.915	0.601	0.931	0.641

Figure 4.10: Backward and Forward Multipliers of Key Industries in South Korea
Source: Bank of Korea (2014)

Examining the example of South Korea, it becomes evident that industries targeted for government support have high values for both Backward Linkage Index (BLI) and Forward Linkage Index (FLI), as shown in Figure 4.20. This illustration emphasizes the success of South Korea's targeted industries, particularly the Primary

Metal and Chemical sectors, which have high values for both types of multipliers. This clearly indicates that both targeted industries can have significant ripple effects throughout the entire economic system, making economic stimulus highly effective when promoting the expansion of these two sectors.