Relationship between labor share and location in the value chain: Upstreamness and Downstreamness

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1. Introduction

It is an interesting issue to see how the labor share and the position of the manufacturing industry in the value chain are related.

As Baldwin, Ito, and Sato (2014) argue, value-added is "U-shaped" in the value chain. In other words, value-added is concentrated at the top (ideas and R&D) and bottom (marketing) of the production of goods, whereas value-added in the middle (assembly) is small.

Therefore, if we assume that the difference in labor allocation (i.e., wages) between industries is insignificant, it is hypothesized that output will be more relatively distributed to the capital side for upstream and downstream industries compared to midstream ones. In other words, the relationship between the labor share and the position of the industry in the value chain will be "inverse U-shaped."

In this paper, we examine the relationship between labor share and the position of the manufacturing industry in the value chain. To numerically indicate the standing point of an industry in the value chain, we use the upstreamness and downstreamness concept, which is used to calculate the global standing of each industry using the Global Input-Output table.

2. Global Input-Output Tables

Global supply chains have become more complex and evolved since the 2000s. Therefore, global input-output tables, which describe the relationship of trade structures not only within a single country but also between industries in different countries, have become increasingly important.

Global input-output tables are published by various organizations. Among these, representative tables that include data on Asian countries are the World Input-Output Tables (WIOT) published by the WIOD, the Asian International Input-Output Tables published by JETRO, the Multiregional Input-Output Tables published by the ADB, and the Interregional Input-Output tables (ICIO) and Trade in Value Added (TiVA) published by the OECD.

In this analysis, we use the WIOD I-O table for several reasons. First, compared with other international I-O tables, the most recent year table (2014) is available, making it easier to analyze the current situation. Additionally,

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data are available for every year from 2000 to 2014, making it possible to observe the trend over time, including the effects of the Lehman shock.

Second, the WIOD I-O table covers 56 industries across 43 countries, making it possible to analyze the relationship between industries across countries. This characteristic is useful for analyzing the position of each industry and country in the global value chain. In contrast, as the trade of intermediate goods is not available in domestic input-output tables, we can only calculate the position of a value chain within a country.

The advantages of using WIOD I-O tables are consistent with the assertions of Suganuma (2016). Note that while Suganuma (2016) analyzed data from 1995 to 2011 based on WIOT2013, the analysis in this study is based on WIOT2016, which covers the most recent year, 2014. Additionally, compared with the previous WIOT2013, WIOT2016 was expanded in terms of both the number of countries and industries covered, facilitating a more detailed analysis.

3. Upstreamness

The concept of upstreamness, proposed by Antras et al. (2012), quantitatively explains an industry's position in the supply chain in terms of the average number of processes its output passes before becoming a final good. In other words, it is the distance measured in terms of the number of processes upstream of the final good.

The calculation method for upstreamness proceeds as follows: First, we organize the figures in the input-output table, as shown in Table 1. Here, a_{ij} indicates that the production of good i is used as an intermediate good in the production of good j. The black bold box indicates that the good is used as an intermediate good, and F_i on the right side shows that it is used as a final good.

Intuitively, if output Y_i is used as an intermediate input, a_{ij}, upstreamness would be higher. In contrast, if the output is used as a final good, F_i, the upstreamness would be lower. However, such a simple intermediate goods ratio would not indicate the paths that a produced good passes as intermediate goods to reach the final goods. The concept of upstreamness attempts to present these paths numerically in terms of the average number of processes a product gets through to reach the final goods.

Specifically, equation (1) represents upstreamness. As shown in the equation, this number has a minimum value of 1. This occurs when all the output of the industry in question is a final good and is not used as an intermediate good in downstream industries through the supply chain. However, the maximum value of upstreamness is theoretically infinite, but in practice, it often falls between 2 and 4.

Table 1 Structure of the Input-Output Table

	Intermediate use (Z_i)			Final use	Output
	$Good_1$	$\cdots$	$Good_n$	(F_i)	(Y_i)
$Good_1$	a_{11}	$\cdots$	a_{1n}	F_1	Y_1
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\vdots$
$Good_n$	a_{n1}	$\cdots$	a_{nn}	F_n	Y_n
Value added	V_1	$\cdots$	V_n		
Output	Y_1	$\cdots$	Y_n		

$$\overrightarrow{US}=[I-B]^{-1}\cdot\vec{1} \quad where\ B=\begin{bmatrix} \frac{a_{11}}{Y_1} & \cdots & \frac{a_{1n}}{Y_1} \\ \vdots & \ddots & \vdots \\ \frac{a_{n1}}{Y_n} & \cdots & \frac{a_{nn}}{Y_n} \end{bmatrix} \tag{1}$$

Suganuma (2016) calculated the upstreamness of four East Asian countries/regions (Japan, China, South Korea, and Taiwan) and showed that the increase in this figure in all four countries is a major characteristic of this region compared with other countries, such as Europe and the United States.

However, as pointed out by Suganuma (2016), upstreamness indicates the distance between an industry and final goods, which corresponds to the lower half of the supply chain. In other words, the upper half of the supply chain is also needed in the analysis to determine the position of an industry in the global value chain.

In this analysis, we also included downstreamness, as proposed by Miller and Temurshoev (2015). Downstreamness is the opposite of upstreamness and is numerically calculated as the average number of processes that an industry goes through from raw materials until the final products of the industry are produced. In other words, it is the distance measured in terms of the number of processes from raw materials to the industry.

Formula (2) shows the calculation method of downstreamness.

$$\overrightarrow{DS}=[I-D]^{-1}\cdot\vec{1}^{T} \quad where\ D=\begin{bmatrix} \frac{a_{11}}{Y_1} & \cdots & \frac{a_{1n}}{Y_n} \\ \vdots & \ddots & \vdots \\ \frac{a_{n1}}{Y_1} & \cdots & \frac{a_{nn}}{Y_n} \end{bmatrix} \tag{2}$$

While analyzing global supply chains, one of the advantages of using both upstreamness and downstreamness is that it makes it possible to identify the industries/countries located upstream or downstream of the goods in the value chain. In other words, it is possible to identify the country in which the output of the industry is used as a back-end process to arrive at the final good or the country in which the output of the industry is used as a front-end process from the raw materials.

In other words, if industries A and B are connected through a supply chain in the sense that output A is used to produce B, then A is located upstream and B is located downstream in the supply chain. At this point, B is a component of upstreamness of A and A is a component of downstreamness of B. In other words, the greater the upstreamness, the more the output of the good is used by downstream industries, while the greater the downstreamness, the more the production of the good depends on upstream industries.

This interpretation might suggest that greater upstreamness (i.e., distance to the final good) is desirable, whereas greater downstreamness (i.e., distance from the raw material) is undesirable. However, in reality, this is not necessarily the case. The location of the value-add varies from good to good, as suggested by the smile curves of Baldwin et al. (2014).

4. Analysis

4.1 Value of Upstreamness and Downstreamness

Table 2 shows the upstreamness and downstreamness values off the Japanese manufacturing industry (17 categories), calculated using the WIOD's International Input-Output Table described in Sections 2 and 3.

The figures in this table confirm several observations. For upstreamness, the minimum value is 1.74 (food products), and the maximum value is 3.88 (chemical products). For downstreamness, the minimum value is 2.01 (printing), and the maximum value is 3.44 (chemical products). Overall, downstreamness is less volatile (i.e., the distance from the raw materials is similar), whereas upstreamness is more volatile (i.e., the distance to the final goods is different).

The two columns on the right show the "relative" upstreamness using the values of upstreamness and downstreamness, by calculating upstreamness (upstreamness + downstreamness). Here, a number above 50 indicates that the industry is located relatively upstream in the overall value chain, and a number below 50 indicates that the industry is located relatively downstream in the overall value chain.

Regarding the relative upstreamness, material industries, such as chemicals, lumber, rubber, and non-metallic products are above 50 (relatively upstream), whereas processing industries, such as automobiles and food products are below 50 (relatively downstream).

However, the relative upstream level of electronic components is below 50, despite the fact that the industry is characterized by the strength of the most upstream materials, such as semiconductors and capacitors, in the IT industry. This is attributable to the classification of the global I-O tables. The name of this industry in the I-O table is "Manufacture of computer, electronic, and optical products," suggesting that it also includes downstream (i.e., close to final goods) industries, such as computers and optical equipment.

Table 2 Upstreamness and Downstreamness (Japan, 2014)

CY 2014	Upstreamness	Downstreamness	diff	relative upstreamness
Food	1.74	2.33	−0.58	42.83
textile	3.05	2.57	0.48	54.28
wood	2.76	2.39	0.37	53.57
paper	3.53	2.66	0.87	57.01
printing	3.25	2.01	1.24	61.82
coke and petroleum	2.71	2.46	0.26	52.49
chemicals	3.88	3.44	0.45	53.06
pharmaceutical product	2.09	2.25	−0.15	48.22
rubber and plastics	3.41	2.92	0.49	53.88
other non-metalic products	2.83	2.35	0.48	54.60
metal products	2.56	2.83	−0.27	47.53
electrical equipment	2.86	2.63	0.23	52.11
computer and electronics	2.21	2.95	−0.74	42.87
machinery n.e.c.	1.92	2.57	−0.65	42.73
motor vehicles	2.19	3.17	−0.98	40.84
other transport equipment	1.94	2.67	−0.74	42.02
Furniture	2.38	2.62	−0.24	47.57

Source: WIOD

4.2 Labor Share

Regarding labor share, we use the one published by JIP database (See Table 3). However, in this paper, to analyze it with upstreamness and downstreamness, we reorganize it into 17 categories using nominal value added (NV) and the denominator of the labor share, to calculate weighted averages.

4.3 Analysis Results

Figure 1 shows the relationship between upstreamness (or downstreamness) and labor share for the 17 manufacturing categories (all in 2014). In the graphs, the regression equation is used up to the second order, which assumes an inverted U-shape, as mentioned earlier.

The results show that although a slightly inverted U-shape (or convexity upward) is observed, the relationship between upstreamness (or downstreamness) and labor share is not necessarily significant. However, by eliminating several sectors (pharmaceuticals, oil, and coal), which have extremely low distribution rates and small value added (NV), the R-squares rise to 0.17 and 0.22, respectively. Similar relationships have been observed in other years.

The implications of these results are as follows. In the Japanese manufacturing industry, we did not necessarily find a significant inverse U-shaped relationship between upstreamness (or downstreamness) and labor share, suggesting a U-shaped smile curve. However, this relationship improves slightly if we eliminate exceptional sectors. Additionally, the data has some limitations, such as the inclusion of computers in electronic components. Furthermore, we only used the manufacturing sector in this analysis. Thus, we may have failed to notice marketing and idea creation, which might be included in the non-manufacturing (service) sector.

One way to address this might be to conduct the same analysis using a domestic input-output table, where more granularly classified data are available. However, it may be less precise in terms of “global” value chains.

4.4 Overall manufacturing sector

Figure 2 shows the relationship between upstreamness (or downstreamness) and labor share in the overall manufacturing industry over time. Evidently, while upstreamness and downstreamness have recorded an upward trend during this period, labor share has recorded a downward trend, with some fluctuations.

This result implies that the increasing complexity and depth of the global value chain, and the decline in labor share occurred simultaneously. Although the fact that there is some causality may not be true, one suggestion is that, as the number of processes to make a good increases, the intermediate margin increases, resulting in a lower allocation to workers.

4.5 Markup

To what index are upstreamness/downstreamness related? In this section, we step away from labor share and examine its relationship with the markup ratio.

As the markup ratio is calculated by dividing profit by cost, a higher markup suggests that the industry is more profitable or competitive. Regarding the relation to the smile curve, similar to the argument that value added is higher at both ends of the smile curve, the markup ratio is predicted to show a U-shape.

As shown in Figure 3, the correlation coefficients between the two are weakly negative, equaling approximately -0.4 for both upstreamness and downstreamness. This relationship is slightly better than the relationship between

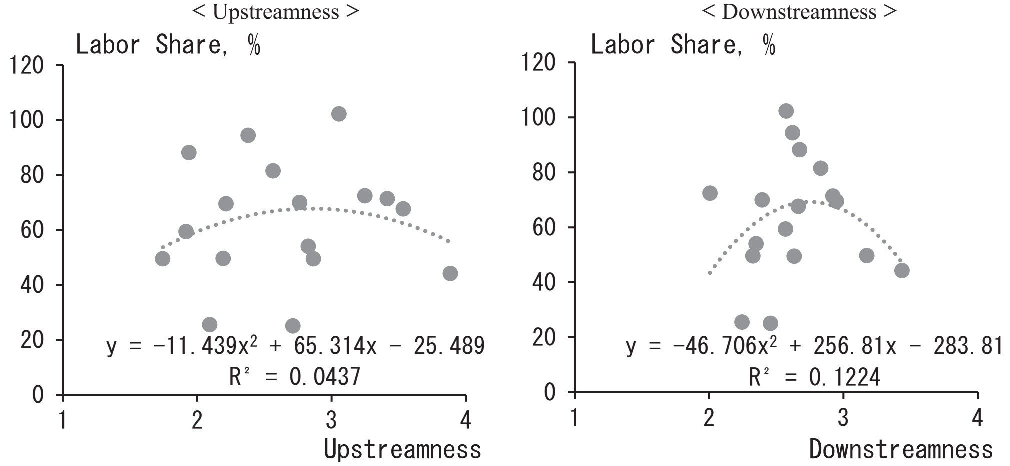
Table 3 Labor Share (Japan)

CY 2014 (54 industries)	Labor Share
Livestock Food Products	80.3
Fisheries Foods Products	86.5
Grain Milling	542.5
Fisheries Foods Products	64.0
Beverages	32.1
Feed and Organic Fertilizers	68.7
Tobacco	4.4
Textile Products	114.6
Chemical Fibers	36.9
Pulp and paper	53.8
Processed Paper Products	79.4
Chemical Fertilizer	17.0
Basic Inorganic Chemical Products	77.3
Basic organic Chemical Products	19.3
Organic Chemical Products	43.8
Chemical Final Products	45.3
Pharmaceutical Product	25.6
Petroleum Products	25.3
Coal Products	23.1
Glass & Glassware	70.1
Cement Products	51.4
Ceramics	72.6
Other Ceramic Products	58.0
Crude Steel	13.4
Other Steel	79.0
Nonferrous metal smelting and refining	23.7
Nonferrous metal fabricated products	75.7
Metal products for construction and building	83.9
Other Metal Products	80.5
General Purpose Machine	68.0
Production Machinery	60.8
Office and Service Equipment	37.0
Other Business Machinery	55.7
Weapons Manufacturing	26.9
Semiconductor devices and IC	59.3
Other Electronic Components and Devices	75.1
Industrial Electrical Machinery and Equipment	57.4
Consumer Electronics and Electrical Equipment	35.8
Electronic Applied Equipment	65.8
Other Electrical Equipment	44.5
Video and Audio Equipment	22.6
Telecommunication Equipment	53.6
Computers and Accompanying Equipment	65.8
Automobiles (including Auto Bodies)	47.5
Automobile Parts and Accessories	50.7
Other Transportation Machinery	88.2
Printing Industry	72.5
Lumber and Wood Products	70.0
Furniture and Equipment	94.4
Plastic Products	76.0
Rubber Products	60.4
Leather Goods and Fur	84.6
Watch Manufacturing	83.6
Other Manufactured Products	70.7

CY 2014 (17 industries)	Labor Share
Food Products	49.6
Clothing Goods	102.3
Wood and Wood Products	70.0
Pulp and Paper	67.6
Printing	72.5
Coal and Petroleum	25.1
Chemical Products	44.2
Pharmaceutical Product	25.6
Plastic and Rubber	71.4
Other Nonferrous Metals	54.0
Metal Products	81.5
Electronic Machinery	49.5
Electronic Parts	69.5
General Machinery	59.4
Automobiles	49.7
Other Transportation Machinery	88.2
Furniture	94.4

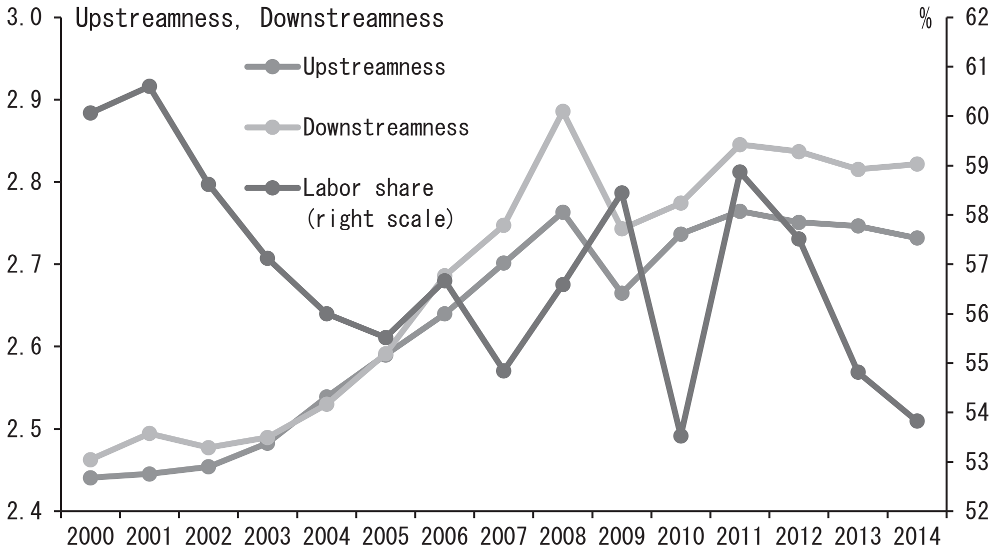
Source: JIP database 2021 (industries are reorganized by the author)

Figure 1　Upstreamness, Downstreamness, and Labor Share



Source: WIOD, JIP database 2021

Figure 2　Upstreamness, Downstreamness, and Labor Share (Manufacturing)



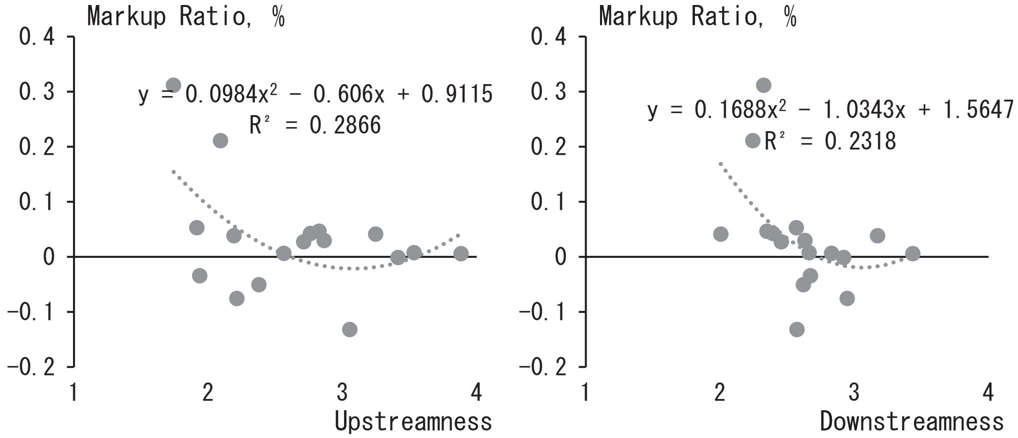
Source: WIOD, JIP database 2021

upstreamness/downstreamness and labor share. Furthermore, this result is convex down, which is consistent with the smile curve, as expected.

5. Conclusion

In this paper, we examine the relationship between labor share and the position of the manufacturing industry in the value chain, using upstreamness and downstreamness. The results above suggest that although the relationship between upstreamness (or downstreamness) and labor share is convex such as “inverse smile curve”, it is not necessarily statistically significant. However, the relationship between upstreamness (or downstreamness) and

Figure 3　Upstreamness, Downstreamness, and Markup (2014)



Source: WIOD, JIP database 2021

markup rate is convex down, suggesting that they are related.

The weak relationship between upstreamness and labor share may be due to the data limitations. One way to address this might be to conduct the same analysis using a domestic input-output table, where more granularly classified data are available. These topics are expected to be analyzed in the future research.

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