Upstreamness in the Global Value Chain: Manufacturing and Services

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This paper investigates "upstreamness," which measures the distance from the final use in terms of the number of production stages, using the World Input–Output Database's global input–output tables, which cover 40 major countries. We find that global upstreamness increased in the mid-2000s. This trend is mainly due to developments in the manufacturing sector, but the service sector also contributed to the increase. In manufacturing, upstreamness increased mainly in East Asian economies including Japan, which is consistent with the recent deepening of global value chains in this area. In services, the growing role of business services contributed to the deepening of value chains, such as outsourcing via leasing and staff agencies, and linkages to new businesses through mobile telecommunications. In further research, the concept of upstreamness can be applied to the analysis of industries' international competitiveness and of the influence of demand shocks across countries.

Keywords: Upstreamness; Global value chain; Production fragmentation; I–O tables
JEL Classification: D57, F14, F60, O14, O24, O53, O57

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I. Introduction

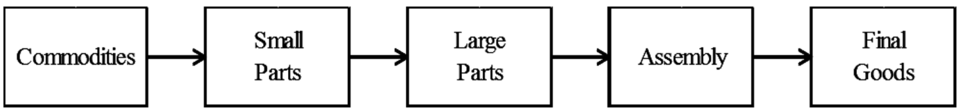
In recent years, supply chains have become increasingly globalized, linking economies ever more closely together. As highlighted by Timmer *et al.* (2014), global value chains (GVCs) are increasingly fragmented across countries, with each country playing a specialized role in particular stages in the production chain. This structural change has happened along with the decreasing cost of trade, transport and communication, and has been influenced by several factors, including the acceleration of free trade agreements, regional integration, the accessibility of cheaper labor, especially after China joined the WTO, and improvements in information technology.

Under these circumstances, maximizing the gains from trade in terms of economic welfare or growth is an important issue for successful industrial and trade policies. Krugman (1980) highlights that a country can be better off by focusing on producing certain goods and obtaining others through trade, under economy of scale. Melitz (2003) insists that trade has an effect of improving productivity of an economy by reallocating factors, such as labor and capital, towards more productive firms, under the heterogeneity of the productivity across firms.

However, those gains from trade are not generally distributed evenly across production stages. Consider the case of the iPhone: most of the value added is created in countries in upstream stages such as the United States where its design takes place, as well as Japan and South Korea where high-end parts and components are produced, while value added created in downstream countries like China where assembly takes place is quite small. In a case like this, it is advantageous for countries to move up the value ladder by replacing downstream activities such as assembly with upstream activities such as research and development (R&D).

To examine this issue in a rigorous manner, it is useful to construct an index which indicates whether a country is located at a relatively upstream or downstream position in GVCs. The basic idea of upstreamness is presented by Antràs and Chor (2013), who define upstreamness as the average distance from final use in terms of the production stages a particular product goes through. The increasing availability of global input–output databases has made it easier to calculate such an index indicating the degree of upstreamness.

The flowchart below provides a schematic representation of the degree of upstreamness. For example, commodity-related activities such as mining and the production of petroleum and basic metals are typical upstream industries, since their output is used as input for the production of goods in many downstream industries. On the other hand, assembly and production of final goods such as machinery, electronics and leather manufacturing are downstream industries, since other industries do not use those goods as the inputs.



Indicators of upstreamness can also be used to examine how demand shocks (both positive and negative) spread from country to country. For example, a country whose main industries are located at an upstream position in the GVC tends to be influenced by demand shocks in downstream countries. Using measures of upstreamness also makes it possible to analyze the competitiveness of industries at a country level, by investigating firms' positions in the GVC and their gains from trade.

There are a number of recent studies that have examined upstreamness. For example, Antràs *et al.* (2012) calculated upstreamness for the United States using the 2002 benchmark input–output (I–O) tables for 426 industries. They also calculated upstreamness for OECD countries. Following Antràs *et al.* (2012), and thanks to global I–O tables becoming available, several studies have calculated upstreamness in the GVC. Fally and Hillberry (2015), for instance, calculated the upstreamness of East Asian countries using the IDE-JETRO database. Using the same database, Ito and Veniza (2015) calculated upstreamness in manufacturing industries in Asian countries and examined the relationship between upstreamness and the share of foreign value-added. Miller and Temurshoev (2015) calculated upstreamness using the World Input–Output Database (WIOD).

Compared to these preceding studies, the present paper is unique in the following points. First of all, this study shows aggregated global upstreamness while previous papers treated upstreamness in individual countries or industries. Next, whereas previous studies calculated the level of upstreamness, this paper investigates changes in upstreamness between 1995 and 2011 and decomposes them into the within and the between effect to uncover changes in the structure of GVCs. In addition, this paper analyzes how global upstreamness has been influenced by American, European, and Asian countries, using global input–output tables from the WIOD. The contribution of sectors—especially manufacturing and services—, to changes in upstreamness is also discussed. Lastly, this paper investigates whether changes in a country's upstreamness were caused by either domestic or foreign use, using a decomposition of upstreamness in the GVC.

The main findings of this paper are as follows. Global upstreamness increased in the 2000s before the financial crisis in 2008. The increase was observed mainly in manufacturing, although services also contributed. In manufacturing, upstreamness increased in East Asia including Japan, which is consistent with the deepening of supply chains in this area. In services, business services contributed to the increase, caused by outsourcing via leasing or personnel provision, and by the appearance of new industries which are likely to use the output of other industries, such as mobile telecommunication.

The remainder of the paper is organized as follows. Section II presents the methodology employed, introducing the database and the calculation method. Section III shows the calculation results regarding the overall trend in upstreamness in the global economy, followed by an analysis of changes in upstreamness in manufacturing and services, respectively. Section IV summarizes the findings and highlights avenues for future research.

II. Methodology

A. Data

Two input–output (I–O) datasets are used for this study, the WIOD tables[1] and Japan's I–O tables published by the Ministry of Internal Affairs and Communications.

The WIOD provides I–O data for 40 countries[2] for every year between 1995 and 2011. For all countries and years, the number of industries is fixed at 35. It provides both global and national I–O tables, and this study uses the former to examine global input–output relationships. The tables contain data on both intermediate and final use across all countries in each industry. For instance, looking at 2011, the table shows that Japan produced electrical and optical equipment worth \$463 billion, using input of basic metal and fabricated metal from South Korea worth \$768 million. Moreover, of the \$463 billion worth of electrical and optical equipment produced in Japan, \$2.2 billion were used as intermediate input for transport equipment in China.

Apart from the WIOD, there are several other global I–O tables provided by IDE-JETRO and the OECD, for example. All these tables are useful, but the advantage of the WIOD for the analysis here are as follows. First, the coverage of the data is extensive. Although the database covers only 40 countries, these make up almost 85% of the world economy in terms of output. Second, the WIOD covers not only the manufacturing sector but also services, which makes it possible to examine a large number of industry and country pairs. Finally, the WIOD provides data for every year from 1995 to 2011, which makes it possible to examine both structural and cyclical change in the global economy.

The I–O tables for Japan are published by the Ministry of Internal Affairs and Communications. These tables have been published every five year. The Ministry also publishes the chain tables to make it possible to adjust data to make them compatible across time. The present study examines changes in upstreamness in Japan by calculating a 1995–2000–2005 chain I–O table for 34 industries and adding a table for 2011 by adjusting for changes in industry classifications.[3]

In contrast with the WIOD, in the domestic I–O tables exports are not divided into intermediate use and final use; instead, all exports are recorded as final use. Since intermediate use consists of only domestic industries, this domestic I–O table can be used for analyzing how industries are connected domestically. Table 1 provides an overview of the two different sources. The comparative analysis in Appendix 1 shows that the overall trends in upstreamness in the global and national I–O tables are not

1. Regarding the detail of the WIOD tables, see Dietzenbacher *et al.* (2013) and Timmer *et al.* (2015).
2. Most of the countries are developed, and 27 of the 40 are members of the European Union (EU). The reason is that the WIOD grew out of the EU KLEMS database based on a project funded by the European Commission. Of the remaining 13 economies, six are in Asia (China, Japan, South Korea, Taiwan, India, and Indonesia), four are in the Americas (United States, Canada, Mexico and Brazil) and three are in other part of the world (Russia, Turkey, and Australia).
3. To adjust the 2011 I–O table to make it consistent with the 1995–2000–2005 chain I–O matrix, the 37 industries in 2011 are adjusted to corresponding to the 34 industries in 2005 by combining some industries. For example, "General machinery" in 2005 was divided into three industries in 2011: "General purpose machinery," "Production machinery" and "Business oriented machinery." Therefore, for this study, the figures for these three subsectors in 2011 were aggregated to correspond to "General machinery." Such adjustment is possible only if an industry is divided into several industries, but not if industries were merged, since weights to split the data are not available.

Table 1　Characteristics of the I–O Tables: WIOD and Japan's Official Tables

	World Input-Output Database	Japan's official input-output tables
Issuer	WIOD	Ministry of Internal Affairs and Communications
No. of industries	35 industries (fixed across years & countries)	34 industries (1995–2000–2005) 37 industries (2011)
Years	1995–2011 (every year)	1995, 2000, 2005, 2011 (every five years)
No. of countries	40 countries + rest of the world	Japan
Nominal / Real database	Nominal (1995–2011) Previous year's prices (1996–2009)	Nominal (1995, 2000, 2005, 2011) 2005 prices (1995, 2000, 2005)

Sources: WIOD; Ministry of Internal Affairs and Communications.

Table 2　Illustration of the Structure of an I–O Table

	Intermediate use (Z_i)			Final use (F_i)	Output (Y_i)
	$Good_1$	$\cdots$	$Good_n$		
$Good_1$	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		

very different.

B. The Structure of Input–Output Tables

The structure of an I–O table is shown in Table 2. In this matrix, Y_i is the gross output of i, F_i is the final use of i, and Z_i is the intermediate use of i. a_{ij} is the value of i used in producing j.

Before the calculation of upstreamness, we define matrixes A and $\mathbb{Y}$ and vectors $\vec{F}$ and $\vec{Y}$ as follows:

$$A:=\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix},\ \vec{F}:=\begin{bmatrix} F_1 \\ \vdots \\ F_n \end{bmatrix},\ \vec{Y}:=\begin{bmatrix} Y_1 \\ \vdots \\ Y_n \end{bmatrix},\ \mathbb{Y}:=\mathrm{diag}(\vec{Y})=\begin{bmatrix} Y_1 & & 0 \\ & \ddots & \\ 0 & & Y_n \end{bmatrix}. \tag{1}$$

Here, the matrix $D=(d_{ij})$ is given by $A\mathbb{Y}^{-1}$.

$$D:=\begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & d_{nn} \end{bmatrix}=A\mathbb{Y}^{-1}=\begin{bmatrix} \dfrac{a_{11}}{Y_1} & \cdots & \dfrac{a_{1n}}{Y_n} \\ \vdots & \ddots & \vdots \\ \dfrac{a_{n1}}{Y_1} & \cdots & \dfrac{a_{nn}}{Y_n} \end{bmatrix}, \tag{2}$$

where d_{ij} is the value of i needed to produce one dollar worth of output j.

In addition to the calculation of upstreamness, I–O tables are also used for analyzing trade on a value-added basis which is directly related to benefits from trade. Johnson and Noguera (2012) and Johnson (2014) show that discrepancies between value-added exports in I–O tables and gross trade flows have been increasing, due to the expansion of intermediate trade. Accordingly, trade economists and policy makers tend to focus more on value-added exports than on gross export, reflecting these discrepancies. Antràs and Yeaple (2014), Timmer *et al.* (2014), and Los, Timmer, and de Vries (2015) use I–O tables to analyze the activities of multi-national firms in the GVC.

C. Calculation of Upstreamness

Regarding the definition of upstreamness, previous studies have introduced several approaches.[4] This paper uses the approach employed by Antràs and Chor (2013), which was also proposed by Antràs *et al.* (2012). In their approach, upstreamness is calculated as follows.

In I–O tables, such as Table 2, gross output of the industry i is written as the sum of its final use (F_i) and intermediate use (Z_i), as shown in equation (3).

$$\begin{aligned} Y_i &= F_i + Z_i = F_i + \sum_{j=1}^{n} a_{ij} = F_i + \sum_{j=1}^{n} d_{ij} Y_j \\ &= F_i + \sum_{j=1}^{n} d_{ij} F_j + \sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j + \sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{il} d_{lk} d_{kj} F_j + \cdots . \end{aligned} \tag{3}$$

Dividing both side of equation (3) by Y_i yields

$$1 = \frac{F_i}{Y_i} + \frac{\sum_{j=1}^{n} d_{ij} F_j}{Y_i} + \frac{\sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j}{Y_i} + \frac{\sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{il} d_{lk} d_{kj} F_j}{Y_i} + \cdots . \tag{4}$$

Assigning weights to each term of the right hand side of equation (4), upstreamness of i (U_i) is calculated as the weighted average distance from final use in terms of the number of production stages:

$$\begin{aligned} U_i &= 1 \cdot \frac{F_i}{Y_i} + 2 \cdot \frac{\sum_{j=1}^{n} d_{ij} F_j}{Y_i} + 3 \cdot \frac{\sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j}{Y_i} \\ &\quad + 4 \cdot \frac{\sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{il} d_{lk} d_{kj} F_j}{Y_i} + \cdots . \end{aligned} \tag{5}$$

4. For instance, Fally (2012) proposes a measure of upstreamness based on the notion that industries selling a disproportionate share of their output to relatively upstream industries should be relatively upstream themselves. This method is proved to be the same as that used in the paper by Antràs *et al.* (2012). Antràs *et al.* (2012) also mention that upstreamness equals the semi-elasticity of an industry's output to a uniform change in input–output linkages within industries, or the dollar amount by which output of all sectors increases following a one dollar increase in value added in the sector. Moreover, the word "upstreamness" in this paper is used in the sense of "output upstreamness" in these previous papers.

From equation (5), upstreamness vector $\overrightarrow{U} = (U_1, \ldots, U_n)^\top$ can be written as

$$\overrightarrow{U} = \mathbb{Y}^{-1} \cdot [I + 2D + 3D^2 + \cdots] \cdot \overrightarrow{F}, \tag{6}$$

using matrix representation. Hence,

$$[I - D] \cdot \mathbb{Y} \cdot \overrightarrow{U} = [I + D + D^2 + \cdots] \cdot \overrightarrow{F} = [I - D]^{-1} \cdot \overrightarrow{F}, \tag{7}$$

$$\overrightarrow{U} = \mathbb{Y}^{-1} \cdot [I - D]^{-2} \cdot \overrightarrow{F}, \tag{8}$$

which is the same as in Antràs *et al.* (2012). Using equation (3), output vector $\overrightarrow{Y}$ can be written as

$$\overrightarrow{Y} = [I + D + D^2 + \cdots] \cdot \overrightarrow{F} = [I - D]^{-1} \cdot \overrightarrow{F}, \tag{9}$$

where $[I - D]^{-1}$ is the Leontief inverse matrix. Substituting equation (9) into equation (8) yields

$$\overrightarrow{U} = \mathbb{Y}^{-1} \cdot [I - D]^{-1} \cdot \overrightarrow{Y} = [\mathbb{Y} - D\mathbb{Y}]^{-1} \cdot \mathbb{Y} \cdot \overrightarrow{1} = [I - \mathbb{Y}^{-1}A]^{-1} \cdot \overrightarrow{1}, \tag{10}$$

using equation (2). Defining

$$B := \mathbb{Y}^{-1}A = \begin{bmatrix} \frac{a_{11}}{Y_1} & \cdots & \frac{a_{1n}}{Y_1} \\ \vdots & \ddots & \vdots \\ \frac{a_{n1}}{Y_n} & \cdots & \frac{a_{nn}}{Y_n} \end{bmatrix}, \tag{11}$$

then upstreamness vector can be rewritten as:

$$\overrightarrow{U} = [I - B]^{-1} \cdot \overrightarrow{1}, \tag{12}$$

which is consistent with Ito and Vezina (2015). The term $[I - B]^{-1}$ is called the Ghosh inverse index (Miller and Temurshoev, 2015).

Regarding the range of the index, upstreamness defined in this method has a minimum value of 1, which means that no further production processes are required. In other words, such industry is zero distance from final-good consumption and produces final good. On the other hand, the maximum value of upstreamness is infinite by definition.[5]

5. However, in practice, even the largest degree of upstreamness takes a finite value. Using the WIOD database, figures are distributed between 1.5 and 3.0 across countries. In industry basis, looking at Japan as an example, the minimum figure is 1.0 and the maximum one is 3.7.

D. Decomposition of Upstreamness

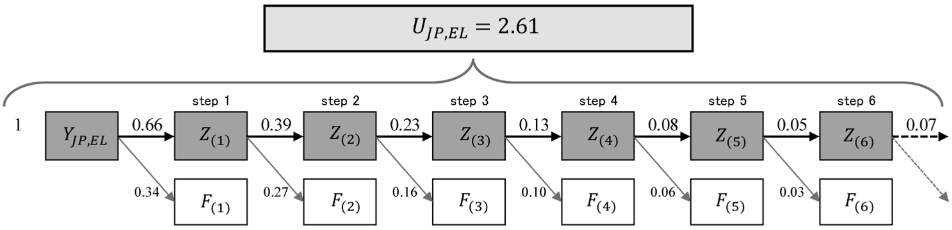
As mentioned, the method of calculating upstreamness presented above follows the approaches in existing studies such as Antràs *et al.* (2012). This section further expands their approach and shows how upstreamness can be decomposed into the contribution of different subsectors.

From equation (12), upstreamness vector can also be written as:

$$\overrightarrow{U} = [I + B + B^2 + \cdots] \cdot \overrightarrow{1}, \tag{13}$$

which means that upstreamness can be calculated as the infinite sum of all production stages (referred to as "steps" below). As shown in the following analysis, equation (13) is the key representation to decompose upstreamness into these steps.

In this equation, $B = (b_{ij})$ is the value of j produced, using one dollar worth of output i. This means that the upstreamness of good i in each step is the share of good i used as an intermediate good in the following step in the initial output of good i. The flowchart below provides a graphic illustration of this decomposition process in Japan's electrical and optical equipment industry in 2011 as an example. As shown above, Z shows the intermediate use and F shows the final use.



Assume that initial output is one, shown on the left of the chart. In the first step, the degree of upstreamness is 0.66, which means that 66% of the initial output of the industry is used in the following step as intermediate goods. In contrast, the remaining 34% are for final use and thus leave the supply chain. In the next step, 39% of the goods (calculated relative to initial output) are used in the further downstream steps, and thus counted as the upstreamness in the second step. Continuing these steps, the number of which in theory could be infinite,[6] the upstreamness value is calculated as the sum of the share used as intermediate goods in all steps. This is one of the advantages of writing upstreamness as $[I + B + B^2 + \cdots]$, since it makes it possible to see which step contributes to the increase in the industry's upstreamness. This kind of decomposition is presented in Section III.

E. Aggregation of Industries and Decomposition of Effects

The upstreamness of an industry in a country is obtained by following the calculation method above. This subsection explains how a country's overall upstreamness

6. The number shown after step 6 is 0.07. This is not the upstreamness in step 7 but the residual sum of upstreamness accumulated after step 6. This figure is calculated by subtracting the sum of upstreamness from step 1 to step 6 from the overall upstreamness and is shown as "step 7+" in Figures 6, 9, and 10.

is calculated by aggregating the upstreamness of individual industries. Industries are aggregated using output as weights.

Let U_{ci} represent the upstreamness of industry i in country c. Using the output weight of the industry, Y_{ci}/Y_c, the country's overall upstreamness, U_c, is calculated as follows:

$$U_c = \sum_{i=1}^{n} \left(U_{ci} \cdot \frac{Y_{ci}}{Y_c} \right). \tag{14}$$

To examine changes in upstreamness over time (ΔU_c), such changes can be divided into the effects of changes in the upstreamness of a particular industry (ΔU_{ci}) and of changes in the output weight of the industry ($\Delta(Y_{ci}/Y_c)$). The former is the "within effect," while the latter is the "between effect." These effects are obtained as follows:

$$\Delta U_c = \sum_{i=1}^{n} \left[\Delta U_{ci} \cdot \left(\frac{Y_{ci}}{Y_c} \right) \right] + \sum_{i=1}^{n} \left[U_{ci} \cdot \Delta \left(\frac{Y_{ci}}{Y_c} \right) \right], \tag{15}$$

where the first term on the right-hand side shows the within effect, representing changes in upstreamness while the output weight remains constant, while the second term indicates the between effect, representing changes in the output weight while upstreamness remains constant.

Upstreamness in the global economy (U) and changes therein (ΔU) are similarly defined:

$$U = \sum_{c=1}^{m} \left(U_c \cdot \frac{Y_c}{Y} \right), \tag{16}$$

$$\Delta U = \sum_{c=1}^{m} \left[\Delta U_c \cdot \left(\frac{Y_c}{Y} \right) \right] + \sum_{c=1}^{m} \left[U_c \cdot \Delta \left(\frac{Y_c}{Y} \right) \right]. \tag{17}$$

III. Analysis

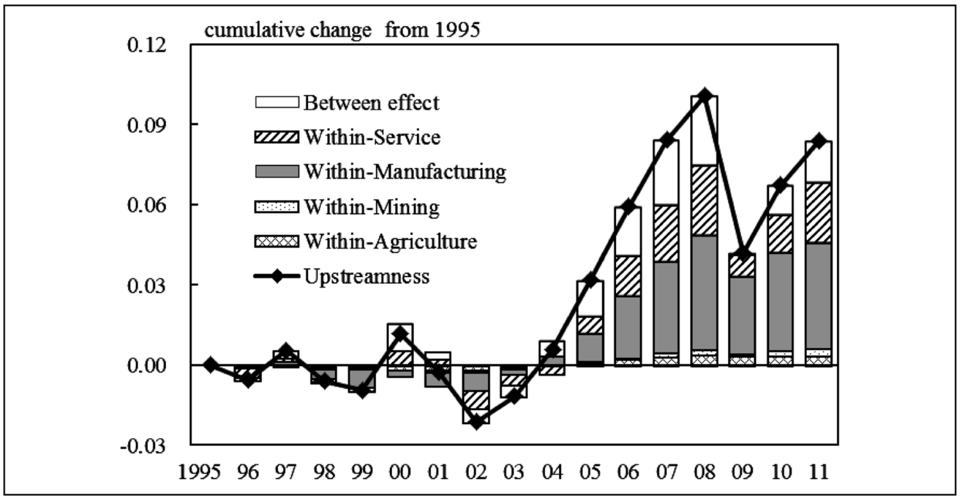
A. Overview of Global Upstreamness

This section presents the calculation of upstreamness and changes in upstreamness using the approach outlined in Section II. Figure 1 depicts changes in upstreamness in the global economy. The figure shows that upstreamness overall increased significantly in the mid-2000s. The upward trend came to a temporary halt in the wake of the global financial crisis.[7] Upstreamness increased again after the crisis, but in 2011 remained below the previous peak.

In the decomposition across sectors, the between effects in different sectors are unified into one to show the within effect in each sector more clearly. These within

7. The decrease in upstreamness during the crisis suggests that the decrease in demand for goods with a relatively long supply chain, such as capital goods (e.g., machine tools) or durable goods (e.g., automobiles), was larger than that for goods with a short supply chain.

Figure 1　Global Upstreamness (1995–2011)



Source: WIOD.

effects show that it is primarily the manufacturing sector that is driving overall development: around two-thirds of the overall within effect can be explained by this sector. In addition, the service sector also contributed, while the contributions of the other two sectors, agriculture and mining, were very small.

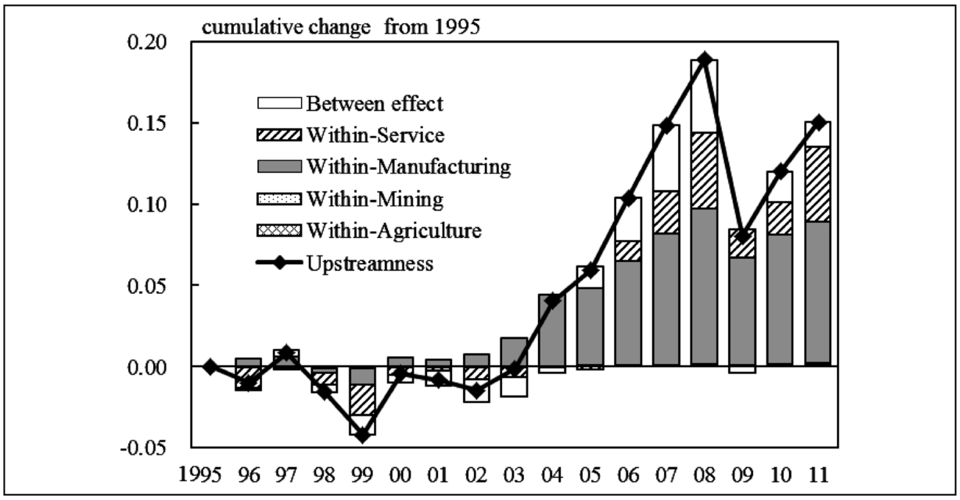
Figure 2 shows the changes in upstreamness in Japan. The overall trend is similar to that for the global economy: upstreamness increased during the mid-2000s, decreased in the wake of the global crisis, and continued to increase again in 2010 and 2011. Again, the main driver was the manufacturing sector, while services also made a contribution. Comparing Figure 1 with Figure 2 indicates that the changes in upstreamness in Japan was much larger than those in the global economy.

Next, Figure 3 examines the contribution of different countries to the changes in the within effect in the manufacturing and service sectors during the period 1995–2011. Figure 3(a) for the manufacturing shows that the main drivers were four East Asian economies: China, Japan, South Korea, and Taiwan. This result implies that supply chain networks in this region strengthened remarkably during the 2000s. As production stages have become more fragmented, products tend to cross national borders more frequently during the fabrication process. These activities have worked to increase upstreamness in all four economies.

In the services sector (Figure 3(b)), the within effect is also substantial in the four Asian economies, reflecting the increase in manufacturing-related service industries.[8] However, advanced European countries (Germany, Spain, Italy, etc.) contributed to the increase as well. This suggests that background to the increase in upstreamness in services differs from manufacturing.

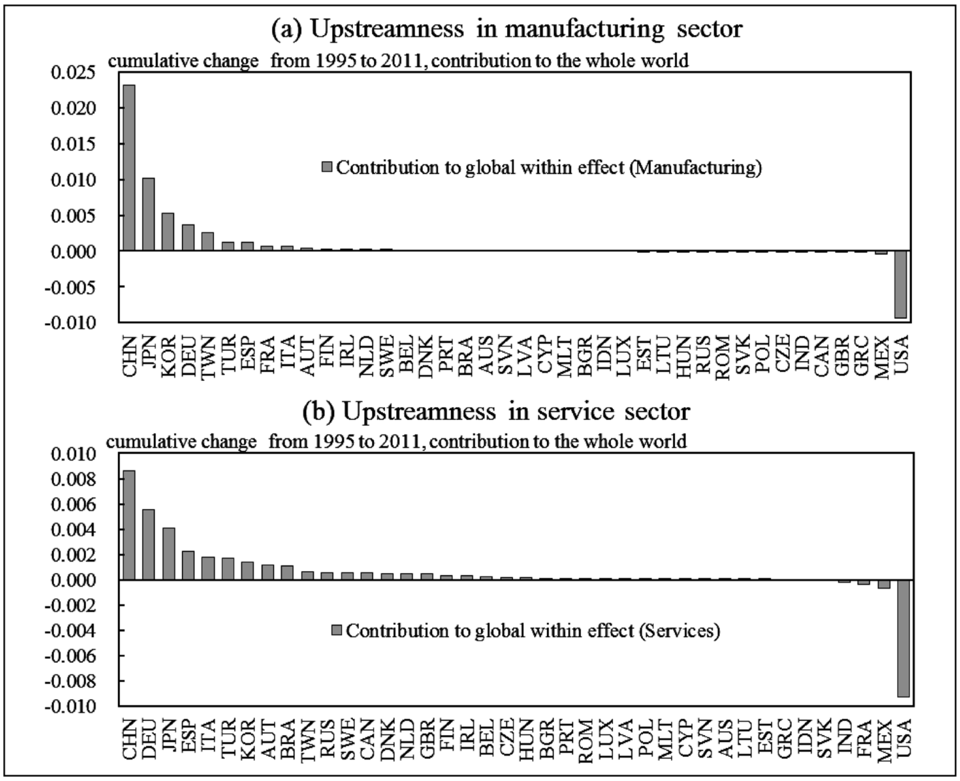
8. For example, increase of the upstreamness in transport industries may be closely related to the increase in upstreamness in manufacturing, since materials or products are transported around during the fabrication process.

Figure 2 Upstreamness in Japan (1995–2011)



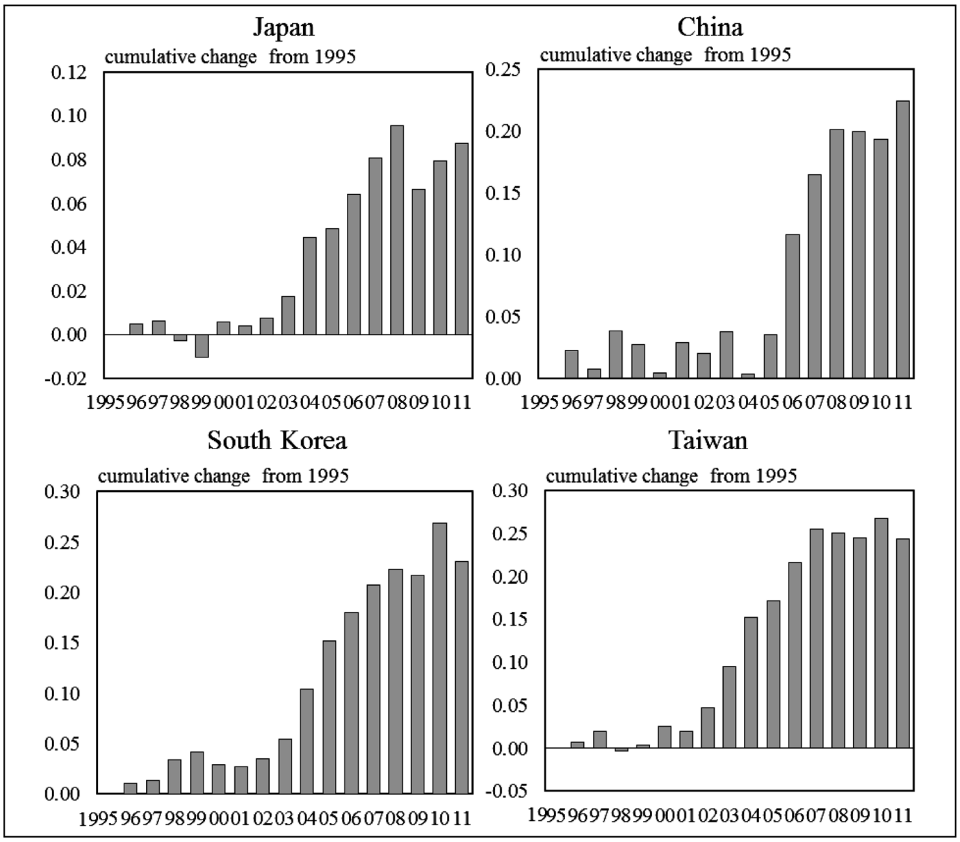
Source: WIOD.

Figure 3 Decomposition of the Within Effect Across Countries: Manufacturing and Services



Source: WIOD.

Figure 4 Within Effect: Manufacturing in East Asian Economies (1995–2011)



Source: WIOD.

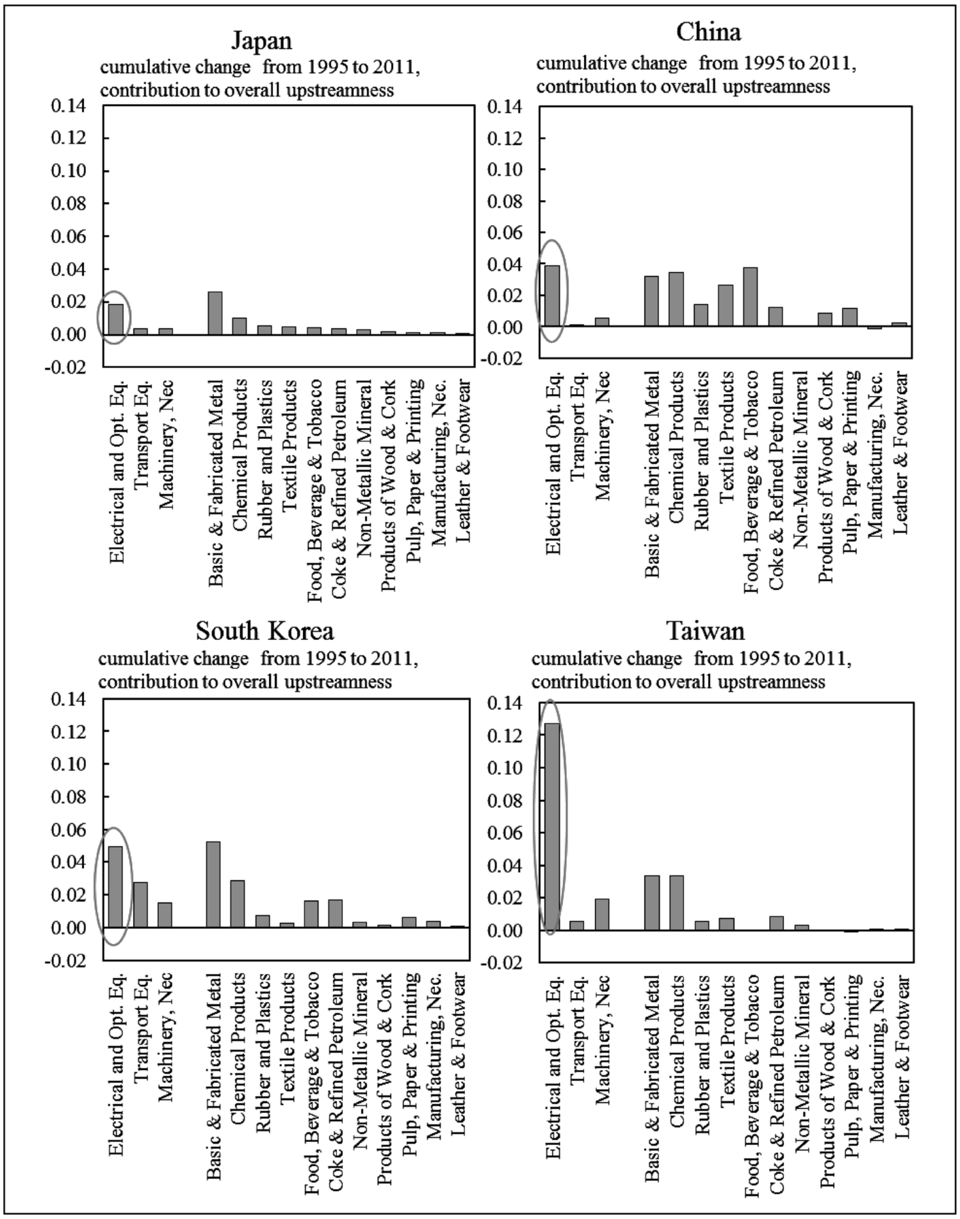
Another notable finding is that upstreamness in the United States decreased in both manufacturing and services. While it is beyond the scope of this study to examine the reasons in detail, one possible explanation is that industries in the United States offshored upstream production stages and increasingly focus on the most downstream stages just before final goods production.

B. Detailed Analysis of Manufacturing

This subsection takes an even more detailed look at developments in the manufacturing sector, while the next subsection focuses on services. Specifically, this subsection more closely examines developments in East Asian economies which, as seen above, showed the greatest increase in upstreamness in the manufacturing sector.

Figure 4 shows the within effect (cumulative since 1995) for the four East Asian economies. The panels indicate that the overall trends are quite similar in the four economies. Upstreamness remained more or less unchanged until the early 2000s, and then started to increase rapidly. In the wake of the global crisis, the increase in upstreamness came to a halt and no clear, consistent trend can be observed across the four economies.

Figure 5 Within Effect: Industries in Manufacturing in East Asian Economies (1995–2011)



Source: WIOD.

Next, Figure 5 decomposes the within effect in manufacturing into the contribution of individual industries. In all four economies, the electrical and optical equipment industry made a substantial contribution to the increase in the manufacturing sector overall.[9]

9. Other industries such as basic metals and fabricated metals as well as chemical product also contributed to the

Given the important role played by the electrical and optical equipment industry, it is instructive to examine this industry in more detail. Using equation (13), it is possible to decompose upstreamness into the contribution of countries, of industries, and of steps.

Figure 6 shows the decomposition of the within effect for the industry in Japan. Figure 6(a) indicates that, as already seen in Section II. D, in the first step, 66% of the initial output in 2011 was used in downstream industries as intermediate goods. In addition, Figure 6(b) shows the contribution of domestic and foreign countries as intermediate users. The right panel in Figure 6(b) shows that in 2011, 43% (or about two-thirds of 66%) of the output in step 1 was used for domestic intermediate use, while the remaining 24% (i.e., about one-third of 66%) was for foreign intermediate use. Similarly, in the second step, 39% of the initial output was used as intermediate goods, but at this stage, foreign use (21%) was larger than domestic use (18%). After the second step, both foreign and domestic use decreased gradually, but the former remained larger than the latter. This means that output of the industry was at first used domestically but soon crossed national borders and was predominantly used abroad.

Comparing the two panels in Figure 6(b) reveals interesting changes in upstreamness. During 1995–2011, almost all of the increase in the upstreamness, from 2.17 to 2.61, was due to foreign use, while the contribution of domestic use remained almost unchanged. This result implies that Japan's electrical and optical equipment industry shifted upstream in the GVC as a result of its output being used more as intermediate goods abroad. Figure 6(c) provides more detail about foreign use. It indicates that China is now a major downstream user, accounting for about half of foreign intermediate use (0.39 out of 0.85 in 2011). Comparing patterns of foreign intermediate use in 1995 and 2011 shows quite a dramatic shift: whereas in 1995, the United States was the most important consumers of Japan's electrical and optical equipment output, by 2011 its role has been dwarfed (from 0.11 to 0.07) by China, and although the United States remained in second place, the contribution of economies such as South Korea (0.03 to 0.05), Germany (0.02 to 0.03) and Taiwan (0.02 to 0.03) slightly increased.

C. Detailed Analysis of Services

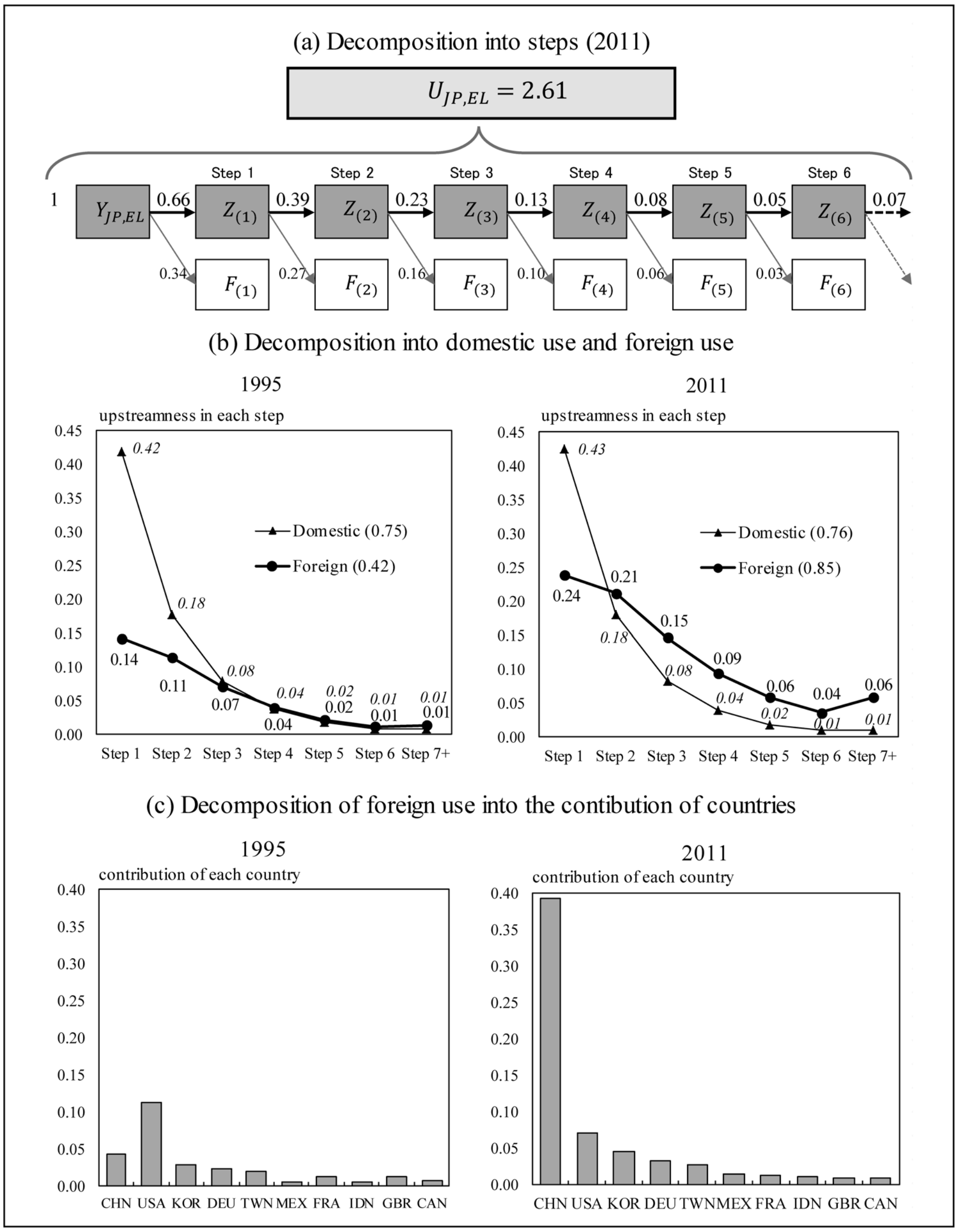
Having examined developments in manufacturing sector in detail, let us now focus on the increase in upstreamness in the service sector. However, in the case of services, a detailed decomposition as in the case of manufacturing is difficult, due to the limitation in the detailed classification of services in the WIOD tables and the great diversity of characteristics of industries within the service sector. Therefore, national I–O tables are used instead of the WIOD tables in this subsection, and some examples are used to show the increase in upstreamness in service sector.

Figure 7 provides a decomposition of the within effect in the global service sector between 1995 and 2011 into the contribution made by the different industries.[10] The industry making the largest contribution is construction, but this may be largely due to

increase in the upstreamness of the four economies, but this is due to the price effect rather than real changes (see Appendix 2 for details of the decomposition of changes into the price and the quantity effect), reflecting the huge increase in commodity prices during the mid-2000s.

10. In this paper, the service sector consists of all industries that are not classified as belonging to agriculture, mining or manufacturing. Therefore, construction and electricity, gas and water supply are categorized as

Figure 6 Upstreamness in the Electrical and Optical Equipment Industry in Japan



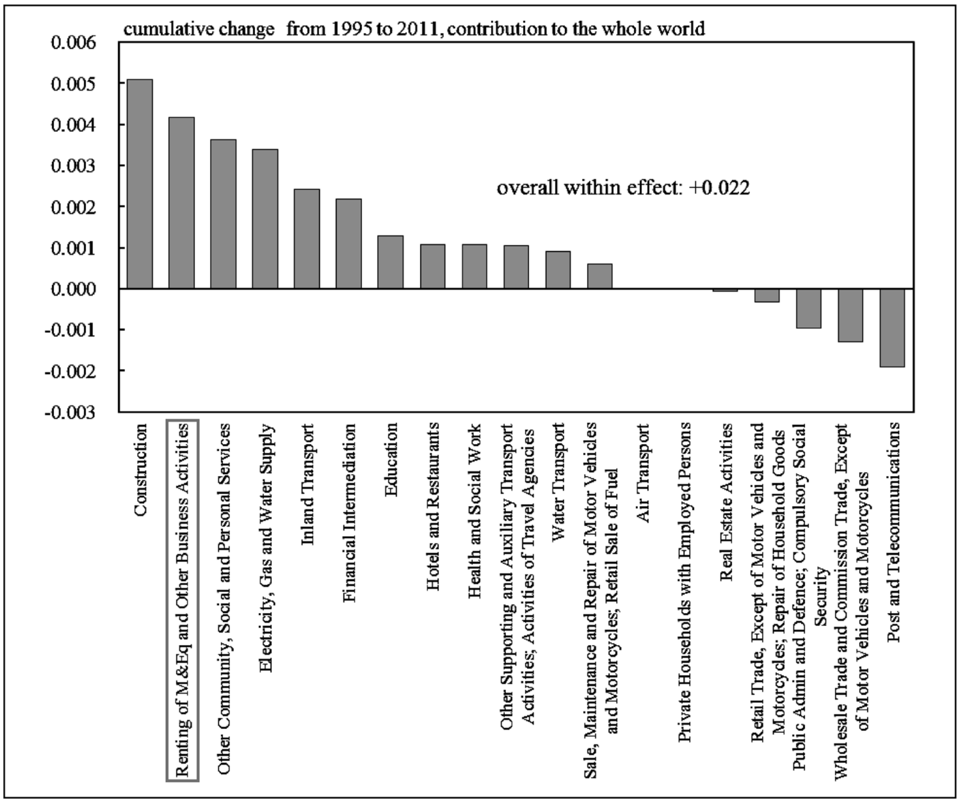
Source: WIOD.

the increase in commodity prices. This subsection therefore, focuses on the industry with the second largest within effect, renting of machinery and equipment and other business activities, which for simplicity will be referred to business services.

Figure 8 presents a decomposition of the cumulative change since 1995 in the within effect in business services into the contribution of individual countries. As can

services here.

Figure 7 Upstreamness of Industries in the Service Sector



Source: WIOD.

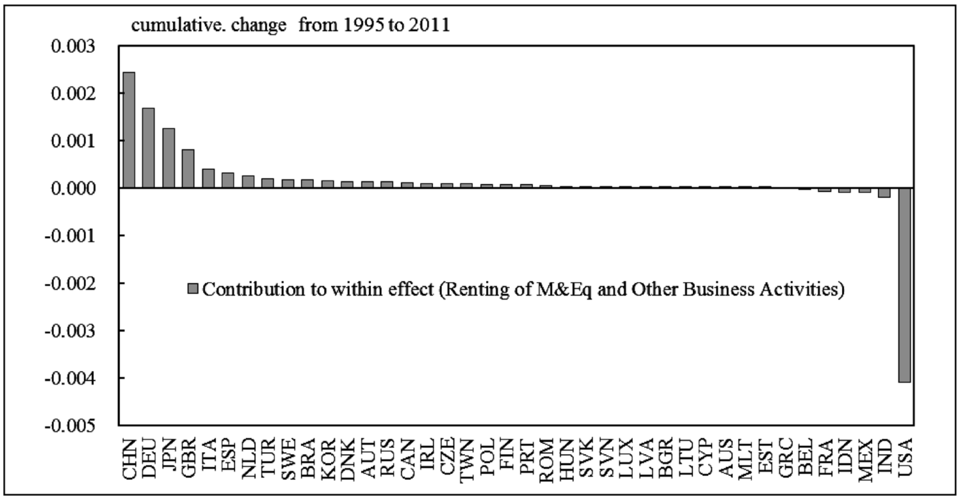
be seen, the largest contribution is made by China, which to some extent reflects the high growth in China's economy. However, most of the other countries contributing to the increase in upstreamness are advanced economies such as Germany, Japan, the United Kingdom and Italy. The reasons for these developments likely differ from those in the manufacturing sector, so that the remainder of this subsection examines why upstreamness increased in these countries.

In the WIOD, industries are classified only into 35 categories, making a detailed analysis difficult. However, there is information about which sub-industries are included in each service industry category.[11] By extracting industries from Japan's I–O tables which correspond to these sub-industries in the WIOD tables (see Table 3), it is therefore possible to calculate upstreamness for the broad industry category of the business services.[12] The following two examples provide detailed illustrations of what entails an increase in upstreamness in business services.

The first example is shown in Figure 9(a), with R&D and other business service (in this case, personnel provision through a staff agency) representing upstream ser-

11. This information is available in the NACE code tables, which is the basis for coding industries in the WIOD.
12. As shown in Section II. A, upstreamness in the WIOD and in Japan's I–O tables is not necessarily the same due to difference in the way foreign intermediate use are recorded. However, since most service sector output is used domestically, the difference does not matter very much for the analysis presented in this subsection.

Figure 8 Upstreamness in the Service Sector (Business Services)



Source: WIOD.

Table 3 Subcategories of Business Services

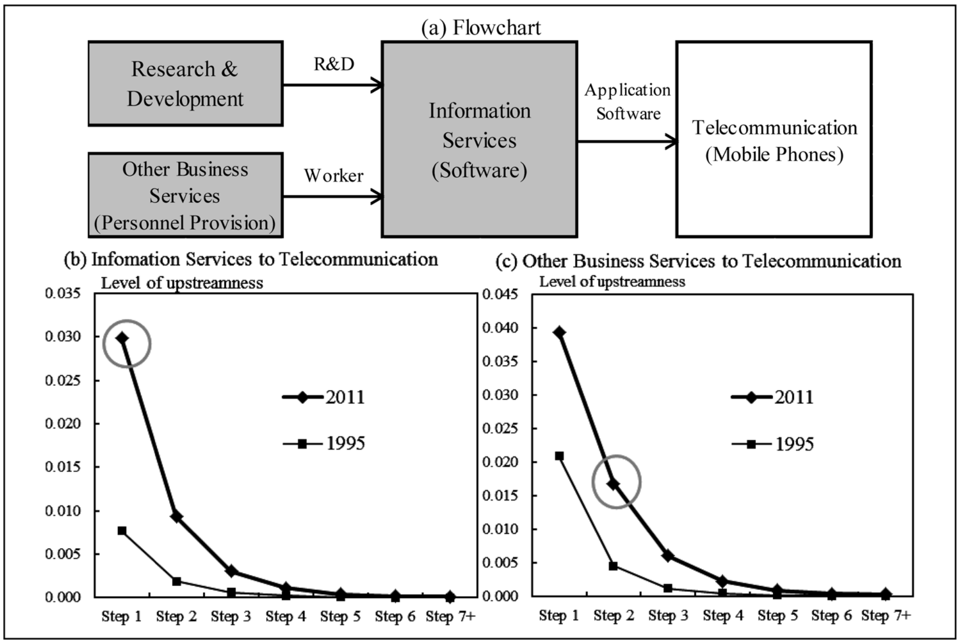
WIOD	NACE and Japan's I−O tables
Renting of machinery and equipment and other business activities	Renting of machinery and equipment
	Computer and related activities
	Maintenance and repair of machinery
	Advertising
	Research and development (R&D)
	Other business services

Sources: WIOD; EU; Ministry of Internal Affairs and Communications.

vice, and telecommunications representing a downstream industry. They are linked through another industry, information services (software supply). Figure 9(b) shows that there was a large increase in the upstreamness in information services vis-à-vis telecommunications in the step 1. This means that the direct linkages between these industries increased. In contrast, Figure 9(c) shows the upstreamness in other business service vis-à-vis telecommunications, where there was also a significant increase in upstreamness in step 2. The increase in step 2 implies that indirect linkages between these two industries increased through another industry between them. Investigating the upstreamness in step 2 in detail reveals that most important intermediary providing this indirect linkage is the information services industry.

These increases in upstreamness can be explained by the following story. Between 1995 and 2011, a drastic change occurred in the telecommunications industry where mobile phones emerged as a major business replacing landline phones. Mobile phone services contributed to the increase in upstreamness of other industries, since mobile phone services use the output of these other industries. For instance, the information

Figure 9 Upstreamness in Services (Japan): R&D and Other Business Services



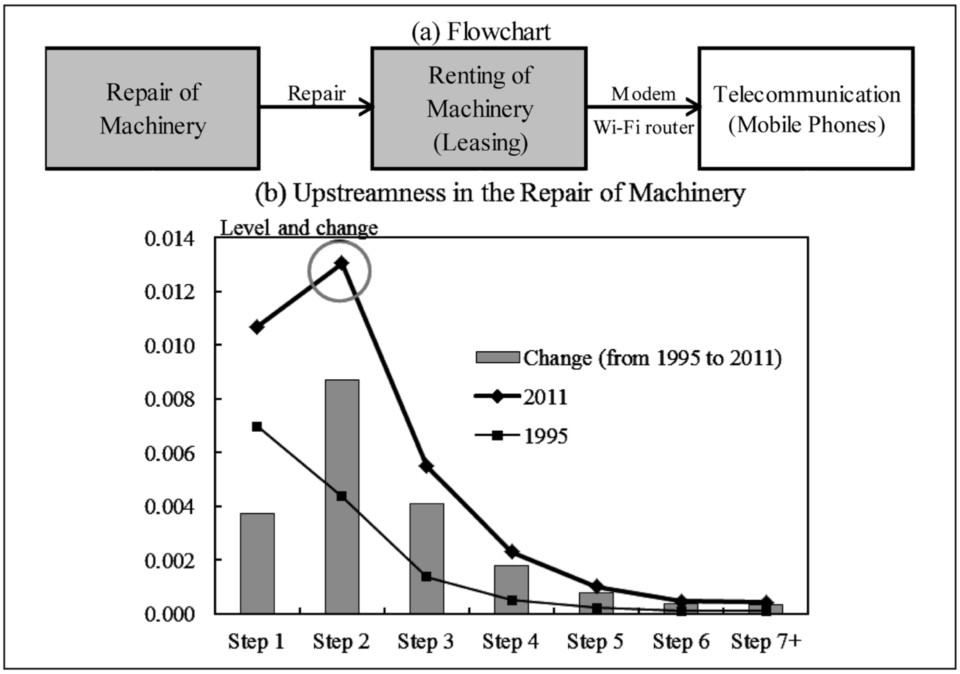
Note: Industries in the shadowed are those of the business services (both Figure 9(a) and 10(a)).
Source: Ministry of Internal Affairs and Communications.

services industry is an upstream provider to the telecommunications industry as a supplier of application software services for mobile phones. Further upstream, information services use the services of other industries such as R&D (creating such application software) and other business services (such as providing dispatched workers). Therefore, these industries are linked to the telecommunications industry indirectly through information services.

In the second example, presented in Figure 10(a), repair of machinery is the upstream industry, telecommunications (mobile phone) is the downstream industry, and renting of machinery (leasing) is the industry linking the two. Figure 10(b) shows that telecommunications (mobile phones) contributed to the increase in the upstreamness of the repair of machinery. Surprisingly, both the highest level and the largest increase in upstreamness are seen in step 2. This implies that the indirect link between these two industries became stronger than the direct link.

This development can be explained as follows. In 1995, the repair of machinery industry and the telecommunications industry were directly linked through the repair of landline phones. However, as shown in the first example, mobile phone and internet access services have replaced landline phone services as the main business in the telecommunications industry. When internet service first appeared, people used landline network to connect the internet. Recently, people have been using modems or Wi-Fi routers to connect to the internet without using landline networks. In Japan, such devices are sometimes provided by internet service providers to household or companies through rental or leasing companies, represented by the arrow on the right in the

Figure 10 Upstreamness in Services (Japan): Repair of Machinery



Source: Ministry of Internal Affairs and Communications.

flowchart of Figure 10(a). As the owners of such devices, such rental and leasing companies may ask providers of repairing and maintenance services to fix these devices, resulting in the link represented by the arrow on the left of the flowchart. These two activities together create a new linkage between repair of machinery and telecommunication, using leasing as an intermediate industry.

These are just small number of examples how the upstreamness of business services has increased.[13] More generally, the way upstreamness in service industries increases can be characterized in the following two patterns. First, upstreamness increases when firms use outsourcing, such as leasing or personnel provision. Second, upstreamness increases when services of an industry are used as intermediate inputs by other service industries.

IV. Conclusion

This paper has shown how to calculate upstreamness using I–O tables, and how it can be used to analyze global value chains. Upstreamness indicates the distance from the final use in terms of the number of production stages. Upstreamness thus represents the sum of intermediate use in the whole GVC process, which allows us to decompose upstreamness into individual transactions in the domestic market as well as foreign

13. This paper focuses on examples in which service industries are located upstream of other service industries. However, there are several cases in which service industries are located upstream of manufacturing. For example, in the case of Japan, R&D comes upstream of transport equipment and pharmaceutical products.

trade. For example, in Japan's electrical and optical equipment industry, more than half of the intermediate use is in foreign countries, especially in China.

This paper also examines change in global upstreamness by decomposing such changes into the within effect (changes in upstreamness while the output weight remains constant) and the between effect (changes in the output weight while the upstreamness remains constant). The main finding is that global upstreamness rose in the mid-2000s, mainly driven by the manufacturing sector, but the service sector also contributed. In manufacturing, upstreamness increased mainly in East Asian economies including Japan, which is consistent with the fact that value chains deepened, especially in the electronics industry. In service sector, business services made a large contribution to the increase in upstreamness. The increase in Japan was caused mainly by (i) outsourcing through the use of leasing and personnel provision, and by (ii) the development of new devices (e.g. mobile phones) which heavily rely on the input from the services of other industries.

The analysis of upstreamness could be extended in a number of directions. First, the approach could be applied to the analysis of spillovers to examine the relationship between the drop in upstreamness and that in trade during past crises. The second issue is the analysis of profitability and value added. Though changes in upstreamness have a positive correlation with profits in Japan, they have a negative correlation with value added ratio (Figure 11).[14] No consensus seems to have been reached as there are different views on this issue. Regarding this point, Ito and Vezina (2015) suggest that upstreamness with respect to the domestic share of value added forms a U-shape, just like the "smile curve," referred to by Baldwin, Ito, and Sato (2014). Third, in addition to the upstreamness of a country or industry, another important measure of location in GVCs is "downstreamness,"[15] which is discussed by Miller and Temurshoev (2015). These two indicators identify the location of a country in the total length of GVCs. The fourth issue is decomposing changes in upstreamness into price and quantity effects. The analysis in Appendix 2 shows that in Japan it was mainly the quantity effect that influenced changes in upstreamness. The final issue is to expand the analysis of the paper more generally into both the level and the change of upstreamness in other countries, to see what has happened in the "global" value chain.

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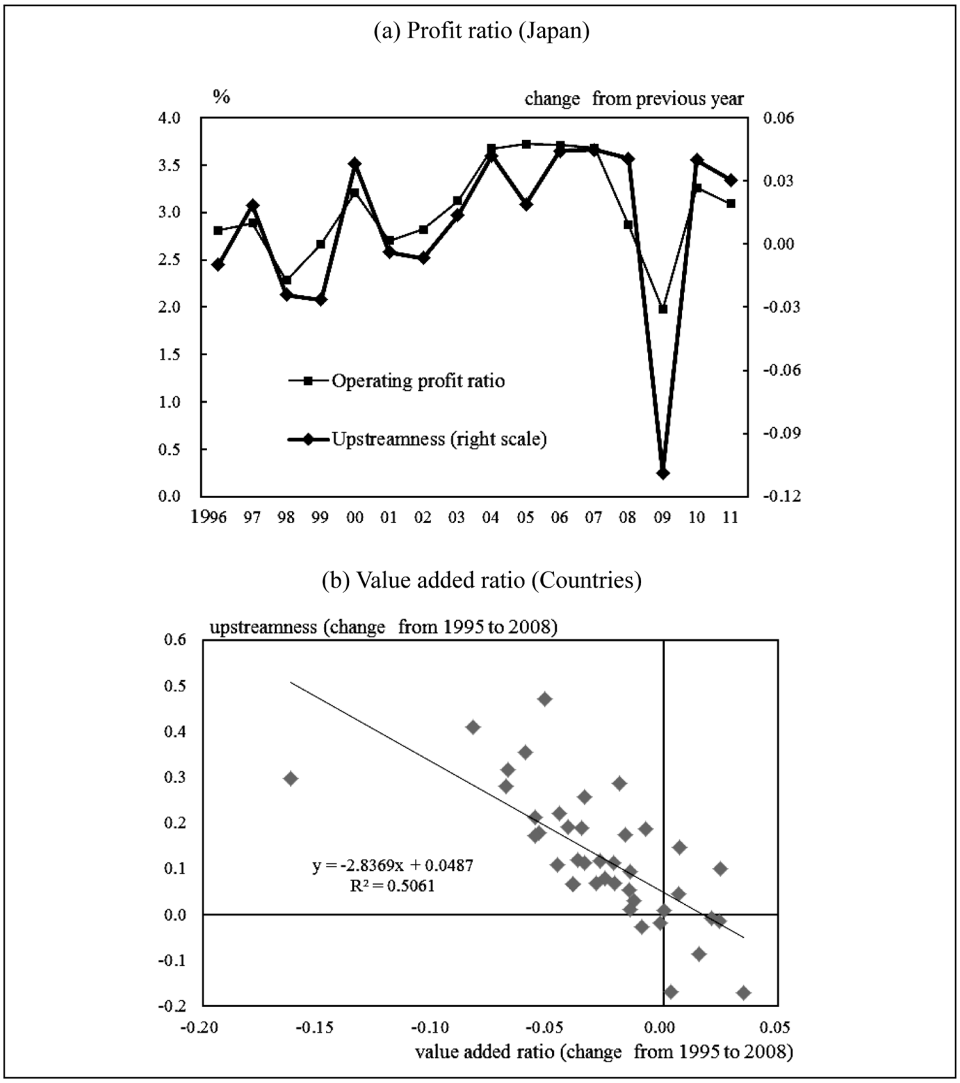
14. This negative relationship may be caused by the fact that some value-added is reduced as a result of offshoring, or it may be due to measurement issues, such as the fact that pre-fabrication (R&D) and post-fabrication (marketing) service cannot be divided in the data due to limitations in the classification in I–O tables.
15. Strictly speaking, downstreamness in previous studies refers to "Input downstreamness."

Figure 11 Upstreamness with Profit and Value Added Ratio



Sources: Ministry of Finance; WIOD.

APPENDIX 1: CONSISTENCY WITH JAPAN'S I–O TABLES

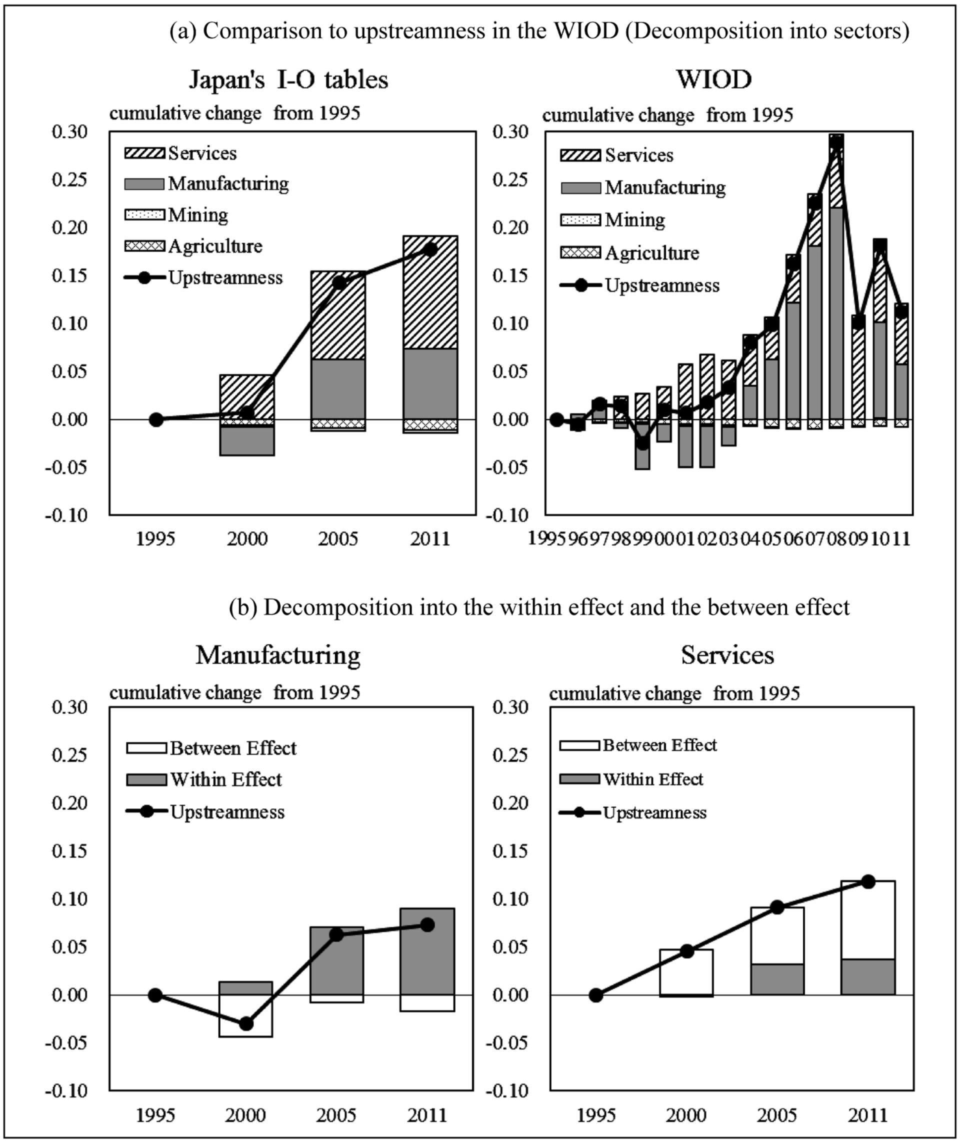
As shown in Section III. A, there are differences between upstreamness calculated using Japan's I–O tables and using the WIOD tables. One of the major differences is whether intermediate use in foreign countries, used in calculating the contribution of these countries in upstreamness, is available or not. In the WIOD tables, both intermediate use and final use in foreign countries are available, which makes it possible to calculate the contribution of foreign countries to upstreamness. On the other hand, in

Japan's I–O tables, all foreign use is recorded in exports as the final use, thus ignored in calculating upstreamness. This means that upstreamness calculated using Japan's I–O tables represents the domestic supply chain.

Comparing upstreamness using Japan's I–O tables with the WIOD, the overall trend is similar (Figure A-1(a)). In both cases, upstreamness remained almost unchanged until 2000 but increased significantly in the mid-2000s, led by manufacturing and service. The difference is that the contribution of the manufacturing sector when using Japan's I–O tables is smaller than that when using the WIOD. While in services domestic use makes by far the largest contribution to upstreamness, in manufacturing foreign use also makes a considerable contribution. Since Japan's I–O tables do not capture foreign intermediate use, upstreamness in manufacturing shrinks by that amount.

Decomposing the change in upstreamness in Japan's I–O table into the within effect and the between effect (Figure A-1(b)), it is mainly the within effect that is responsible for the increase in upstreamness in manufacturing, while in services, both the within effect and the between effect made a contribution.

Figure A-1 Upstreamness Using Japan's Input–Output Tables



Source: Ministry of Internal Affairs and Communications; WIOD.

APPENDIX 2: DECOMPOSITION INTO THE PRICE AND THE QUANTITY EFFECTS

A. Why Do Price and Quantity Effects Matter?

As mentioned in the conclusion, it is important to analyze whether changes upstreamness are due to price effect or quantity effect. If an increase in upstreamness is caused by price effect, this may be harmful for the country as the price effect in each industry may reflect the increase in commodity price, discussed in Section III. Another possibility is that the price effect in the whole economy may reflect the Baumol effect: output price increases led by wage increase, without an improvement in productivity. This is most likely to arise as economies mature, especially when economic activity shifts from manufacturing to services.[16] While overall productivity growth decelerates as many service industries tend to be less productive than manufacturing, this shift increases the wage cost of the economy. Such wage increases present a challenge for firms' competitiveness.

On the other hand, the quantity effect is caused by several factors. First, as highlighted by Markusen (2013), off-shoring, or vertical specialization increases the extensive margin:[17] a country can enjoy consuming variety of goods by focusing on a particular stage of production. In addition, a shift from fabrication to R&D and marketing (i.e. servicification) also give a rise to the quantity effect. Finally, technological innovation also leads to a quantity effect, since technological progress makes it possible to produce more goods in upstream stages (e.g. high-end components) in GVCs, without affecting their output price. Figure A-2(b) shows that the increase of upstreamness in Japan was mainly due to the quantity effect. The next issue to examine is which factors are dominant in this effect.

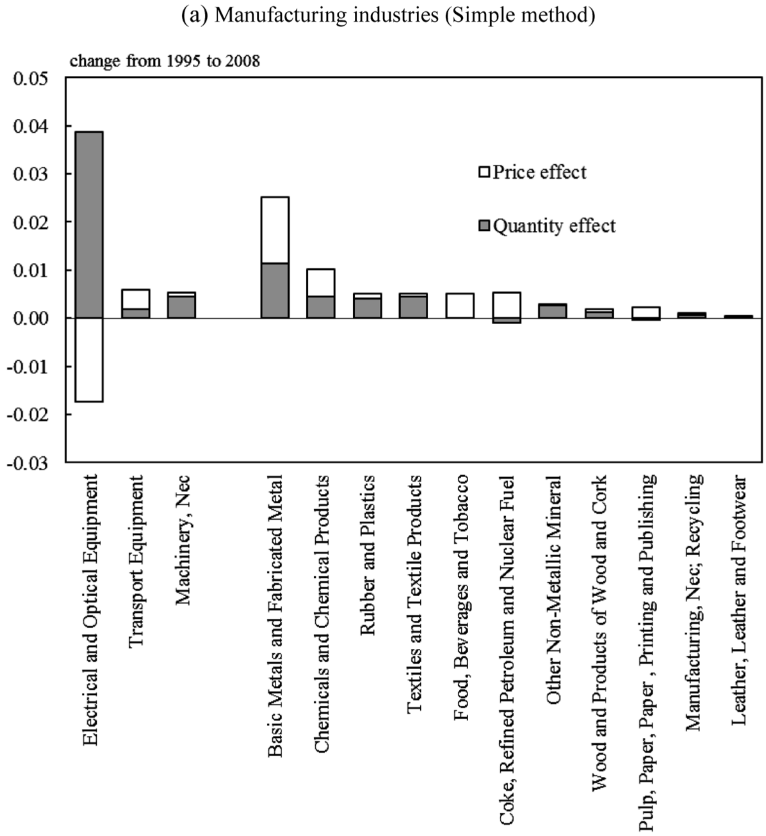
B. Simple Method: Use of Constant Value I–O Tables for the Quantity Effect

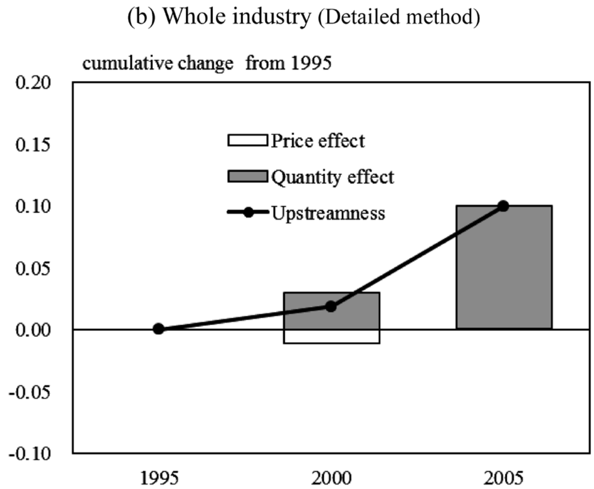
A simple method of decomposing changes in upstreamness into the price and the quantity effect is to calculate the quantity effect using constant price I–O tables. In the constant price tables, all of the figures in the tables are standardized in base year prices. In Japan's I–O tables, both current price tables and constant price tables are available as chain-linked tables.[18] Price effect is calculated by subtracting the quantity effect from the total effect.[19]

Figure A-2(a) presents this decomposition for manufacturing industries in Japan.

16. In this case, a lot of these effects may be categorized as between effect, not as within effect.
17. Helpman, Melitz, and Rubinstein (2008) show that trade volume can be decomposed into an extensive margin (the number of goods traded) and an intensive margin (the volume of trade per good). In the empirical analysis, Bernard *et al.* (2007) show that the extensive margin plays a greater role in changes in the trade of the United States than the intensive margin.
18. In the 1995–2000–2005 chain I–O tables, it is possible to obtain the constant prices tables (in 2005 prices) for both 1995 and 2000.
19. In the WIOD, no constant price I–O tables are available. The only tables available are those on a previous year's price (PYP) basis. These tables have some price information, but the base year is not fixed (i.e., the base year of the PYP–1998 table is 1997, and that of the PYP–1999 table is 1998.) Here, a price table for each year is calculated by dividing values in the current price table by the values in the PYP table of the same year. By multiplying these price tables iteratively, price indexes of industries across years are obtained, with the base year 1995. Finally, by dividing values in the current prices tables by this price index, I–O tables for each year in constant prices are obtained.

Figure A-2 Price Effect and Quantity Effect (Decomposition of the Within Effect) in Japan





Sources: Ministry of Internal Affairs and Communications; WIOD.

As explained in Section III. B, the price effect accounts for about half of the increase in the basic metal industry, reflecting the increase in commodity prices. In contrast, the price effect was negative in the electrical and optical equipment industry, so that the quantity effect in this industry is larger than the total effect.

C. Limitation of the Simple Method

In the simple method, the price effect is calculated by simply subtracting the quantity effect from the total effect. However, differences in price indexes across industries in the I–O tables are not fully captured in this method.

In this context, Fally's (2012) approach of calculating upstreamness is helpful. Applying his approach, it is possible to decompose the within effect in each industry into the price effect and the quantity effect with greater precision.

D. Detailed Method: Decomposition of the Within Effect into the Price and the Quantity Effects

Fally (2012) defines N_i as the average number of production stages which use output i, and $\mu_{ij,t}$ as the value of input j which uses one dollar's worth of output of good i (A.1). However, in this study, the approach employed by Antràs *et al.* (2012) to calculate upstreamness is used and applied to Fally's method for decomposition. Using the relationship between U_i (upstreamness) and N_i, the change in upstreamness ΔU_i is decomposed into the price and the quantity effects.

$$\mu_{ij,t} = \frac{P_{j,t} Q_{ij,t}}{P_{i,t} Q_{i,t}}, \tag{A.1}$$

where $P_{j,t}$ is the price of input j and $Q_{i,t}$ is the quantity of produced of good i. In addition, using (A.2), $\mu_{ij,t}$ is replaced by $\varphi_{ij,t}$, the fraction of demand corresponding to intermediate input demand from j:

$$\varphi_{ij,t} = \frac{Y_{j,t}}{Y_{i,t} + M_{i,t} - X_{i,t}} \mu_{ji,t} = \left(\frac{P_{j,t}}{P_{i,t}} \cdot \frac{y_{j,t}}{y_{i,t} + m_{i,t} - x_{i,t}} \right) \mu_{ji,t}. \tag{A.2}$$

In this equation, $Y_{i,t}$, $M_{i,t}$ and $X_{i,t}$ are gross output, imports and exports, respectively, and $y_{i,t}$, $m_{i,t}$ and $x_{i,t}$ are their real values. The change in $\varphi_{ij,t}$ is shown in (A.3), while (A.4) shows the decomposition of the change in $\varphi_{ij,t}$:

$$\Delta\varphi_{ij,t} = \varphi_{ij,t} - \varphi_{ij,t-1}, \tag{A.3}$$

$$\Delta\varphi_{ij,t} = \Delta\varphi^{P}_{ij,t} + \Delta\varphi^{Q}_{ij,t}, \tag{A.4}$$

where $\Delta\varphi^{P}_{ij,t}$ is the price effect and $\Delta\varphi^{Q}_{ij,t}$ is the quantity effect.

Using equation (A.2), these effects can be written as follows:

$$\begin{aligned}
\Delta\varphi_{ij,t} &= \Delta\left(\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\cdot\mu_{ji,t}\right)\\
&= \left[\Delta\left(\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\right)\cdot\mu_{ji,t}\right]+\left[\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\cdot\Delta\mu_{ji,t}\right]\\
&= \left[\Delta\left(\frac{P_{j,t}}{P_{i,t}}\cdot\frac{y_{j,t}}{y_{i,t}+m_{i,t}-x_{i,t}}\right)\cdot\mu_{ji,t}\right]+\left[\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\cdot\Delta\left(\frac{P_{j,t}Q_{ij,t}}{P_{i,t}Q_{i,t}}\right)\right]\\
&= \left\{\left[\Delta\left(\frac{P_{j,t}}{P_{i,t}}\right)\cdot\frac{y_{j,t}}{y_{i,t}+m_{i,t}-x_{i,t}}+\frac{P_{j,t}}{P_{i,t}}\cdot\Delta\left(\frac{y_{j,t}}{y_{i,t}+m_{i,t}-x_{i,t}}\right)\right]\cdot\mu_{ji,t}\right\}\\
&\quad+\left\{\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\cdot\left[\Delta\left(\frac{P_{i,t}}{P_{j,t}}\right)\cdot\frac{Q_{ji,t}}{Q_{j,t}}+\frac{P_{i,t}}{P_{j,t}}\cdot\Delta\left(\frac{Q_{ji,t}}{Q_{j,t}}\right)\right]\right\}. \qquad (A.5)
\end{aligned}$$

Accordingly, the price effect and the quantity effect are defined as follows:

$$\Delta\varphi^{P}_{ij,t} = \left[\Delta\left(\frac{P_{j,t}}{P_{i,t}}\right)\cdot\frac{y_{j,t}}{y_{i,t}+m_{i,t}-x_{i,t}}\right]\cdot\mu_{ji,t}+\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\cdot\left[\Delta\left(\frac{P_{i,t}}{P_{j,t}}\right)\cdot\frac{Q_{ji,t}}{Q_{j,t}}\right], \qquad (A.6)$$

$$\Delta\varphi^{Q}_{ij,t} = \left[\frac{P_{j,t}}{P_{i,t}}\cdot\Delta\left(\frac{y_{j,t}}{y_{i,t}+m_{i,t}-x_{i,t}}\right)\right]\cdot\mu_{ji,t}+\frac{Y_{j,t}}{Y_{i,t}+M_{i,t}-X_{i,t}}\cdot\left[\frac{P_{i,t}}{P_{j,t}}\cdot\Delta\left(\frac{Q_{ji,t}}{Q_{j,t}}\right)\right]. \qquad (A.7)$$

Next, using $\varphi_{ij,t}$, define upstreamness and its changes as follows:

$$U_{i,t} = 1+\sum_j \varphi_{ij,t}U_{j,t}, \qquad (A.8)$$

$$\Delta U_{i,t} = \sum_j\left(\Delta\varphi_{ij,t}\cdot U_{j,t}\right)+\sum_j\left(\varphi_{ij,t}\cdot\Delta U_{j,t}\right). \qquad (A.9)$$

Using this price-quantity decomposition, $\Delta U_{i,t}$ can be decomposed as follows:

$$\Delta U_{i,t} = \sum_j \mathrm{a}_{ik,t}\left(\sum_j \Delta\varphi_{ij,t}\cdot U_{j,t}\right). \qquad (A.10)$$

Substituting equation (A.4) into (A.10) yields

$$\Delta U_{i,t} = \sum_j \mathrm{a}_{ik,t}\left[\sum_j\left(\Delta\varphi^{P}_{ij,t}+\Delta\varphi^{Q}_{ij,t}\right)U_{j,t}\right], \qquad (A.11)$$

where $\mathrm{a}_{ik,t}$ is the coefficient of the matrix $(I-M_{t,t-1})^{-1}$. Here, I is the identity matrix and $M_{t,t-1}$ is the matrix with coefficients $\varphi_{ij,t}$.

By substituting (A.6) and (A.7) into (A.11), the within effect in industry i is decomposed into the price effect and the quantity effect.

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