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An Analysis of Japanese Industrial Structure Using Input-Output Table

Hiroyuki Matsuoka
Department of Management and Information Sciences,
Faculty of Environmental and Information Sciences, Fukui University of Technology,
Gakuen 3-6-1, 910-8505 Fukui, Fukui, Japan

Abstract: The input-output table are widely recognized for the usefulness and importance in the analysis of industrial structure and for economic forecasting. They are developed by Dr. Leontief, a US Nobel laureate economist. Using 2011 input-out table of Japan (most recent version, 2015 publication) compiled by the ministry of internal Affairs and communications of Japan, this research discussed the relationship between "index of power of dispersion" and "index of sensitivity of dispersion" of each industry. Furthermore, it calculated production inducement by consumption, investment and export, ripple effect to added value and ripple effect to employment. Particularly an adjustment research related to the number of section was necessary when calculating ripple effect to the employment. That is because industrial classification is different from each other, the table of total employee number according to production activity section and the basic transaction table. Furthermore, this research focuses on 13 industries with processing the data, therefore we can see all table from a coherent viewpoint and easily understand industrial structure. Fact finding is that both influence degree on other industries and response degree from other industries are the biggest in the case of "Manufacturing industry" compared to other industries. Moreover, in production inducement by export, "Manufacturing industry" produces most amount of production. About ripple effect to employment, consumption for "Services" produces the most employment and "Construction" and "Manufacturing" have the biggest value in investment and export, respectively. This research reached the conclusion that "Manufacturing" industry is extremely crucial in respect of overall production in Japan and in particular, consumption for "Services" should be emphasized for Japan's employment policy.

Key words: Input-out table, index of the power of dispersion, index of the sensitivity of dispersion, production inducement, consumption, investment, export

INTRODUCTION

The input-output table are widely recognized for the usefulness and importance in the analysis of industrial structure and for economic forecasting. As Ronald and Blair, 2009, describe they are developed by Dr. Leontief in the late 1930s, a US Nobel laureate economist who received in 1973.Now they are compiled in >80 countries. Using the input-out Table of Japan, 2011(most recent version), this research discussed the relationship between "index of the power of dispersion" and "index of the sensitivity of dispersion" of each industry. Furthermore, it calculated production inducement by consumption, investment and export, ripple effect to added value and ripple effect to employment. The input-output table systematically clarify all the economic activities in a single country. As shown in Table 1, the table show how goods and services produced by a certain industry in a year are distributed among the industry itself, other industries, household, firms and so on (row, output). Furthermore, the table show how goods and services produced by industries in a year are spent to a certain industry (column, input). The input-output table for Japan have been compiled every 5 years since 1955 in a joint program involving governmental organizations. The ministry of internal affairs and communications (coordinator), the cabinet office, the financial services agency, the ministry of finance, the ministry of education, culture, sports, science and technology, the ministry of health, labor and welfare, the ministry of agriculture, forestry and fisheries, the ministry of economy, trade and industry, the ministry of land, infrastructure, transport and tourism and the ministry of environment are the present members of the joint program of compiling of the output input table (MIACJ, 2016a-c). The input-output table are widely used by administrative agencies of to the the governments of Japan and by research organizations in private sector for economic forecasts, predicting the effectiveness of public investments and estimating demand for a particular industry. In particular that is because the relationship among industries cannot be confirmed by the table of national accounts.

Table 1: Input-output table

<Domond sector (buyer)>/ <Supply sector (seller)>	Intermedate demand: Agriculture, forestry and fisheries	Mining manufacturiing	Total	Final demand: Consumation	Investment	Export	Total	(Less) import	Domestic production
Intermediate input									
Agriculter, forestry and fisheries	-	-	-	-	-	-	-	-	-
Mining									
Manufacturing									
Total									
Valu-added									
Valu-added 1	-	-	-	-	-	-	-	-	-
Valu-added 2									
Total									
Domesti production	-	-	-	-	-	-	-	-	-

Using the input-out table of Japan (2011), most recent version) this research discussed the relationship between "index of power of dispersion" and "index of sensitivity of dispersion" of each industry. Furthermore, it calculated production inducement by consumption, investment and export, ripple effect to added value and ripple effect to employment. About the following model and calculation method.

MATERIALS AND METHODS

Input-output analysis

Basic model: "Input coefficients" represent basic unit prices and are obtained by dividing the amount of raw materials and fuels which input into each sector by the domestic production value of that sector. A list of input coefficients indicated for each industry is referred to as an "input coefficient table." To simplify if the national economy is deemed to be comprised only of Industry 1 and 2, the basic transaction table may be as indicated in Table 2. The first row shows how goods and services produced by a certain industry (Industry 1) in a year are distributed among the industry itself (Industry 1) other industries (Industry 2) household, companies and so on (final demand). The second row shows how goods and services produced by Industry 2 are distributed among Industry 1, 2 and so on. Furthermore, the first column shows how goods and services produced by industries (Industry 1 and 2) in a year are spent to a certain industry (Industry 1). The second column shows how goods and services produced by Industry 1 and 2 are spent to Industry 2. Therefore, supply-demand balance equation is as follows:

$$\begin{cases} x_{11} + x_{12} + F_1 - M_1 = X_1 \\ x_{21} + x_{22} + F_2 - M_2 = X_2 \end{cases} \quad (1)$$

Income-expense balance (Eq. 2):

$$\begin{cases} x_{11} + x_{21} + V_1 = X_1 \\ x_{12} + x_{22} + V_2 = X_2 \end{cases} \quad (2)$$

Table 2: Basic trancation table

Variables	Industry 1	Industry 2	Find demand	Import	Domestic production
Industry 1	X_{11}	X_{12}	F_1	$-M_1$	X_1
Industry 2	X_{21}	X_{22}	F_2	$-M_2$	X_2
Gross. value added	V_1	V_2			
Domestic production	X_1	X_2			

Here, "a11" represents the input from Industry 1 required to produce one unit of production of Industry 1. It is called "input coefficient":

$$a_{11} = \frac{x_{11}}{X_1} \quad (3)$$

Similarly, "a21" represents the amount of raw materials, etc. that Industry 1 input from Industry 2 to produce one unit of the product of Industry 1:

$$a_{21} = \frac{x_{21}}{X_1} \quad (4)$$

As in the case of Eq. 3 and 4 "a11", a21, etc. are calculated and substituted into Eq. 1, resulting in the following modifications:

$$\begin{cases} a_{11}X_1 + a_{12}X_2 + F_1 - M_1 = X_1 \\ a_{21}X_1 + a_{22}X_2 + F_2 - M_2 = X_2 \end{cases} \quad (5)$$

Equation 5 can be expressed in a matrix as follows:

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} F_1 - M_1 \\ F_2 - M_2 \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \quad (6)$$

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \quad (7)$$

"A" is referred to as the input coefficient matrix. The final demand column vector is defined as:

$$\begin{bmatrix} F_1 - M_1 \\ F_2 - M_2 \end{bmatrix} = F - M \quad (8)$$

and the domestic production column vector is defined as:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = X \quad (9)$$

$$AX + F - M = X \quad (10)$$

can be obtained. The solution for X is:

$$X - AX = F - M \quad (11)$$

$$(I - A)X = F - M \quad (12)$$

$$(I - A)^{-1}(I - A)X = (I - A)^{-1}(F - M) \quad (13)$$

$$IX = (I - A)^{(-1)}(F - M) \quad (14)$$

$$\therefore X = (I - A)^{-1}(F - M) \quad (15)$$

Where:
"I" = An Identity matrix
$(I-A)^{-1}$ = The Inverse matrix of (I-A)

as follows:

$$(I - A)^{-1} = \begin{bmatrix} 1 - a_{11} & -a_{12} \\ -a_{21} & 1 - a_{22} \end{bmatrix}^{-1} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \quad (16)$$

(I-A) is called Leontief's inverse matrix.

Modified models: This model divides Final demand (F) into domestic Final demand (F_d) and Export (E) giving the following Eq. 17:

$$F = Fd + E \quad (17)$$

This is substituted into Eq. 10. The Supply demand balance equation can be expressed as follows:

$$AX + Fd + E - M = X \quad (18)$$

The diagonal matrix (m) can be assumed to have an "Import coefficient" (m) as the diagonal element and zero as the non-diagonal element:

$$\widehat{M} = \begin{bmatrix} m & 0 & 0 \\ & m & 0 \\ 0 & 0 & m \end{bmatrix} \quad (19)$$

Here "import coefficients" (m) represent the ratio of imports in product. For example, the imports of Industry 1 within total domestic demands:

$$m_1 = \frac{M_1}{X_{11} + X_{12}} \quad (20)$$

$$\therefore M = \widehat{M}(AX + Fd) \quad (21)$$

$$M = \widehat{M} \bullet AX + \widehat{M} \bullet Fd \quad (22)$$

This is substituted into Eq. 18:

$$AX + Fd + E - \widehat{M} \times AX - \widehat{M} \times Fd = X \quad (23)$$

$$X - AX + \widehat{M} \times AX = Fd - \widehat{M} \times Fd + E \quad (24)$$

$$(I - A + \widehat{M} \times A)X = (I - \widehat{M})Fd + E \quad (25)$$

$$(I - (I - \widehat{M})A)X = (I - \widehat{M})Fd + E \quad (26)$$

$$\begin{aligned} &\left(I - (I - \widehat{M})A\right)^{-1}\left(I - (I - \widehat{M})A\right) \\ &X = \left(I - (I - \widehat{M})A\right)^{-1}\left((I - \widehat{M})Fd + E\right) \end{aligned} \quad (27)$$

$$\therefore X = \left(I - (I - \widehat{M})A\right)^{-1}\left((I - \widehat{M})Fd + E\right) \quad (28)$$

Index of power of dispersion: The figure in each column in the inverse matrix coefficient table Eq. 16 indicates production required at each row sector when the final demand for the column sector (that is demand for domestic production) increases by one unit. The sum of column indicates the scale of "production repercussions on entire industries", caused by one unit of the final demand for the column sector. The vertical sum of every column sector of the inverse matrix coefficients is divided by the mean value of the entire sum of column to produce a ratio. This ratio indicates "the relative magnitudes of production repercussions on entire industries when the final demand for a column sector increases by one unit." This is called the "Index of Power of Dispersion" and can be calculated as follows (Shuntarou, 2010), the index of power of dispersion P: From Eq. 16:

$$\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} b_{ij} & b_{ij} \\ b_{ij} & b_{ij} \end{bmatrix} \quad (29)$$

$$P = \frac{b_{*j}}{\bar{B}} \quad (30)$$

Where:

$$b_{*j} = \sum_{i}^{n} b_{ij}$$

Each sum of column in inverse matrix coefficient table:

$$\bar{B} = \frac{1}{n}\sum_{j}^{n} b_{*j} \frac{1}{n}\sum_{j}^{n}\sum_{j}^{n} b_{ij}$$

Mean value of entire vertical sum in the inverse matrix coefficient table.

Index of sensitivity of dispersion: The figure for each row in the inverse matrix coefficient (Table 3) indicates the supplies required at each row sector when one unit of the final demand for the column sector occurs, respectively. The ratio produced by dividing the total (horizontal sum) by the mean value of the entire sum of row will indicate the relative influences that is to say, "the relative magnitudes of production inducement of a row sector when one unit of the final demand for all column sectors occurs". This is called the "Index of Sensitivity of Dispersion" which can be calculated as follows (Shuntarou, 2010): the index of sensitivity of dispersion S:

$$S = \frac{b_{i*}}{\bar{B}} \quad (31)$$

Here:

$$b_{i*} = \sum_{j}^{n} b_{ij}$$

Each sum of row in inverse matrix coefficient table:

$$\bar{B} = \frac{1}{n}\sum_{i}^{n} b_{i*} = \frac{1}{n}\sum_{i}^{n}\sum_{j}^{n} b_{ij}$$

Mean value of the entire horizontal sum in the inverse matrix coefficient table.

RESULTS AND DISCUSSION

Relationship between power of dispersion and sensitivity of dispersion: By combining the indices of power of dispersion and those of sensitivity of dispersion we can draw a typological presentation of the functions of each industrial sector. The figures the sectors are plotted on a chart with the indices of power of dispersion on vertical axis and those of of sensitivity of dispersion on horizontal axis. A position on the chart can reveal characteristics of an industrial sector (Table 3).

Table 3: Index of the power of discersion and sensitivity of discersion 2011

Industry	Power	Sensitivity
Agriculture, forest and fisheries	1.0597	0.7004
Mining	1.0985	0.5805
Monufacturing	1.2139	2.3307
Construction	1.0929	0.7224
Electricity, gas and water supply	1.0342	0.8524
Commerce	0.8658	0.9793
Financial and insurance	0.8891	0.8252
Red estate	0.7498	0.7566
Transport and posted	1.0448	1.1757
Information and communication	1.0232	0.9674
Public administration	0.8725	0.7154
Services	0.9366	1.7500
Activities not elsewhere classified	1.1207	0.6438
Average	1.0000	1.0000

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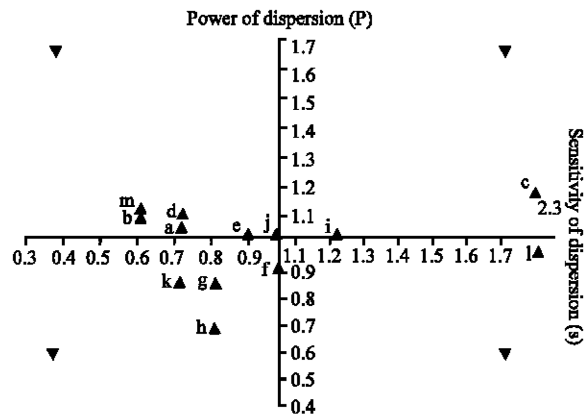

Fig. 1: Index of the power of dispersion and sensitivity of dispersion (2011): a) Agriculture; b) Mining; c) Manufacturing; d) Construction; e) Electricity, gas and water supply; f) Commerce; g) Financial and insurance; h) Red estate; i) Transport and postal; Information and communications; k:) Public administration; Services; m) Activities not elsewhere classified

Sectors plotted in qinfluence on entire industries and are most influenced by the final demand of other industries. Typically, it is "Manufacturing" sector as shown in Fig. 1. Quadrant "2" includes sectors whose influence on entire industries is high, however whose sensitivity is low. Typically, these sectors involve "Construction", including "Mining", "Agriculture, forestry and fisheries" and so on. Quadrant "3" includes sectors whose influence and sensitivity are both weak; typically, these are "Real estate", "Financial and insurance" and "Public administration". Quadrant "4" includes sectors with weak influence on entire industries but relatively strongly influenced by other industries. Typically, this sector provides services to other sectors, that is to say, the sector is "Services".

Domestic production induced by final demand items: Every industry supplies goods and services to each industrial sector as well as final demand sectors. On the whole, however, the industrial activities produce to just satisfy the final demand and their production levels depend on the size of respective final demands. Based on the model which imports fluctuate in proportion to domestic demand as indicated by Eq. 22, the following relationship holds in input-output Table as indicated by Eq. 26, through the inverse matrix coefficients:

$$X=\left(I-(I-\widehat{M})A\right)^{-1}$$

$$X=\left(I-\left(I-\widehat{M}\right)A\right)^{-1}\left(\left(I-\widehat{M}\right)Fd+E\right) \quad (32)$$

Here, final demand (F_d+E) can be classified into the following categories: consumption (C), investment (V) and exports (E). Domestic products induced by individual final demand items refer to the production of every industry induced by individual final demand items. Domestic products induced by individual final demand items can be an indication for analyzing the items in the final demand that influence value fluctuations in domestic production. Production value induced by consumption C and (or) investment N can be calculated as follows:

$$X_1=\left(I-\left(I-\widehat{M}\right)A\right)^{-1}\left(\left(I-\widehat{M}\right)(C+V)\right) \quad (33)$$

Production value induced by exports E can be expressed as follows:

$$X_2=\left(I-\left(I-\widehat{M}\right)A\right)^{-1}E \quad (34)$$

Since, the aggregate of induced production values by the respective final demand items is equivalent to the total value of domestic production (X), the following equation can be derived (Table 4):

$$X=X_1+X_2 \quad (35)$$

"Production Inducement Coefficient" (PIC) by final demand item is defined as the domestic products induced

Table 4: Production inducement coefficient 2011

Industry	Consumption	Investment	Export
Agriculture, forest and fisheries	0.019	0.023	0.034
Mining	0.001	0.002	0.003
Monufacturing Construction	0.331	0.692	1.306
Electricity, gas and water supply	0.020	0.473	0.014
Commerce	0.051	0.029	0.041
Financial and insurance	0.164	0.158	0.200
Red estate	0.071	0.019	0.032
Transport and posted	0.173	0.018	0.018
Information and communication	0.079	0.068	0.148
Public administration	0.099	0.003	0.002
Services	0.489	0.185	0.177
Activities not elsewhere classified	0.008	0.013	0.009
(Average)	0.122	0.140	0.155

by individual final demand item (e.g., consumption) divided by the total for corresponding final demand (e.g., consumption). This indicates the rate of increase of domestic production of an industry by a final demand item for all industry divided by the "total" of a certain final demand item for all industries which means per unit of a certain final demand item. That is to say, production inducement coefficient is per unit magnitude of "Production inducement" in an industry by a certain final demand item of all industries. In other words, the production ripple power of each final demand item (consumption, investment and export) for an industry per unit of each final demand. For example an industry's PIC of the consumption is:

$$PIC=\frac{X'}{C} \quad (36)$$

Here, X' is the domestic products of an industry induced by the consumption for all industry. C is the total of consumption for all industries.

Production inducement coefficient by consumption is 0.122 on average as shown in Table 4. The value of "Services" is the largest and "Mining" industry has the smallest value. The difference is 0.488. The values of 4 industries, "Services", "Manufacturing", "Real estate" and "Commerce", exceed the average and the values of other industries are <0.1. Production inducement coefficient by investment is 0.140 on average. The values of 4 industries, "Manufacturing", "Construction", services" and "commerce", exceed the average. The largest value is "Manufacturing", 0.692 and the smallest one is 0.002, "Mining" industry. The difference is 0.690. The average value of production inducement coefficient by export is 0.155. The largest value is 1.306 of

Table 5: Ripple effect to added value (unit: 1 milion yen, 2011)

Industry	Consumption	Investment	Export
Agriculture, forest and fisheries	3, 623, 767.19	1, 014, 996.10	972, 903.4
Mining	175, 359.08	62, 66273	69, 923.58
Monufacturing	37, 237, 561.70	18, 203, 444.78	21, 970, 273.31
Construction	3, 523, 741.78	19, 731, 578.23	386, 266.77
Electricity, gas and water supply	5, 430, 275.22	722, 404.42	673, 966, 30
Commerce	44, 292, 944.58	10, 010, 400.68	8, 934, 285.96
Financial and insurance	18, 446, 401.07	1, 183, 11923	1, 338, 708.34
Red estate	54, 993, 449.72	1, 336, 953.96	925, 086.92
Transport and posted	15, 732, 819.17	3, 176, 962.76	4, 751, 073.64
Information and communication	16, 466, 359.86	6, 392, 273.59	1, 231, 450.63
Public administration	26, 646, 595.14	188, 157.15	82, 487.34
Services	119, 013,755.97	10, 526, 739.53	6, 816, 972.87
Activities not elsewhere classified	1, 264, 611.43	484, 139.25	212, 244.60
(Average)	26, 680, 587, 84	5, 617, 987.11	3, 720, 434.13

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Table 6: Ripple effect to employment (unit: person)

Industry	Consumption	Investment	Export
Agriculture, forest and fisheries	2, 989, 267	837, 276	802,554
Mining	16, 511	5, 900	6, 584
Monufacturing	4, 215, 457	2, 060, 711	2, 487.132
Construction	915, 356	5, 125, 636	100, 340
Electricity, gas and water supply	225, 427	29, 989	27, 978
Commerce	7, 886, 035	1, 782, 279	1, 580, 684
Financial and insurance	1, 423, 443	91, 297	103, 303
Red estate	820.954	19, 958	13, 810
Transport and posted	2, 210, 490	446, 388	667, 534
Information and communication	1, 163, 265	451, 582	86, 996
Public administration	1, 848, 310	13, 051	5, 722
Services	21, 649, 362	1, 914, 881	1, 240, 051
Activities not elsewhere classified	21.897	8, 383	3, 675
(Average)	3, 491.213	983, 639	548, 951

"Manufacturing" and the smallest one is 0.002 of "Public administration" and 0.304 is the difference. Although, the values of 3 industries, "Manufacturing": "Commerce" and "services", exceed the average, the value of "manufacturing" is overwhelming.

Final demand and value added: The domestic production of each sector is comprised of intermediate input and value added. As domestic production can be induced by final demand, value added which is part of domestic production can be similarly induced by final demand. It is thus possible to apply the relational expression between domestic production and final demand introduced in above, Eq. 26 to value added and final demand in exactly the same manner.

As shown in Table 5, about the value-added inducement by consumption, investment and export, the values of "Manufacturing", "Commerce" and "Services" are all exceed each average value. Moreover, about value-added inducement by consumption, "Services" has the biggest value. The effect of investment is that "Construction" causes the largest value-added and "Manufacturing" is the biggest one in the case of export. "Mining" industry has the smallest effect of value-added inducement in all three final demands.

Final demand and employment: Inducement effect to employment of an industry can be calculated as follows:

- The number of employees in each industry/each industry's domestic production)×production inducement for each industry
- Labor input coefficient in each industry×production inducement for each industry

The rate of the number of employees in each industry divided by each industry's domestic production is called "labor input coefficient". When labor input coefficient matrix is L:

$$L' = L\left[\left(I-\left(I-\widehat{M}\right)A\right)^{-1}\left(\left(I-\widehat{M}\right)(C+V)+E\right)\right] \quad (37)$$

Here, L' is the inducement effect to employment. That is to say, this indicates the inducement effect to a sector's employment by each final demand. In this case an adjustment work related to the number of section was necessary when calculating inducement effect to employment. That is because industrial classification is different from each other, the table of total employee number according to production activity section (employment table, 108 sectors) and basic transaction table (13 sectors).

About employment inducement by consumption, the biggest one is "Services" as we can see in Table 6. The largest inducement effect by investment is "construction" and export is "Manufacturing". On the other hand about all cases, consumption, investment and export, "Mining" industry has the smallest effect of employment inducement. "Manufacturing", "Services" and "Commerce" industries all exceed each average value.

CONCLUSION

Fact finding is that both influence degree on other industries and response degree from other industries are the largest in the case of "manufacturing" industry compared to other industries. Moreover in production inducement by export, "manufacturing industry" produces most amount of production. About ripple effect to employment, consumption for "services" produces the most employment and "construction" and "manufacturing" have the biggest value in investment and export, respectively. This research reached the conclusion that "manufacturing" industry is extremely crucial in respect of overall production in Japan and in particular, consumption for "services" should be emphasized for Japan's employment policy. Finally, I would like to thank my laboratory undergraduate student, Shou Ohbayashi who helped me with calculating the table.

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The study primary contribution is finding that both influence degree on and response degree from other industries are the biggest in the case of "manufacturing industry" in Japan. About ripple effect to the employment, the consumption for "services" produces most employment.

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