[Preliminary version]

Structural Changes in the Global Value Chain: Analysis of the length and position of the countries in GVCs from upstreamness and downstreamness

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Abstract

This paper uses the Global Input-Output Table to analyse changes in GVCs over the past 60 years, with a main focus on Japan. The main characteristics of the study is that we combine 'upstreamness' and 'downstreamness', which express GVCs quantitatively, to calculate the 'length of GVC' and 'position on GVC', for our analysis. Chronologically, the global division of labor in the production process was limited until the 1970s, and Japan shifted to upstream processes in electrical and optical equipment (semiconductors), transport equipment (automobiles) and basic metals (iron and steel) from the 1980s. In the 1990s, the groundwork for GVC expansion such as the conclusion of FTAs was formed, and in the 2000s, GVCs expanded significantly, particularly in the IT goods industry in East Asia. In the 2010s, however, after the Lehman shock, GVCs entered a phase of stagnation, in step with slow trade. However, even during this period, the position of each country changed, and South Korea and Taiwan succeeded in improving their industrial competitiveness by shifting to upstream processes in the IT goods industry. In the 2020s, the intensifying friction between the US and China and the increasing the production of EVs become new topics of discussion, part of which are observed in GVCs.

Keyword: Global Value Chain, Slow Trade, Global Input-Output Table, Upstreamness, Downstreamness

1. Introduction

It is widely said that the globalization of supply chains can have begun in earnest in the 1990s, with the end of the Cold War between the US and the Soviet Union. Subsequently, globalization progressed rapidly against a background of free trade agreements (FTAs), economic integration of the EU, ASEAN and other countries, China's accession to the WTO, the increasing use of cheap labor, and advances in information and communications technology (IT). As a result, as shown in

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Figure 1, the volume of world trade grew faster than world GDP in the 2000s.

However, since the collapse of Lehman Brothers in 2008, the growth of trade volume has slowed down and there has been a noticeable divergence from real GDP. Such phenomenon in trade in the 2010s is known as 'slow trade'.

More recently, delay of supply associated with the COVID-19, US-China trade friction in the IT goods, and the Russian invasion of Ukraine, have forced globally active companies to restructure and strengthen their supply chains. Alfaro and Chor (2023) argue that the key word in supply chains has shifted from 'efficiency' in the 1990s and 2000s to 'disruption risk' in the 2010s and 2020s, with companies undergoing 'Great Reallocation".

When analysing these highly globalized supply chains, the concept of the Global Value Chain (GVC) is very useful, as it describes the flow of 'value added' that is sequentially added to the production of goods and services as they progress from upstream to downstream. GVCs represent the flow of 'value added' in the production of goods and services as they are progressed from upstream to downstream.

Attention to GVCs has increased in recent years. One of the reasons for this is that each industry's position in GVCs is deeply related to the competitiveness of the industry and the country. As Baldwin, Ito and Sato (2014) argue, value added in GVCs is known to follow a 'smile curve', or U-shape, from upstream to downstream. Taking the iPhone as an example, value added is concentrated in the upstream (R&D) and downstream (marketing) of the process, while the value added in the midstream (production process) is considered to be small, with the majority of sales benefiting Apple, which is responsible for development and marketing. Fally and Hillberry (2015) also argue that a shift upstream or downstream in GVC can increase the share of value added in output.

However, to conduct these analyses, it is necessary to quantitatively measure which process in the supply chain each industry or country is responsible for, i.e. its 'position on the GVC'. It is also necessary to measure the scale, or 'length of GVCs' for each industry or country, in order to assess the impact of changes in GVCs on the industry and the country. In this regard, this paper calculates the 'length of GVC' and 'position on GVC' by synthesising information on 'upstreamness' and 'downstreamness', indicators that quantitatively express GVC. Using these indicators, we analyse the structural changes in GVCs and their background and implications, with a main focus on Japan, covering a period of approximately 60 years from 1965 to 2022. To the author's underposition, this is the first study to analyse GVC over such a long period using these indicators.

The structure of this paper is as follows. Section 2 describes the global input-output table used to analyze GVC and the upstream and downstreamnesss calculated from it. Section 3 describes a main feature of this paper, the calculation of the 'length' and 'position' indicators by

synthesising both indicators. Section 4 uses these indicators to analyze the structural changes in the GVC in Japan from the 1960s to 2020s. Section 5 provides a summary.

2. Global input-output table, upstreamness and downstreamness

2.1 Structure of input-output tables

In the analysis of GVC, input-output relations between industries are often used. In particular, the recent expansion in the publication of the global input-output table, which combines the input-output tables of different countries, has made it possible to grasp the links between countries and their respective goods. By using the global input-output table, it is now possible to understand the upstream-downstream relationship between industries, for example, "how much of good Y in country B was produced by using the good of country A."

2.1.1 Several global input-output tables

The global input-output table shows the input-output relationship between countries and industries. The specific structure is shown in Figure 2. From the input side, it shows how much of a good in one country is used to produce a good in another industry in another country. From the output side, it shows how much of the goods of other industries in other countries are used in the production of a certain good in a certain country.

Such global input-output tables are published by various organisations, including ADB, IDE-JETRO, OECD and WIOD. The characteristics of each tables (period covered, number of countries, number of industries and published series) are presented in Figure 3. The weight of the countries included in these global input-output tables in global GDP has also reached 85% in the WIOD and 93% in the ADB, making it possible to cover most of the global exchange of goods and services.

Lots of global input-output tables began to be available from the 1990s onwards, which was the period of the establishment of the EU in 1993, the WTO in 1995 and other developments that have continued to the present day for the global trade frameworks. Against these backgrounds, as Timmer *et al.* (2014) state, there has been an increase in the segmentation of production processes and a significant expansion of trade in intermediate goods across borders. According to calculations by Borin and Mancini (2019), trade through GVCs reached about half of global trade in the mid-2010s.

However, while output and exports in terms of gross statistics would increase in each country, part of the increase would be double or triple-counted in several countries. Koopman, Wang and Wei (2014) argue that there exists a gap between gross export statistics and value-added exports, and argues that there is a need to link information from both index. Thus, the transformation of the interest from 'gross export' to 'value added export' is also considered to increase a need for the

development of global input-output tables which has information on value added.

This paper analyses GVCs over the long term, making use of these various global input-output tables. Details of the analysis are given in section 4. In short, the analysis is conducted using the WIOD's long-term time series tables for the 1960s-90s, the WIOD's World Input Output Tables (WIOT) for the 2000s, the OECD's Inter-Country Input Output Tables (ICIO) for the 2010s, and the ADB's Multi Regional Input Output Tables (MRIO) for 2020s.

2.1.2 Studies using global input-output tabels

As mentioned in Figure 3 and Section 2.1.1, the range of countries covered by the global input-output tables and the period covered by them have been expanding over the years. Under these circumstances, the number of studies that have analysed GVCs using these tables has also continued to grow.

In a study focusing on trade in intermediate goods in GVCs, Johnson and Noguera (2012) analysed global and national input-output tables together and showed that the gap between value-added trade and gross trade has widened in recent years. Johnson (2014) also used the WIOD's global input-output table and analysed that trade of intermediated goods increased much more than that of final goods. Borin and Mancini (2019) used the global input-output table to show that the weight of GVC trade (i.e. trade of intermediate goods) in the whole global trade increased significantly in the 1990s and 2000s.

Some analysed business activity of companies. Antras and Yeaple (2014) combines input-output tables and balance of payments statistics to analyse the global economic activity of US firms. Timmer *et al.* (2014) and Los, Timmer, and de Vries (2015) also use the WIOD's global input-output table to analyse business activities through the GVC.

Currently, with some events which may potentially affect GVCs, some studies have analysed these themes using input-output tables; Antras (2020) cites political factors such as US-China friction and the UK's exit from the EU as a background for the headwind of the globalisation trend. Inomata (2023), in analysing the impact of US-China friction, calculated the Pass-through Frequency (PTF) index as a weighted average of the number of times an industry from a high-risk country appears in the supply chain path, to analyse the concentration risk.

2.2 Upstremness and dowanstreamness

2.2.1 Attempts to quantify linkages between industries

In the simple two-country, two-good GVC example presented in Section 2.1, Good X in Country A locates upstream and Good Y in Country B locates downstream. In reality, however, the industries of each country are very intricately linked to each other, and some of these relationships are not only direct, but also indirect, through different goods. Therefore, it is difficult to

quantitatively measure the position of an industry or country on the GVC by simply looking at the figures in the input-output table. In other words, a kind of indexation is necessary.

As a pioneer of such quantification of inter-industry relationships, Dietzenbacher, Luna, and Bosma (2005) measured the distance between industries, and their proposed average propagation length (APL), was used in many subsequent studies, including Oostarhaven and Bouwmeester (2013) and Escaith and Inomata (2016).

Koopman, Wang and Wei (2014) calculated 'forward and backward GVC participation rates' after decomposing gross exports into home country value added and the double-counted portion with other countries.

Wang *et al.* (2017) used the global input-output table to calculate the length of forward and backward production processes in each industry and calculated the industry's position in GVC by dividing forward length by backward length.

2.2.2 Upstreamness and downstreamness: conceptual definition

As useful tools for considering the standpoint on GVCs, this paper uses 'upstreamness' and 'downstreamness'. Upstreamness is a concept proposed by Antràs and Chor (2013) and others, and downstreamness by Miller and Temurshoev (2017). Both of these use an input-output table as a quantitative indicator which have information of the position of an industry or country in GVC. A comprehensive compilation of these indicators is provided in Antras and Chor (2022).

First, to explain the 'concept' of both indicators, upstreamness is defined as 'the average number of processes that the output of an industry goes through before reaching the final goods via GVCs'. In other words, it is 'the number of production processes upstream from the final good, measured upstream to the industry in question', and in this sense is referred to as 'upstreamness'.[2]

Downstreamness, on the other hand, is defined as 'the average number of processes that an industry has gone through from its output back up the GVC to the raw materials'. In other words, it is 'the number of production processes from raw materials measured downstream to the industry concerned'. Figure 4 gives a conceptual pictures of these two indices.

2.2.3 Upstreamness and downstreamness: quantitative definition

Next, we provide a quantitative explanation of upstreamness and downstreamness. The following description is the systematised definition of both indicators. See Appendix 2 and Suganuma (2016) for the concept of upstreamness proposed by Antras and Chor (2013) and the detailed formula development until it is finally explained in the following equation.

In explaining the formula, we use Figure 2 (see above), the standard form of global input-

[2] In the early 2010s, various definitions were proposed for upstreamness, including Antras and Chor (2013), Antràs *et al.* (2012) and Fally (2012). However, Antràs *et al*. (2012) proves that all of these indicators ultimately take the same value.

output table which consists of m countries and n industries. Here, Y_{ci} represents the output of industry i in country c, F_{ci} represents the amount of the output of industry i in country c that leaves the GVC and is consumed as a final good. $a_{ci,ej}$ represents the amount of the output of industry i in country c that is used as an intermediate good in the next process of the GVC for production in industry j in country e. V_{cj} is the value added by the industry j in country c to its own production, not due to intermediate goods from other industries.

Suppose U_{nm} be the upstreamness and D_{nm} the downstreamness of country m and industry n. The aggregated vetor $\vec{U}$ and $\vec{D}$ are written as $\vec{U} = (U_{11}, \cdots, U_{1n}, U_{21}, \cdots U_{2n}, \cdots, U_{m1} \cdots U_{mn})^T$, and $\vec{D} = (D_{11}, \cdots, D_{1n}, D_{21}, \cdots D_{2n}, \cdots, D_{m1} \cdots D_{mnm})$, respectively, which is calculated as follows. Here, $[I-B]^{-1}$ and $[I-G]^{-1}$ in equations (1) and (2) are called the Ghosh and Leonchev inverse matrices respectively, and their vertical and horizontal sizes are both m × n.

$$\vec{U} = [I-B]^{-1} \cdot \vec{1} \ where \ B = \begin{bmatrix} \frac{a_{11,11}}{Y_1} & \cdots & \frac{a_{11,mn}}{Y_1} \\ \vdots & \ddots & \vdots \\ \frac{a_{mn,11}}{Y_n} & \cdots & \frac{a_{mn,mn}}{Y_n} \end{bmatrix} \quad (1)$$

$$\vec{D} = [I-G]^{-1} \cdot \vec{1} \ where \ G = \begin{bmatrix} \frac{a_{11,11}}{Y_1} & \cdots & \frac{a_{11,mn}}{Y_n} \\ \vdots & \ddots & \vdots \\ \frac{a_{mn,11}}{Y_1} & \cdots & \frac{a_{mn,mn}}{Y_n} \end{bmatrix} \quad (2)$$

To calculate the upstreamness U_c and downstreamness D_c for an entire country, by taking weight average of upstreamness and downstreamnesss of each industry, using output share of each industry in the country's output Y_c as weight (equation (3)). Furthermore, global upstreamness U_w and global downstreamness D_w are also calculated, by taking weighted average of the upstreamness and downstreamnesss of each country, using output share of each country in the global output Y, as weight (equation (4)).

$$U_c = \sum_{i=1}^{n} \left(U_{ci} \cdot \frac{Y_{ci}}{Y_c} \right), \qquad D_c = \sum_{i=1}^{n} \left(D_{ci} \cdot \frac{Y_{ci}}{Y_c} \right) \quad (3)$$

$$U_w = \sum_{c=1}^{m} \left(U_c \cdot \frac{Y_c}{Y} \right), \qquad D_w = \sum_{c=1}^{m} \left(D_c \cdot \frac{Y_c}{Y} \right) \quad (4)$$

Note that for the world as a whole, the upstream and downstreamnesss coincide ($U_w = D_w$). This is because the upstreamness for one country (industry) always corresponds to the downstreamness for another country (industry).

2.2.3 Studies focused on upstreamness and downstreamness

This section provides an example of an analysis using upstreamness and downstreamnesss, which

is the subject of this analysis. In the following, studies are summarized by gropes by the input-output table they use.

First, using the OECD database, Antràs et al. (2012), is an early study. The paper calculates the upstreamness for each EU country and shows that the rank correlations by industry are high, i.e. the degree of upstreamness of industries is similar in each country.

Second, studies using IDE-JETRO tables include Fally and Hillberry (2015), Ito and Vezina (2016), Escaith and Inomata (2016). Fally and Hillberry (2015) analysed the relationship between upstreamness and value-added ratios and argued that shifting to either upstream or ownstream would improve economic welfare. to and Vezina (2016) similarly focused on the relationship between upstreamness and value added and showed that the overseas value added ratio was low in China. Escaith and Inomata (2016) analysed the change of the position of Asian countries and the US at two points in time, 1985 and 2005, using a matrix combining the upstreamness and downstreamness of each country with the length of the supply chain as measured by APL.

Studies using WIOD include Miller and Temurshoev (2017), Suganuma (2016) and Antras and Chor (2018). Miller and Temurshoev (2017) proposed downstreamness as a counterpart concept to upstreamness and taking decomposition of its change into domestic and international sectors. Suganuma (2016) also used the upstreamness to show that the global upstreamness increased significantly in the 2000s and that its growth was driven by the East Asian electronics industry; Antras and Chor (2018) used the upstreamness, downstreamness, value added ratio (value added divided by output), the final goods ratio (final goods divided by output) to analyse each country's position in GVCs.

Other studies used the national input-output tables to calculate the upstreamness and downstreamness of industries in each country. Antras *et al.* (2012) and Fally (2012) use the US input-output table to calculate the upstreamness of each industry, with a focus on the manufacturing sector. Most recently, Alfaro and Chor (2023) used the US input-output table to analyse developments on the US industries since the US-China friction, with trade shifts to neighbouring countries such as Canada and Mexico (nearshoring) and to friendly countries such as Vietnam (friendshoring). Chor, Manova, and Yu (2021) use China's input-output table to calculate the degree of upstreamness by industry in the country and, together with customs data, analyse the position of firms on the GVC.

3. Length of / Position on GVCs

3.1 Synthesis of upstreamness and downstreamness

The concepts of upstreamness and downstreamness presented in section 2.2 are quantitative indicators of the position of an industry or country in GVCs, measured by the number of processes

from final goods or raw materials. Many of the previous studies presented in Section 2 also use upstreamness and downstreamness separatedly to analyse each country and industry.

However, as shown in Figure 4, the scope captured by the upstreamness (or downstreamness) alone is only a part of GVCs. In other words, the upstreamness only has information on "the industry to final goods (downstream part of GVC)" and the downstreamness only has information on "raw materials to the industry (upstream part of GVC)," implying that they do not capture the entire GVC alone.

For example, even if the upstreamness of an industry is large, it does not necessarily mean that the position of the industry is truly upstream of GVCs. If the downstreamness of the industry is greater than its upstreamness, the industry stands rather downstream on GVCs. Similarly, it is not possible to understand how an industry's GVC position has truly changed simply by looking at changes in its upstreamness (or downstreamness). Even if the upstreamness of an industry has increased, if the downstreamness has increased by a greater amount, the industry's position would rather shift downstream. As shown in Figure 5, there are four patterns of combinations of the changes in upstreamness and downstreamness, but in cases where both are expanding (or contracting), the shift in the GVC position of the industry in question is not uniform, as it depends on the size of changes in two indicators. Conversely, in cases where one expands (or shrinks) and the other shrinks (or expands), a situation arises where it is possible to tell whether the position of the GVC has shifted upstream or downstream, but it is not possible to say uniformly how the length of the GVC has changed.

In addressing these issues, this paper has combined upstreamness and downstreamness to capture overall GVCs of each industry or country as a whole. As noted above, we recognise that a key feature of this paper is that it analyses GVCs using indicators that combine information of both upstreamness and downstreamnesss.

The first indicator is the 'downstreamness plus upstreamness'. By adding up both indices, we obtain the total number of processes 'from raw materials to final goods' for an industry, which is the sum of 'from raw materials to the industry' and 'from the industry to final goods'. In other words, this can be defined as the 'length of GVCs' for the industry.

The second indicator is the 'downstreamness minus upstreamness'. By taking the difference between the two indices, it is possible to measure whether the industry is located either upstream or downstream of the GVC. If the upstreamness is greater than the downstreamness, the index is negative, indicating that the industry is located upstream. On the other hand, if the downstreamness is greater than the upstreamness, this indicator is positive, indicating that the industry is located downstream. In other words, this indicator can be regarded as each industry's 'position on the GVC'. In addition, considering that the length of the GVC are different between industries, which implies that the meaning of difference between the upstreamness and

downstreamness also differs from industry to industry, we divide it by the first 'length' index as the standardisation process.

In terms of equations, the 'length of the GVC' is expressed by equation (5) and the 'position on the GVC' by equation (6).

$$L_{ci} = U_{ci} + D_{ci} \quad (5)$$

$$P_{ci} = \frac{D_{ci} - U_{ci}}{L_{ci}} \quad (6)$$

In the example in Figure 6, the 'length of GVC' of the electronics industry is 5 (= 3 plus 2). In addition, the 'position on GVC' is +0.2 (= (3-2)/(3+2)), which quantitatively shows that this industry is located 'downstream'.

The advantage of creating these composite indicators, especially the second one, is that it is possible to understand whether the position of the industry is 'truly' upstream (or downstream). For example, as shown in Figure 7, suppose that upstreamness of industry A is 3 and that of industry B is 4. We understand that industry B is farther 'from final good' than industry A. On the other hand, if the downstreamness of industry A is 2 and that of industry B is 6, industry B is also farther 'from raw material' than industry A. At this stage, it is not known whether industry A or B, locates truly upstream on the GVC. However, using the 'position on GVC' used in this paper, we can quantitatively understand that the position of industry A is slightly upstream at -0.2 while that of industry B is slightly downstream at +0.2. Thus, for the first time, it is realised that 'position of industry B is a more downstream than industry A'.

The use of the two composite indices in this paper also makes it possible to see whether an industry's GVC position has 'truly' shifted upstream or downstream as a result of the tug-of-war between the two indicators, upstreamness and downstreamness, which is a major advantage in analysing GVCs.

The approach in this paper, which uses global input-output tables to quantify the distance toward upstream (or downstream) in an industry or country, and uses these to calculate the 'length' and 'position' of it, is similar to the approach in previous studies, such as Escaith and Inomata (2016) and Wang et al. (2017). However, the main difference between this paper and previous studies is that we uses 'upstreamness' and 'downstreamness' when calculating 'length' and 'position'. Other difference is in the method used to calculate “position.” Escaith and Inomata (2016) and Wang *et al.* (2017) obtaining it by division[3], whereas this paper calculates it by taking the difference between the downstream and upstreamnesss and then dividing it by the length of the GVC. In this regard, the upstreamness and downstreamnesss include not only of other

[3] The former calculated by 'backward APL / forward APL' and the latter by 'forward length of production process / backward length of production process'.

industries, but also the utilisation of output within the industry ifself. By taking the difference, the impact of the position on the GVC is eliminated.

3.2 Position of industries and countries on GVCs

We next confirm the calculated 'position on GVCs' to see whether their values are consistent with our intuition, by industry and by country. In this case, we use values from the OECD's Global input-Output table for 2018.

Figure 8 shows that the 'upstream' industries in terms of the position on GVCs are the mining, basic metals, chemicals and other materials industries, while the 'downstream' industries are the processing industries, such as food and transport equipment, and the industries close to final consumer goods, such as health and construction. These characteristics are common across countries, albeit to a slightly different degree, which are consistent with Antras *et al.* (2012), who show that the degree of upstreamness of each industry is similar across EU countries.

Next, looking at the position on the GVC by country in Figure 9, resource-rich countries such as Brunei, Saudi Arabia and Russia are located upstream, while downstream countries are such as Cambodia and Vietnam, which are responsible for downstream processes in the manufacturing industry (e.g. sewing), and countries where tourism is their major industry, such as Malta and Croatia.

These results are also consistent with our intuitive perceptions. In other words, the 'position on GVCs' calculated from the upstreamness and downstreamness using the input-output table does not deviate significantly from our images of the position of each country and each industry in GVCs.[4]

4. Analysis of GVC: from 1965 to 2022

The chronological analysis of GVCs in Section 4 starts from the 1960s-1990s in Section 4.1, then the 2000s in Section 4.2, followed by the 2010s in Section 4.3 and finally the recent 2020s in Section 4.4. Although the used global input-output tables are different in each period, the length and position of GVCs calculated from each input-output table do not differ significantly (see Appendix 1 for details). Therefore, we conclude that our analysis are consistent across periods.

4.1 From 1960s to 1990s

We start our analysis from the 1960s-1990s. Here, we use the WIOD long-term time series tables (1965-2000). The long-term time series table consists of 23 industries in 25 countries (including 12 manufacturing and 9 services industries).

[4] However, it should be noted that the analysis using the input-output table assumes that transactions between industries and transactions between firms (actual number of processes) obtained from the table are consistent or approximate.

4.1.1 Global

First, looking at the length of GVCs of the world in Figure 10, they remained within a roughly constant range from the 1960s to the 1980s, albeit with a bit fluctuations. At that time, with the US-USSR confrontation still ongoing, the economic bloc was largely divided into eastern and western groups, and supply chains had not been established globally. This implies that trade was not necessarily the driver of global economic growth at that time.

However, since 1990, there has been a noticeable growth in the length of GVCs, and this growth has occurred simultaneously with the growth of global GDP. The 1990s starts from the end of the Cold War and the collapse of the Soviet Union, which led to a significant expansion of global goods and services exchange. At the same time, global trade expanded significantly with the establishment of the WTO, the development of a global trade framework and the creation of new 'economic groups' such as NAFTA and the EU.

4.1.2 Japan: overview

Next, we see the changes in GVCs in Japan from 1960s to 1990s using the length and position of GVCs. We find that there were no significant changes in either length or position until the 1970s, but that significant changes occurred from the 1980s onwards.

First, Figure 11 shows that the length of GVCs in Japan remained within a same level, with some fluctuations, until the 1970s, but has rapidly shortened since the 1980s. We next analyse this change through a decomposition of the 'within effect' and the 'between effect'. $L_{c,t}$ in equation (7) is the length of GVC for an entire country at time *t*, and equation (8) is its decomposition. The first term in equation (8) is the 'within effect', which is the change in the length of GVC for each industry, and the second term is the 'between effect', which is the change in the weight of each industry. Figure 12 shows that the between effect has contributed to the reduction in the length of GVCs in Japan, implying that the weight of industries with relatively short value chains has increased.

$$L_{c,t} = \sum_{i=1}^{n} \left(L_{ci,t} \cdot \frac{Y_{ci,t}}{Y_{c,t}} \right) \quad (7)$$

$$\Delta L_{c,t} = \sum_{i=1}^{n} \left(\Delta L_{ci,t} \cdot \frac{Y_{ci,t}}{Y_{c,t}} \right) + \sum_{i=1}^{n} \left(L_{ci,t} \cdot \Delta \frac{Y_{ci,t}}{Y_{c,t}} \right) + \varepsilon_{c,t} \; where \; \Delta L_{c,t} = L_{c,t} - L_{c,t-1} \quad (8)$$

The background to these points can be the changes in the economic structure in Japan, i.e. the servicisation of the economy. The post-war Japanese economy has shifted from agriculture to manufacturing at first and then from manufacturing to services. As the length of the value chain

is relatively short in service sector, the increased weight of the sector have contributed to the decline in the length of the GVC.

At the same time, Figure 13 shows that there has been a rapid shift toward upstream since the 1980s with regard to the position of GVCs. During this period, the value-added ratio has also increased significantly, indicating that in Japan a shift to upstream processes and an increase in competitiveness occurs simultaneously.

Looking at the change in the position by each industry in manufacturing in Figure 14, we find that the shift to upstream has occurred in a number of industries. In the following, we select several industries and provide an analysis of the background to this shift.

4.1.3 Japan: Basic metal(iron and steel)

First, we analyse the basic metal industry, including iron and steel. In Japan, this industry was a representative of the heavy industry. Figure 15 shows the change in the position of metals since 1965, with a significant shift in the upstream direction during the 1980s and 1990s.

By dividing this change into domestic and foreign contributions in Figure 16, we see that contribution of domestic is large. By dividing it into the contribution upstreamness and downstreamnes, we find that a decline in downstreamness is large, implying a shift to upstream production processes.

In considering these results, we look back at the environment surrounding the steel industry in Japan. Since the 1980s, as competition with other countries intensified, companies closed blast furnaces and consolidated factories, leading to a shift to more upstream production processes. For example, Nippon Steel's Kamaishi factories closed its No. 2 blast furnace in 1985 and No. 1 blast furnace in 1989, ending integrated production of iron and steel from blast furnaces, and shifting to the production of wire rod and other special steel products, which are located further upstream in GVC.

As a result of this shift, the value-added ratio of the basic metal industry increased, as shown in Figure 17, suggesting that the shift to upstream processes was linked to improved competitiveness.

4.1.4 Japan: Transport equipment (automobiles)

Next, we look at the transport equipment industry, including automobiles, which have played a leading role in the industry since the 1980s, including in the context of friction between Japan and the US. Figure 18 shows the change in the position of the industry since 1965, which shows that there has been a significant shift toward upstream in the 1980s and 1990s in this industry, too.

When breaking down the change into domestic and foreign contribution, or into upstreamness and downstreamness contributions in Figure 19, we find that a decline in the

domestic downstreamness, i.e. a shift to upstream production processes, mainly contributed to the shift. In addition, increase in upstreamness to foreign countries has also contributed a bit.

In considering this point, we look back at the environment surrounding the Japanese automobile industry. Since the 1980s, domestic automobile manufacturers have moved their production bases overseas in response to increasing headwinds on automobile exports due to the friction between Japan and the United States, and to rising domestic production costs. As a result, within transport equipment, companies located in more upstream processes, such as automotive components, remained in Japan, resulting in an overall shift in transport equipment in the upstream direction. In addition, the small increase in the upstreamness toward foreign countries would be due to the export of parts for automobiles to Japanese automobile manufacturers who moved to overseas.

Looking at the impact of this shift on the value-added ratio in Figure 20, the recovery has been very modest since the decline in the late 1980s. This suggests that, as much of the added value of automobiles was concentrated in the hands of automobile manufacturers, their shift to overseas declines the value-added ratio as the profit margins of parts manufacturers remained in Japan are relatively low.

4.1.5 Japan: Electrical and optical equipment (semiconductors)

Finally, we analyse the electrical and optical equipment industry, including the semiconductor industry, which flourished in the 1980s and 1990s. Figure 21 shows the change in position since 1965, and we find a significant shift to upstream in the 1980s and 1990s as well.

However, when breaking down the change into domestic and overseas, and into upstream and downstream contributions in Figure 22, we find that the increase in upstreamness to overseas is significantly contributed, which are quite different from the change of previous two industries. In other words, the goods produced in this industry are now used much more globally in GVCs, which has contributed to the upstream shift in its position.

This result is consistent with the large increase in semiconductor production and exports in the 1980s. Japan's semiconductor shipments reached the world's largest during this period, and continued to flourish from 1985 to 1993. This large increase in the production of "goods used in the production of downstream industries in the supply chain" contributed to the shift to upstream of the industry. As seen in Figure 23, the value-added ratio has also increased significantly since the 1980s, suggesting that the upstream shift has contributed significantly to the increase in industrial competitiveness.

4.1.6 Summary of the 1960-90s

In the summary of the 1960s-1990s, GVCs on a global scale did not change significantly until the

1980s, but changed a lot from the 1990s onwards, boosted by trade liberalization. This significant growth came to synchronise with the global economic growth. Looking at Japan's GVCs, while the 'length' of GVCs declined with the development of services, the 'position' of GVCs shifted in the upstream direction in several manufacturing industries, and this was accompanied by an increase in industrial competitiveness.

4.2 2000s

4.2.1 Motivation and data for analysis

Second, we analyse the structural changes in the 2000s. As observed in section 4.1, in the 1990s, supply chains began to globalize with the end of the Cold War, the creation of new economic blocs through free trade agreements (FTAs) and the establishment of the WTO, the international organisation which supervise global trade. The 2000s saw a further acceleration of this trend with China's accession to the WTO.

The analysis of this section extends the work of Suganuma (2016), which also analyses this period. Using the upstreamness, Suganuma (2016) showed that (i) the global upstreamness expanded significantly during 2000s, (ii) the expansion was particularly prominent in the electrical and optical equipment industry in East Asian countries, and (iii) after the Lehman shock in 2008, the upstreamness contracted significantly but then began to gradually return to a recovery trend. In this paper, we combine downstreamness with this study, and analysed from the perspective of the 'length' and 'position' of GVCs. We focuse on the electrical and optical equipment industries of East Asian countries in the 2000s, as well as Suganuma (2016).

As with Suganuma (2016), we use the World Input Output Table (WIOT) of the WIOD as the global input-output table. The WIOT covers 35 industries (of which 14 are manufacturing and 19 services) in 40 countries, which is more extensive in terms of the number of countries and industries than the WIOD long-term time series table in section 4.1.

4.2.2 Global and countries

Suganuma (2016) showed that the upstreamness in global has grown significantly since the 2000s, as illustrated in Figure 24. In this respect, as explained in section 2.2.2, the upstreamness of one country is always the downstreamness of another country, so the values of upstreamness and downstreamnesss are equal for the entire world. Therefore, as Figure 25 shows, the length of GVCs in the world is twice of the upstreamness (or upstreamness plus downstreamness), indicating that the 'length of GVCs' also shows significant growth in the 2000s.

Next, looking at change by country in Figure 26, we find that all of the four East Asian economies (Japan, South Korea, Taiwan and China) have experienced significant increases in GVC length, which is the consistent of the results Suganuma (2016) derived using upstreamness.

With regard to the position of GVCs, Figure 27 shows the shift in each country. We find that the change of the positions in GVCs are varying from one industry to another. The analysis below focuses on the electrical and optical equipment industry, where the direction of the shift in position are different from country to country.

4.2.3 Electrical and optical equipment in East Asia

Figure 28 shows that the length of GVCs in the electrical and optical equipment industry in all of the four East Asian economies has increased significantly. This result is consistent with Suganuma (2016) who confirmed that upstreamness in the industry has increased in each economy. That is, we firmly confirmed the deepening of GVCs in the electrical and optical equipment industry in the 2000s.

On the other hand, regarding the position of GVCs, which was not analysed by Suganuma (2016), the result is different across economies. Figure 29 shows that in Japan, South Korea and Taiwan, the position of the electrical and optical equipment industry shifted in the upstream direction in the 2000s, while in China, the position of the industry shifted in the downstream direction.

Suganuma (2016), by breaking down the increase in the upstreamness of Japan, South Korea and Taiwan by partner country contribution, showed that it was due to the movement to integrate China into their own downstream supply chain. This paper confirms that these three economies also shifted upstream in terms of their "true GVC position", which takes downstreamness into account.

The shift of China's position to downstream is the new result of the analysis in this paper. China was positioned as the 'factory of the world' during this period, and was actually entering the GVC in the form of taking part in the process of assembling several manufacturing parts produced in other countries to complete the final product. Therefore, the downstream shift in the position of China's electrical and optical equipment industry in this paper is consistent with the actual events that occurred during this period.

4.2.4 Summary of the 2000s

In the 2000s, global GVC grew significantly, driven by the electrical and optical equipment industries in four East Asian countries and regions. In addition, this paper newly uses the GVC position to show that different movements were occurring across economies, with the position of Japan, South Korea and Taiwan shifting upstream, while that of China shifted downstream.

However, this growth in GVCs temporarily stalled following the Lehman shock in 2008, along with a contraction in economic activities. Although there have been some signs of recovery after that, the WIOD input-output table does not confirm whether the trend has returned to its

original level. The subsequent developments that occurred in the 2010s are analysed in the following section 4.3.

4.3 2010s

4.3.1 Motivation and data for analysis

Third, we analyse structural changes in the 2010s. The analysis of this period draws on a previous study, Suganuma (2023). The paper finds two facts: first, that the length of GVCs globally slowed down in the 2010s, consistent with slow trade, second, changes in the position of GVCs are different across East Asian economies.

We use the OECD's Inter-Country Input Output Table (ICIO) as the global input-output table in this section. This table covers 45 industries (20 manufacturing and 22 services) in 67 countries. Classification of industries are based on the International Standard Industry Classification (ISIC), making it possible to use detailed industries. As an example, the 'Electrical and Optical Equipment' industry in the WIOD and ADB is divided into 'Computer, Electronic and Optical Equipment' and 'Electrical Equipment' in the OECD input output tables. This section refers to the former as 'IT goods' and provides a more detailed analysis of its shifts.

4.3.2 Length of GVC

Looking at the length of GVCs in Figure 30, we see a reversal from the growth in the 2000s, as discussed in section 4.2, to stagnation in the 2010s. These results are also consistent with the stagnation of trade volumes in the 2010s (slow trade).

By looking at the changes in the length of GVCs by region in Figure 31, we find that in all regions, Americas, Europe and Asia, growth slowed or contracted in the 2010s, indicating that slow trade occurred globally. Among these, a sharp slowdown is evident in East Asia, where GVCs grew significantly in the 2000s.

Figure 32 shows that, by economies in East Asia, Japan, South Korea and Taiwan grew its length of GVCs significantly in the 2000s, as discussed in the previous section, but the trend of expansion stalled in the 2010s. Looking at these changes by industry, these shift are particularly pronounced in IT goods, which once drove the growth of GVCs in the 2000s. In other words, the IT property industry in East Asia underwent a major structural change in the 2010s, with the stagnation of the scale of the GVCs.

4.3.3 Position on GVC

Although the growth in the length of GVCs, particularly in East Asia stagnated in the 2010s, this result does not necessarily mean that the role of GVCs themselves has declined. Antras (2020) also argues that although global trade volumes have fallen below GDP growth in the 2010s, there

is no evidence of 'de-globalisation'.

When we decompose the change in the length of GVCs by contribution of upstreamness and downstreamnesss in Figure 33, we find that the reason of the slowdown is different across economies; a decline in the upstreamness in Japan, decline in the downstreamness in South Korea and Taiwan. These differences suggest that the position of GVCs in each country shifted differently across countries. We next analyse the changes in position on GVC in the IT goods industry in each economy.

Looking at the 'position on GVC' in the IT goods industry in East Asian economies in Figure 34, as suggested above, we find a there are differences across economies.

First, South Korea and Taiwan have shifted significantly upstream in the 2010s. Second, China has shifted slightly upstream in the 2010s, but it does not offset the change from the significant downstream shift in the 2000s. Third, Japan shows little movement in its position on the GVC.

In terms of the background of these shift, we analyse the contribution of Japan to the position of the IT goods industries on GVC in South Korea and Taiwan. Figure 35 shows that Japan's contribution has remained positive (i.e. contributed to downstream) for both South Korea and Taiwan, implying that their relative position, with Japan in the upstream and South Korea and Taiwan in the downstream direction, has not changed in the 2010s. However, the contribution of Japan has shrunk significantly in both South Korea and Taiwan.

These changes are consistent with the situation that emerged in the IT goods industries of Japan, South Korea and Taiwan during this period. Looking back at the history of the IT goods industry, until the 1990s, as discussed in section 4.1, Japan occupied upstream chemical and semiconductor production, while South Korea and Taiwan were responsible for producing downstream final products (TV, PC, smartphone). However, from the 2000s to 2010s, as semiconductor manufacturers such as Samsung, SK Hynix and TSMC increased their market share, South Korea and Taiwan experienced a growing tendency to control semiconductor production in addition to the production of final goods. The results suggest that the dependence on Japan, which was on the upstream of GVC, decreased as South Korea and Taiwan shifted to upstream processes.

Next, with regard to China, we analyse its changes in GVCs in conjunction with the Chinese government's aims for increasing in-house production, replacing upstream component to domestic manufacturing, in addition to the downstream assembly process. If the in-house production of upstream parts were to progress, there would be a shift to upstream in terms of position on the GVC. However, Figure 34 shows the position of China's IT goods industry on GVC reversed only slightly in the 2010s. This suggests that, in China, although some change is occurring from the dependence on foreign countries in the 2010s, there has not been a significant shift towards full

in-house production.

4.3.4 Position on GVC and competitiveness of industries

In the final analysis of section 4.3, we review the impact of the changes in the position on GVCs on a country's industrial competitiveness, as in Fally and Hillberry (2015) and Ito and Vezina (2016). Previous studies have shown that value added is not evenly distributed in GVCs and is known to follow a 'smile curve'. It is therefore extremely important to see the impact of the changes in position on GVCs on a country's industrial competitiveness. Here, the value-added ratio (value added divided by output) in the global input-output table is used as an indicator of industrial competitiveness.

Figure 36 shows the position and value-added ratio of GVCs in the IT goods industries of East Asian countries and regions over time. We find that in South Korea and Taiwan, a shift in the position of GVCs to upstream led to an improvement in industry competitiveness. On the other hand, in China, which aims at in-house production, though its position has shifted slightly to upstream, its value-added ratio has rather declined, suggesting that little improvement in industrial competitiveness has occurred in the 2010s.

For Japan, both its position on the GVC and its value-added ratio have remained largely unchanged during in 2010s. This suggests that, for the Japanese IT goods industry, the response to such structural changes has remained passive compared to other countries. In other words, it suggests that their action were not as prominent as in South Korea and Taiwan, which aimed to shift to upstream, or in China, which aimed to shift to in-house production.

4.3.5 Summary of the 2010s

In section 4.3, we find a slowdown in the growth of GVCs in the 2010s, which was below the rate of economic growth. This trend was consistent with the stagnation in the global trade during this period (slow trade), which was particularly pronounced in the IT goods industry. On the other hand, there were significant differences in the position of East Asian economies, with a contrast between South Korea and Taiwan, which experienced to shift upstream in the 2000s, and China and Japan, which did not experience the shift in the position on GVC. In South Korea and Taiwan, such changes in the position on GVCs was accompanied by a change in the value-added ratio, with an increase in industrial competitiveness.

Will these developments continue into the 2020s? In addition, what impact did the US-China frictions have on GVCs? We analyse this point in the last part of our analysis, section 4.4.

4.4 2020s

4.4.1 Motivation and data for analysis

We finally our analysis with the structural changes in the 2020s. Specifically, we focus on developments after 2018, which were not mentioned in section 4.3. One of the major events during this period has been the trade friction between the US and China over semiconductors and other products. While various analyses of the impact of US-China frictions on GVCs have been conducted, including Inomata and Hanaka (2021), this paper analyses GVCs from the perspective of their 'length' and 'position'.

We use the Multi Regional Input Output Table (MRIO) of the ADB as the global input-output table. The MRIO covers 35 industries (14 manufacturing and 19 services) in 62 countries for the period 2007-2022. The table also contains not only for nominal values, but also for real values (based on 2010).

Figure 37 shows that the length of GVCs worldwide has continued to slow since the 2010s, although a slight increase is seen in the most recent year, 2022. This suggest that, from a global perspective, no major structural changes in GVCs have occurred in the 2020s. In the following, in addition to the US-China friction, we analyse individual topics such as the increasing production of electric vehicles (EVs), the economic downturn associated with the COVID-19, and the surge in resource prices following Russia's invasion of Ukraine, with the impact of these factors on the length of / position on GVCs.

4.4.2 US-China conflict

It is said that friction between the US and China surged since 2018. The US has exerted pressure on China in terms of both exports and imports, with tariff rates being raised on imports and a ban on imports of goods produced in the Uygur Region. On the export side, the US imposed export restrictions by items, and by companies on the entity list who require a permission from the Bureau of Industry and Security (BIS) of the Ministry of Commerce. Such export restrictions have been strengthened with the addition of smartphone manufacturer Huawei in 2019 and semiconductor manufacturer SMIC in 2020 to this entity list.

We analyse the impact of these changes from the standpoint on GVCs. With regard to the impact of US export restrictions, we look at the position of the US on on GVCs vis-à-vis China in Figure 38. We find that the US was positioned slightly upstream as of 2018, but is now approaching the normal point. This may be due to the fact that since the US-China friction, the number of US-made products used in the production in China has decreased in line with export restrictions, which made the upstreamness declined.

Looking at the left of Figure 39 for the general machinery and electrical and optical equipment in the US, their position on GVCs vis-à-vis China has shifted from upstream to downstream. This shift is consistent with the fact that, following the friction, the US, which is located upstream of GVCs, imposed restrictions on exports of semiconductors and related

equipment to China, resulting the fewer use of US parts for production in China.

With regard to the import side of the US, right figure of Figure 39 shows China's contribution to the position of the US retail sector on GVC We find that there was an expansionary trend until 2017, but a turnaround in the direction of contraction from 2018 onwards. This is also consistent with the fact that US imports from China declined significantly from 2018 onwards, which caused the decrease of the US sales for goods produced in China.

The US-China friction over GVCs has no end in sight, as the US restricts exports of advanced semiconductor manufacturing equipment in 2023, while China also tightens export controls on graphite, a material used in EV batteries, as well as rare metals (gallium and germanium). These points continue to be research interest in the I-O table. Inomata (2023) argues that GVCs now constitute one of the strategies that move the balance of power between countries, i.e. GVCs and geopolitical risks are closely related.

Figure 40 shows the length of / position on GVC in Japan for general machinery and electrical and optical equipment in relation to China. Although some Japanese companies have considering about restructuring or reviewing their production bases in response to the US-China friction, its position implies that such movement are limited compared to the US.

4.4.3 EV (Electric vehicles)

Next, we analyse from the perspective of the increase in the production of EVs in the automotive industry, a major change that has occurred over the past few years. The shift to EVs implies that many automotive components are replaced by EV batteries and other electronic components, creating a supply chain with electrical and optical equipment upstream and transport equipment downstream in terms of the position on GVC.

It should be noted, however, that a similar trend, the electrification of vehicles has already been underway since the 2010s and is not always easy to distinguish from EVs in the input-output table. Therefore, this section analyses the period from 2018 onwards when EVs began to increase in earnest.

Figure 41 shows the length of / position on GVCs of electrical and optical equipment vis-a vis transport equipment in each country. We find that the length shrunk slightly in almost all country, which is thought to be due to the structural change common to each country. In China alone, the length of GVCs is expanding, which implies that part of this trend may be due to the increase in EV production in China.

Regarding the position on the GVCs, we analyse the position of each country, by standardizing China as zero. In 2018, China and Europe were located in the same position, with the US, Japan and South Korea being upstream from China. However, in 2022, Europe is positioned downstream from China, and the gap between China and upstream countries, Japan,

the US and South Korea, is narrowing. In other words, as a result of Chinese electrical and optical equipment output being used more in transport equipment, its shift in its position on GVC in the upstream direction in China is greater than in other countries.

In 2023, China overtook Japan as the world's leading exporter of vehicles, led by the growth of the production of EVs. Japan has been said to have strengths in electronic components for EVs, such as power semiconductors and EV batteries. However, looking at the length and position of GVCs in electrical and optical equipment, the competitive circumstances with other countries is expected to intensify.

4.4.4 Economic shock during the COVID-19

Next, we look at the impact of COVID-19 on GVCs. Looking at the global and Japan in Figure 42, GDP declined significantly in 2020 with the expansion of COVID-19, while the length of GVCs, surprisingly, did not move a lot. This suggests that although the real economy of each country contracted in the wake of the COVID-19, its impact on the trade structure was limited.

Considering the reasons, the biggest impact of the COVID-19 on the real economy was a decrease in service consumption, such as restaurant and accommodation, due to curbs on outings. On the other hand, the demand for goods did not decline by much during this period, which rather caused supply constraints, such as container shortages.

Similar developments were seen during the 2011 when Great East Japan Earthquake happened in Japan. At that time, too, the economy was pushed down by supply constraints such as electricity shortages, but the demand for goods did not change significantly, and as a result, the impact on the structure, such as the length and position of GVCs, was limited.

These developments are much different from the demand shock of 2008, i.e. the Lehman Brothers collapse, which led to a significant global contraction in demand for goods and forced a reduction in the size of GVCs along with economic activity.

4.4.5 Impact of rising resource prices following Russia's invasion of Ukraine

Finally, we look at GVC movements under rising resource prices following Russia's invasion of Ukraine, which began in 2022: since there are two ADB input-output tables, nominal and real (2010 prices), we make a comparison of indices between the two tables.

Conceptually, increase in resource prices increase the output of the resource sector who located in the most upstream of GVC. This may therefore affect the length of GVCs globally or for a country as a whole, through weighting effects, or shift their position in a downstream direction in the form of increased downstreamness outside of the resource sector.

However, when comparing nominal and real values for the length of global GVCs in Figure 43, the difference between the two is only slight in the world as a whole. The increase in GVCs

in 2022 is partly explained by price factors, but it is also affected by other real factors. This is also observed during the increase in resource price in 2007-08. These result suggest that the impact of increasing resource prices on GVCs is at least not as large as it could be.

5. Conclusion

This paper analyses GVCs using the global input-output table, whose use has expanded significantly in recent years. The main feature of this study is that, as a tool in this context, we use the 'upstreamness' and 'downstreamness', which quantitatively express GVCs, to calculate the 'length of GVCs' and 'position on GVCs' by combining this information. We then used these indices to analyse changes in GVCs over the past 60 years, with a focus on Japan and East Asia.

The results of the time-series analysis are as follows: until the 1970s, the length of GVCs remained within a range while the division of labor in the global production process was limited. In Japan, since the 1980s there has been a shift to upstream processes in electrical and optical equipment (semiconductors), transport equipment (automobiles) and basic metals (steel), which was accompanied by increase in industrial competitiveness.

In the 1990s, after the end of Cold War, GVC deepened due to the conclusion of FTAs. In the 2000s, GVC expanded significantly, particularly in the IT goods industry in East Asia, triggered by China's accession to the WTO. In the 2010s, GVC entered a phase of stagnation, in step with slow trade, During this period, however, the position of each country on GVC changed differently across economies, and South Korea and Taiwan succeeded in improving their industrial competitiveness by shifting to upstream processes in the IT goods industry. In the 2020s, as friction between the US and China intensifies, some of the effects of export restrictions and other measures are also being observed in GVCs.

Two points should be noted in conducting such an analysis: first, the number of industry classifications. Although the number of classifications has increased from 23 in the WIOD long-term time series table covering the 1960s-90s to 45 in the OECD linkage table, the number of classifications is not yet available for detail industries. Therefore, as Inomata (2023) argues, it should be noted that the movement of GVCs in each industry cannot necessarily be explained solely by the factors of individual goods. In the future, it is hoped that the global input-output table will be developed to include detailed classifications closer to individual goods, such as electronic components and production machinery, for example.

The second point is the impact of exchange rates. In the global input-output table, all figures are available in US dollars, implying that output and other figures may differ from the figures input-output tables in each country. However, it is unclear to what extent such exchange rate effects have, as the upstreamness and downstreamness are distances measured in terms of the

number of processes between the industry and final goods, or raw materials and the industry. These aspects should be taken into account in the future, if possible.

Finally, although this paper has analysed Japan and East Asia, it will be important to carry out such analysis for other countries and other industries, and to analyse the relationship between the position of an industry on the GVC and its industrial competitiveness, from the viewpoints of strategic planning of industrial policy. In particular, as this research has made it possible to calculate the GVC position of each industry, it will be possible to line up the GVC position of each industry on the horizontal axis and the value-added ratio on the vertical axis to see whether the 'smile curve' proposed by Baldwin, Ito, and Sato (2014) are actually observed. Figure 44 shows the position of each industry in Japan on the GVC and its value-added ratio. Although the correlation is not so strong, we find the existence of a smile curve. It will be of great interest to see whether such a relationship can also be observed in other countries and industries.

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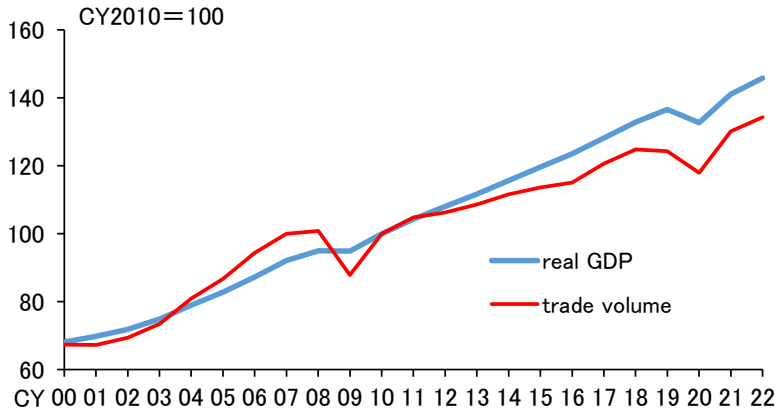
[Figures]

[Figure 1] Real GDP and trade volume



Sources: IMF, CPB

[Figure 2] Structure of global input output table

			intermediate demand(Z_i)											final goods (F_i)	output (Y_i)
			country 1			country 2			…	country m					
			industry 1	…	industry n	industry 1	…	industry n	…	industry 1	…	industry n			
intermediate input (Z_j)	country 1	industry 1	$a_{11,11}$	…	$a_{11,1n}$	$a_{11,21}$	…	$a_{11,2n}$	…	$a_{11,m1}$		$a_{11,mn}$		F_{11}	Y_{11}
		⋮	⋮	⋱	⋮	⋮	⋱	⋮	…	⋮	⋱	⋮		⋮	⋮
		industry n	$a_{1n,11}$	…	$a_{1n,1n}$	$a_{1n,21}$	…	$a_{1n,2n}$	…	$a_{1n,m1}$	…	$a_{1n,mn}$		F_{1n}	Y_{1n}
	country 2	industry 1	$a_{21,11}$	…	$a_{21,1n}$	$a_{21,21}$	…	$a_{21,2n}$	…	$a_{21,m1}$		$a_{21,mn}$		F_{21}	Y_{21}
		⋮	⋮	⋱	⋮	⋮	⋱	⋮	…	⋮	⋱			⋮	⋮
		industry n	$a_{2n,11}$	…	$a_{2n,1n}$	$a_{2n,21}$	…	$a_{2n,2n}$	…	$a_{2n,m1}$		$a_{2n,mn}$		F_{2n}	Y_{2n}
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	…	⋮	⋮	⋮		⋮	⋮
	country m	industry 1	$a_{m1,11}$	…	$a_{m1,1n}$	$a_{m1,21}$	…	$a_{m1,2n}$	…	$a_{m1,m1}$	…	$a_{m1,mn}$		F_{m1}	Y_{m1}
		⋮	⋮	⋱	⋮	⋮	⋱	⋮	…	⋮	⋱	⋮		⋮	⋮
		industry n	$a_{mn,11}$	…	$a_{mn,1n}$	$a_{mn,21}$	…	$a_{mn,2n}$	…	$a_{mn,m1}$	…	$a_{mn,mn}$		F_{mn}	Y_{mn}
value added (V_j)			V_{11}	…	V_{1n}	V_{21}	…	V_{2n}	…	V_{m1}	…	V_{mn}			
output (Y_j)			Y_{11}	…	Y_{1n}	Y_{21}	…	Y_{2n}	…	Y_{m1}	…	Y_{mn}			

$a_{ci,ej}$: output of industry i in country c used for producing industry j in country e

Y_{ci}、F_{ci}、V_{ci} : ouput, final goods, and value added of industry i in country c

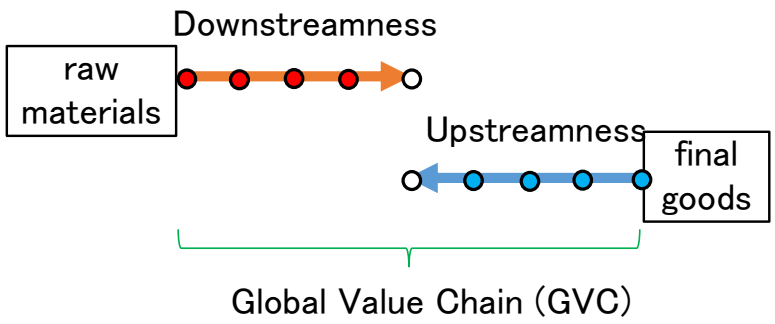
Source: created by author

[Figure 3] Comparison of global input-output tables

institution	publication period	countries	industries	index
ADB	2000, from 2007 to 2022	62	35	nominal/real
	from 2017 to 2022	72	35	nominal
OECD	from 1995 to 2018	67	45	nominal
WIOD	from 1965 to 2000	25	23	nominal/real
	from 1995 to 2011	40	35	nominal/real
	from 2000 to 2014	43	56	nominal/real

Sources: ADB, OECD, WIOD

[Figure 4] Upstreamness and downstreamness



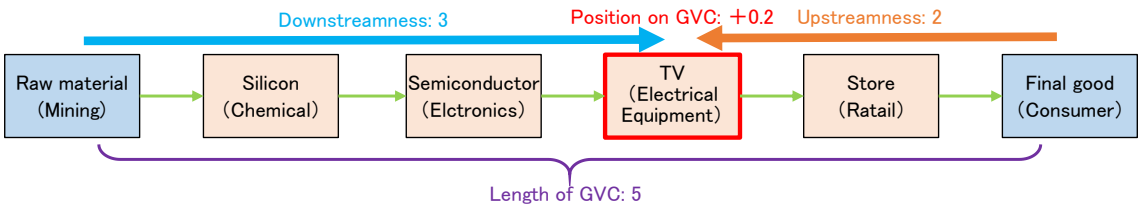
Source: created by author

[Figure 5] Change of upstreamness and downstreamness

	Upstreamness	Downstreamness	Length of GVC	Position on GVC
Pattern 1	increase (toward upstream)	decrease (toward upstream)	tug-of-war	toward upstream
Pattern 2	decrease (toward downstream)	increase (toward downstream)	tug-of-war	toward downstream
Pattern 3	increase (toward upstream)	increase (toward downstream)	increase	tug-of-war
Pattern 4	decrease (toward downstream)	decrease (toward upstream)	decrease	tug-of-war

Source: created by author

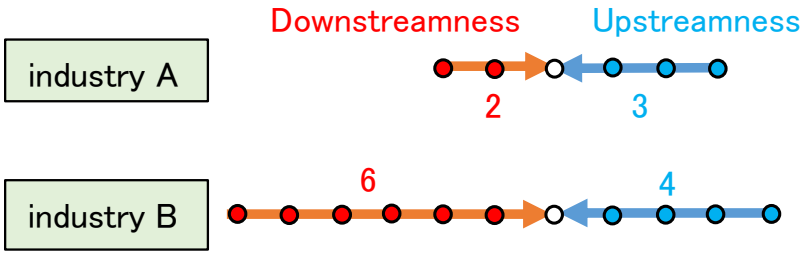
[Figure 6] Length of GVC and Position on GVC: actual case



	Chemical	Electronics	Electricalal Equipment	Retail
Upstreamness(U_{ci})	4	3	2	1
Downstreamness(D_{ci})	1	2	3	4
Length of GVC ($D_{ci} + U_{ci}$)	5	5	5	5
Position on GVC $\left(\frac{D_{ci} - U_{ci}}{D_{ci} + U_{ci}}\right)$	$-\frac{3}{5}$	$-\frac{1}{5}$	$+\frac{1}{5}$	$+\frac{3}{5}$

Source: created by author

[Figure 7] Length of GVC and Position on GVC: comparison



Source: created by author

[Figure 8] Position on GVC (industries)

Upstream industries		Downstream industries	
Mining	▲0.35	Construction	0.29
Financial activities	▲0.14	Human health	0.22
Chemicals	▲0.12	Motor Vehicles	0.20
Basic metals	▲0.10	Food products	0.19
Land transport	▲0.10	Public administration	0.19

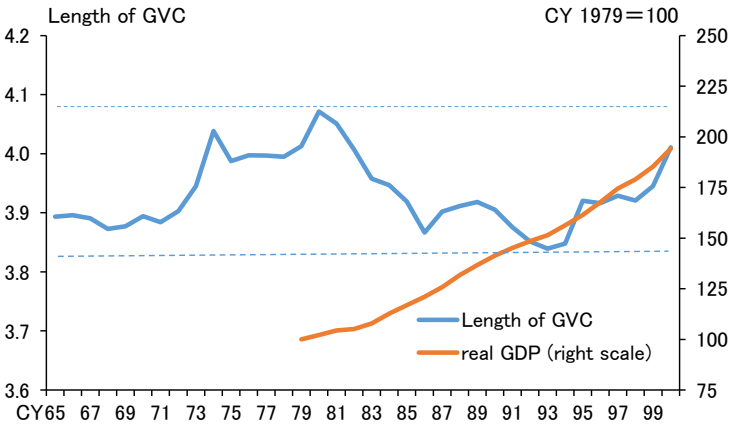
[Figure 9] Position on GVC (countries)

Upstream countries		Downstream countries	
Brunei	▲0.16	Cambodia	0.08
Saudi Arabia	▲0.14	Vietnam	0.07
Kazakhstan	▲0.12	Malta	0.07
Russia	▲0.08	Croatia	0.06
Peru	▲0.07	Tunisia	0.06

Note: Figures are those of CY2018.

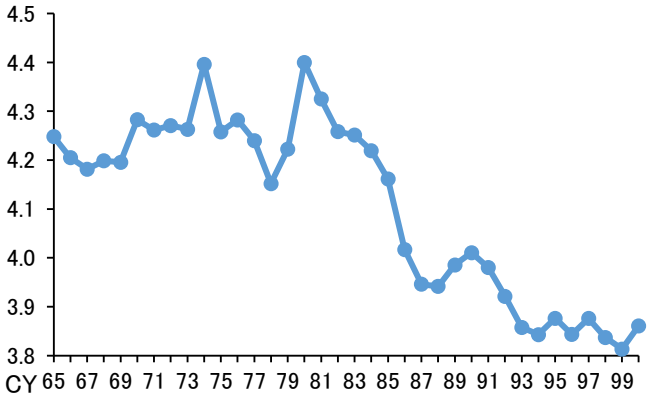
Source: OECD

[Figure 10] Length of GVC in the world (1965-2000)



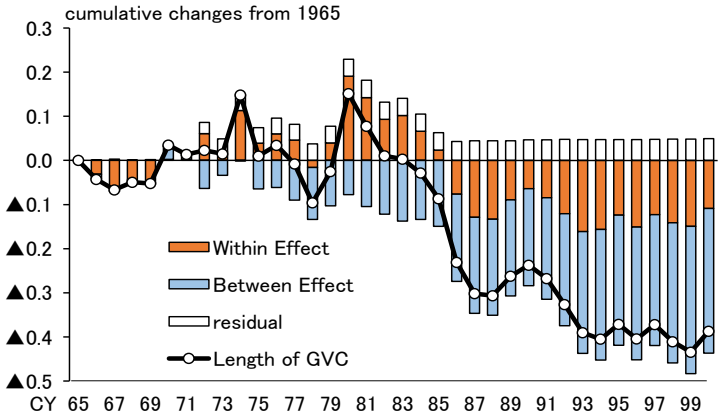
Sources: WIOD, IMF

[Figure 11] Length of GVC in Japan (1965-2000)



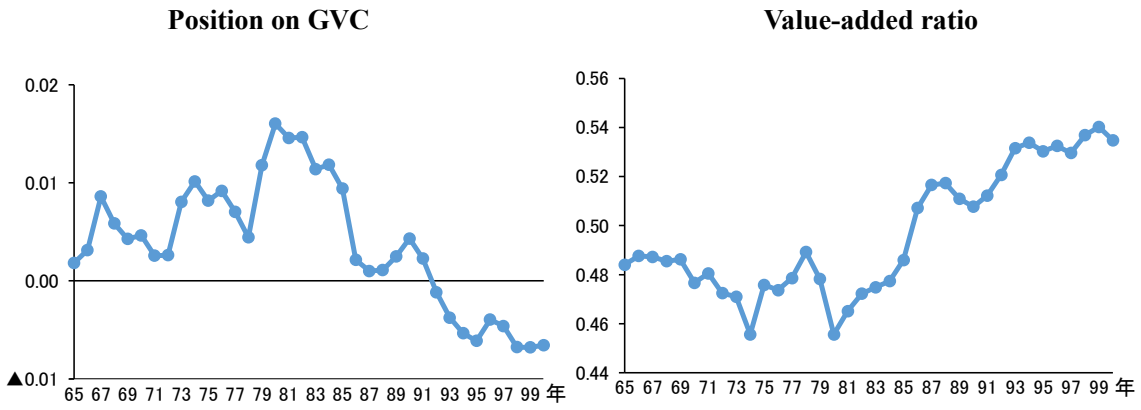
Source: WIOD

[Figure 12] Decomposition of GVC change in Japan: within effect and between effect



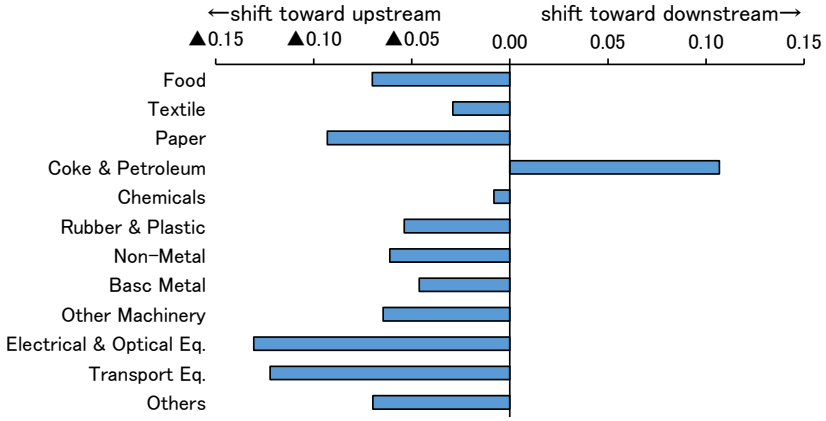
Source: WIOD

[Figure 13] Position on GVC and value-added ratio: the case of Japan



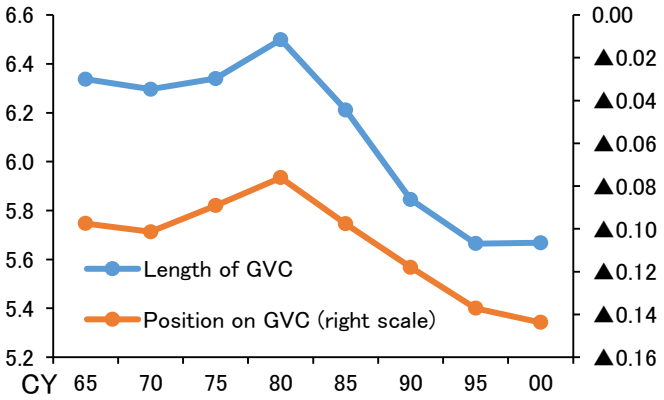
Source: WIOD

[Figure 14] Position on GVC and value-added ratio: the case of Japan



Source: WIOD

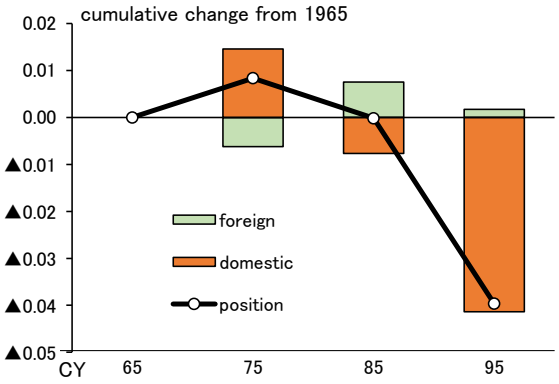
[Figure 15] Length of / position on GVC (Japan, Basic metal)



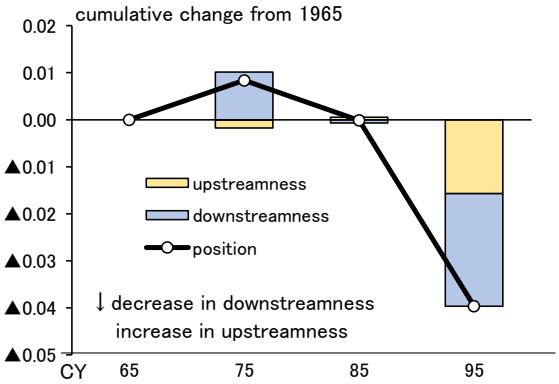
Source: WIOD

[Figure 16] Change of position on GVC (Japan, Basic metal)

Domestic and foreign

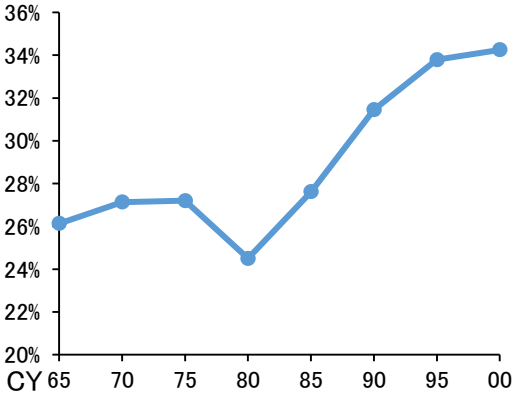


Upstreamness and downstreaness



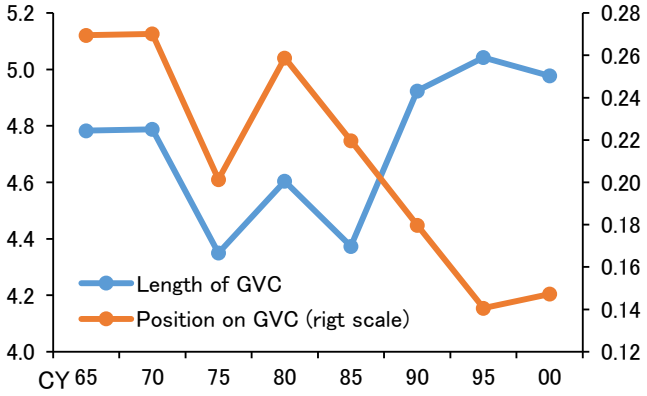
Source: WIOD

[Figure 17] Value-added ratio (Japan, Basic metal)



Source: WIOD

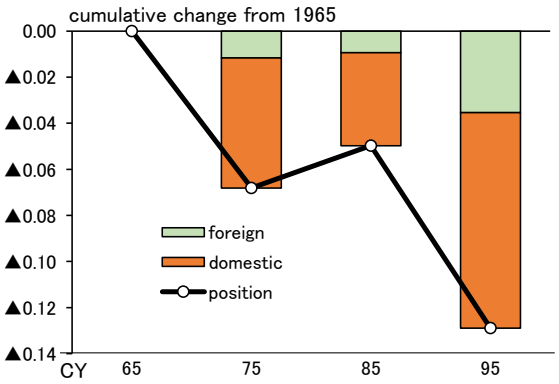
[Figure 18] Length of / position on GVC (Japan, Transport equipment)



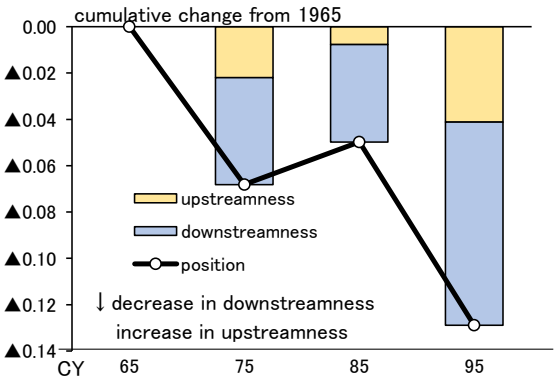
Source: WIOD

[Figure 19] Change of position on GVC (Japan, Transport equipment)

Domestic and foreign

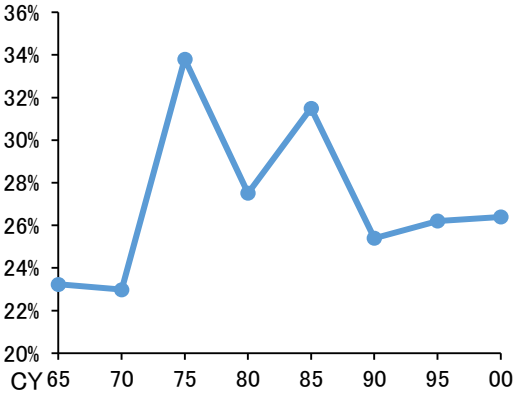


Upstreamness and downstreaness



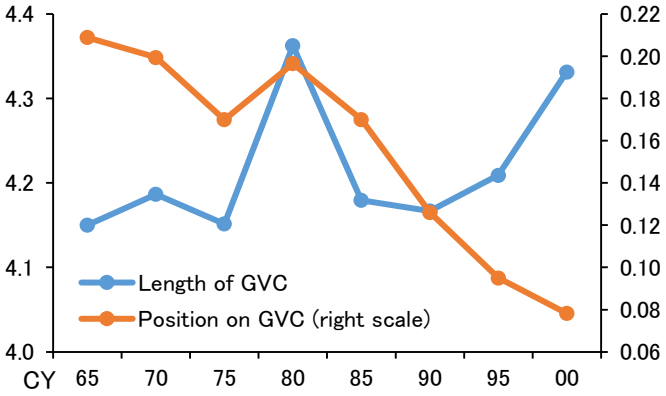
Source: WIOD

[Figure 20] Value-added ratio (Japan, Transport equipment)



Source: WIOD

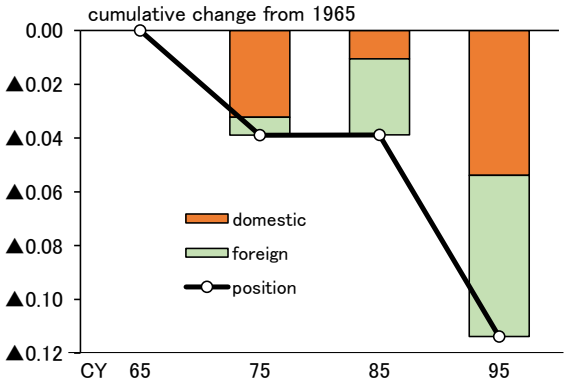
[Figure 21] Length of / position on GVC (Japan, Electricalal and optical equipment)



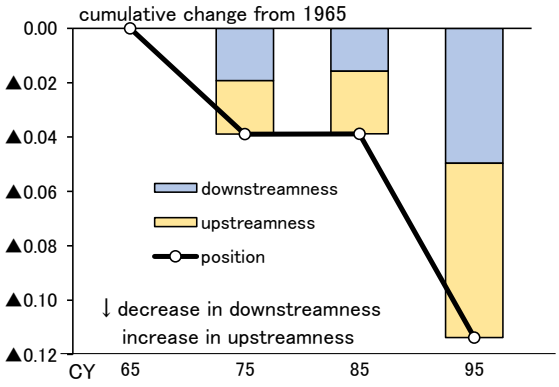
Source: WIOD

[Figure 22] Change of position on GVC (Japan, Electricalal and optical equipment)

Domestic and foreign

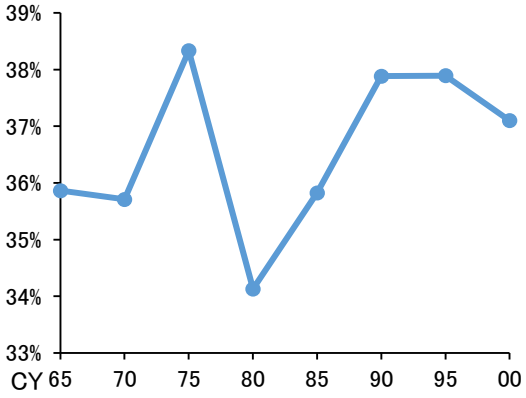


Upstreamness and downstreaness



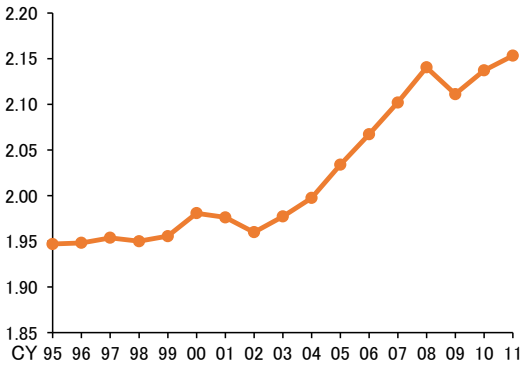
Source: WIOD

[Figure 23] Value-added ratio (Japan, Electricalal and optical equipment)



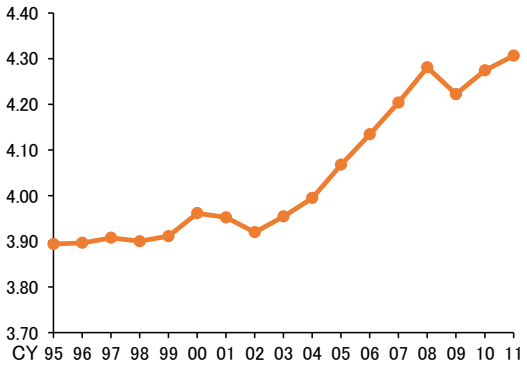
Source: WIOD

[Figure 24] Upstreamness (World)



Source: WIOD

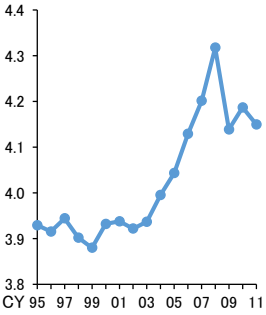
[Figure 25] Length of GVC (World)



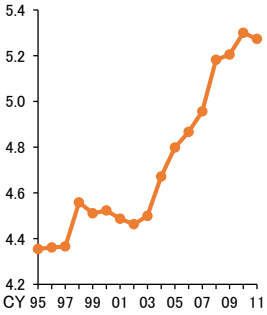
Source: WIOD

[Figure 26] Length of GVC (East Asia)

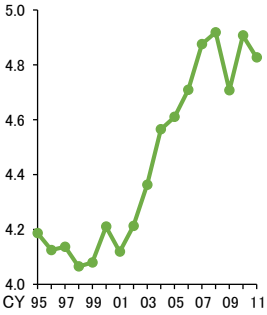
Japan



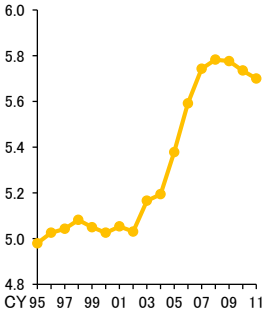
South Korea



Taiwan



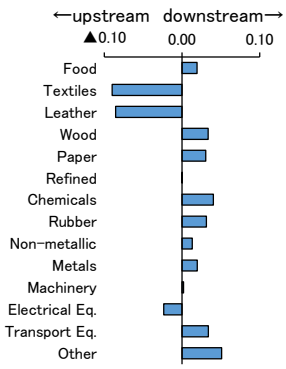
China



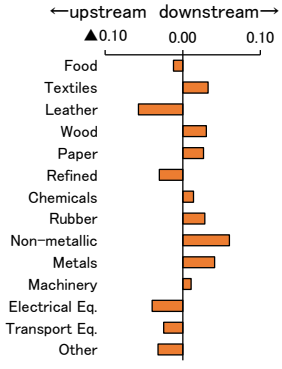
Source: WIOD

[Figure 27] Position on GVC (East Asia, Manufacturing, change from 2000 to 2008)

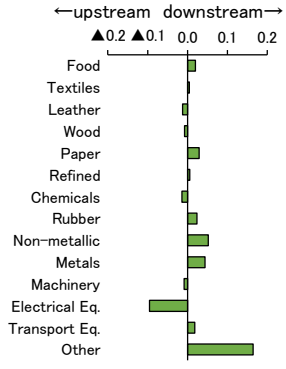
Japan



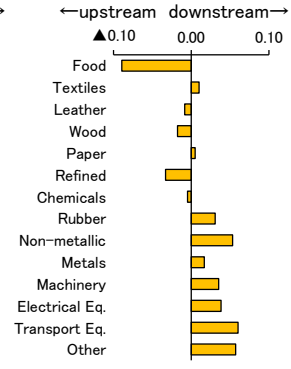
South Korea



Taiwan

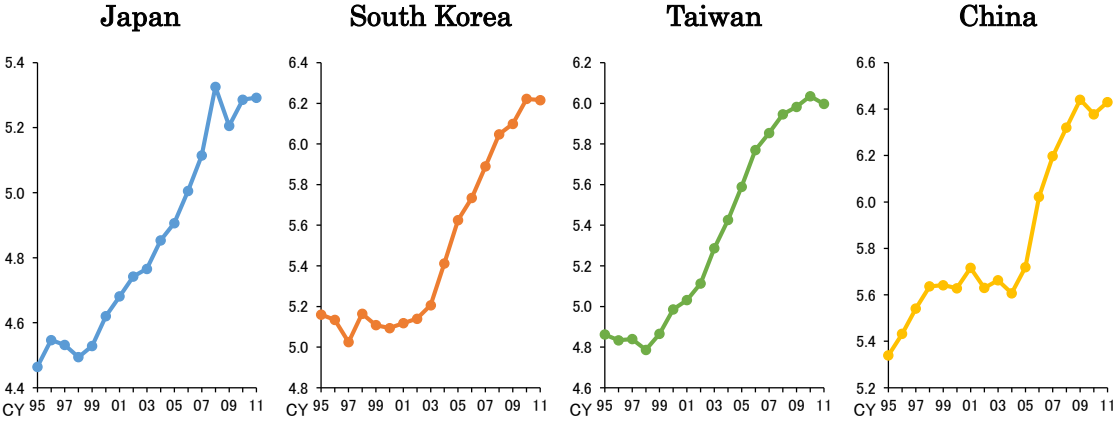


China



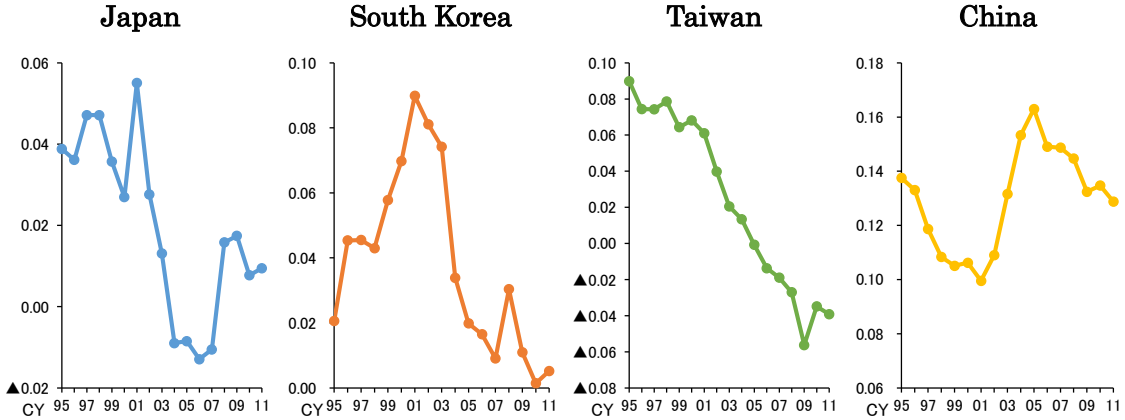
Source: WIOD

[Figure 28] Length of GVC (East Asia, Electrical and optical equipment)



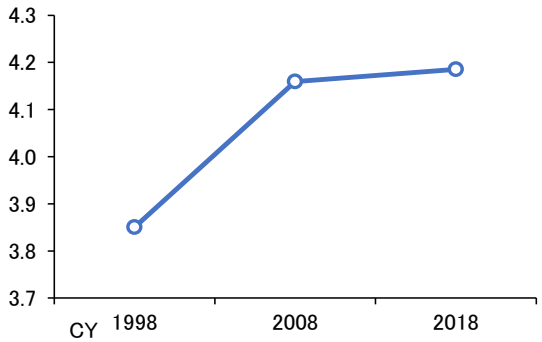
Source: WIOD

[Figure 29] Position on GVC (East Asia, Electrical and optical equipment)

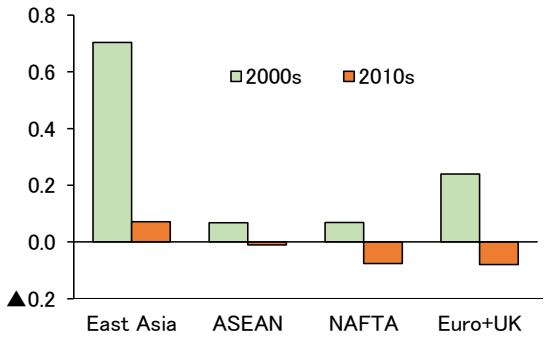


Source: WIOD

[Figure 30] Length of GVC (World)



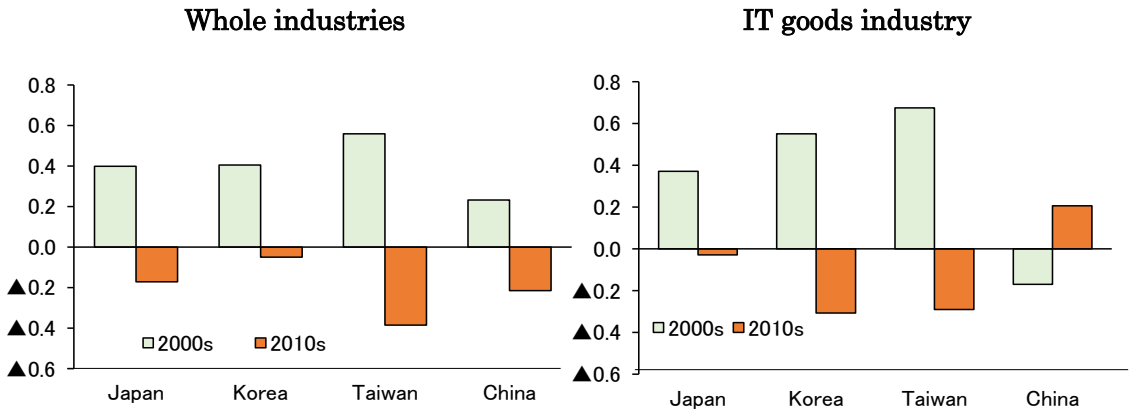
[Figure 31] Change in length of GVC



Note: East Asia includes China, Japan, South Korea, and Taiwan.

Source: OECD

[Figure 32] Change in length of GVC (East Asia)

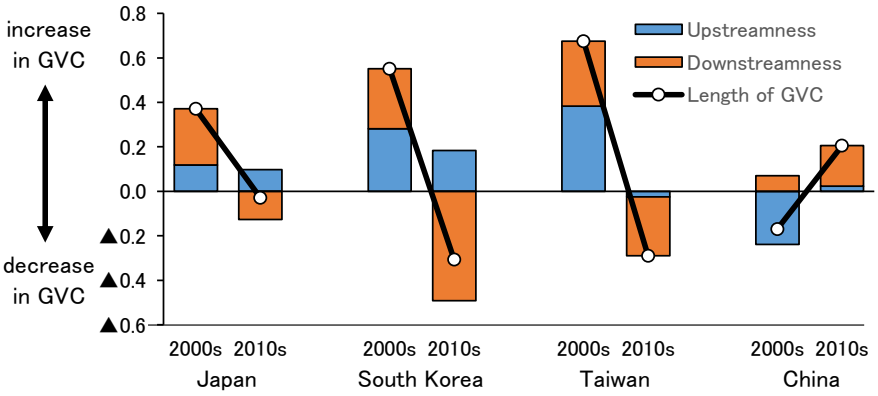


Note: IT goods industry is for "Computer, electronic and optical equipment."

2000s is from 1998 to 2008, 2010s is from 2008 to 2018.

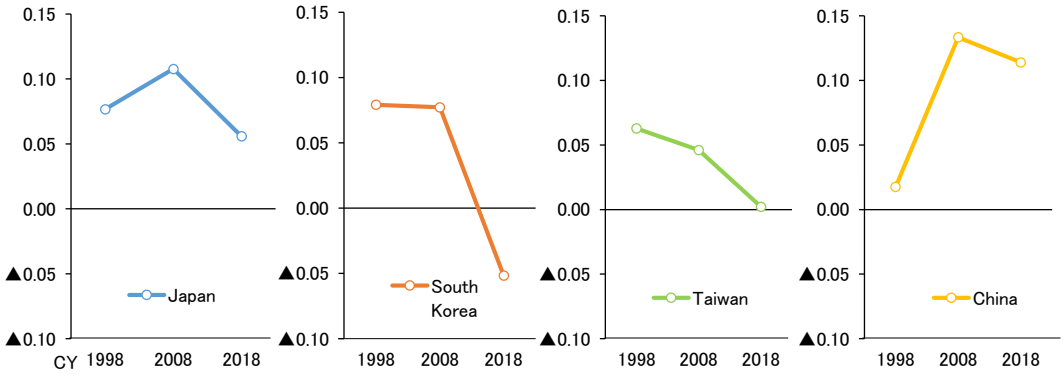
Source: OECD

[Figure 33] Change in length of GVC (IT goods, decomposition)



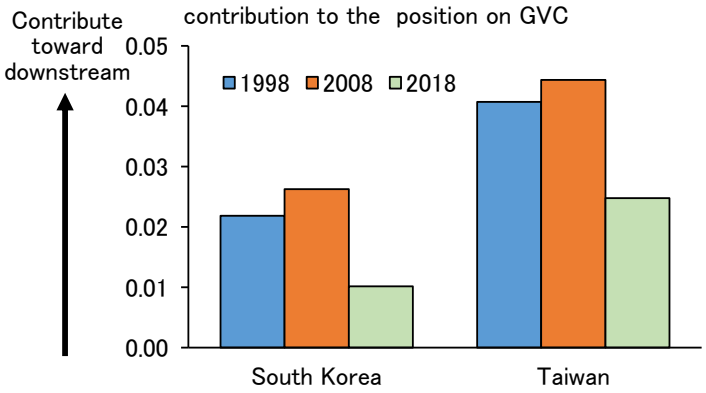
Source: OECD

[Figure 34] Position on GVC (IT goods)



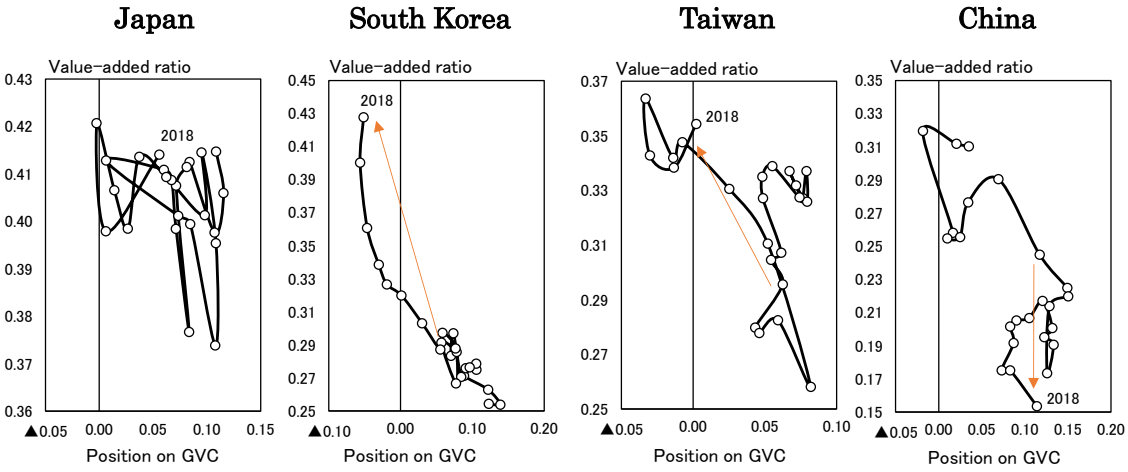
Source: OECD

[Figure 35] Contribution of Japan to the change in the position on GVC (IT goods)



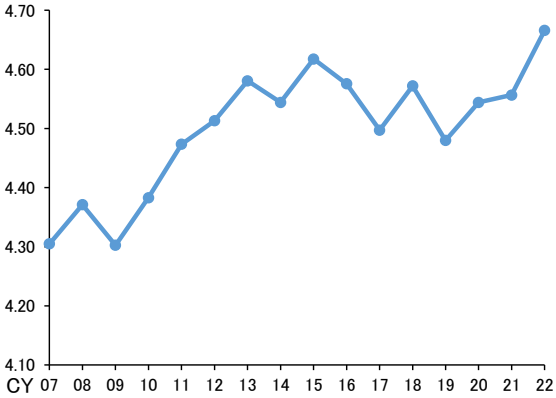
Source: OECD

[Figure 36] Position on GVC and value added ratio (IT goods)



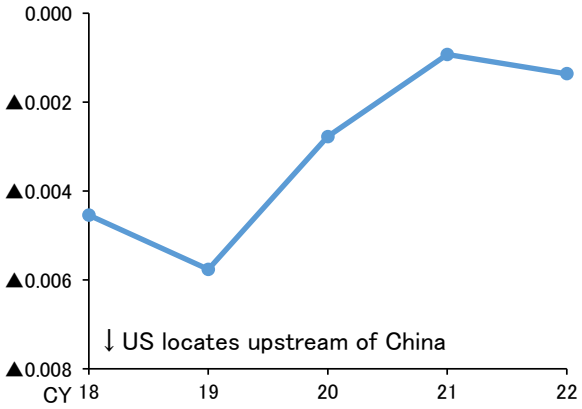
Source: OECD

[Figure 37] Length of GVC (World)



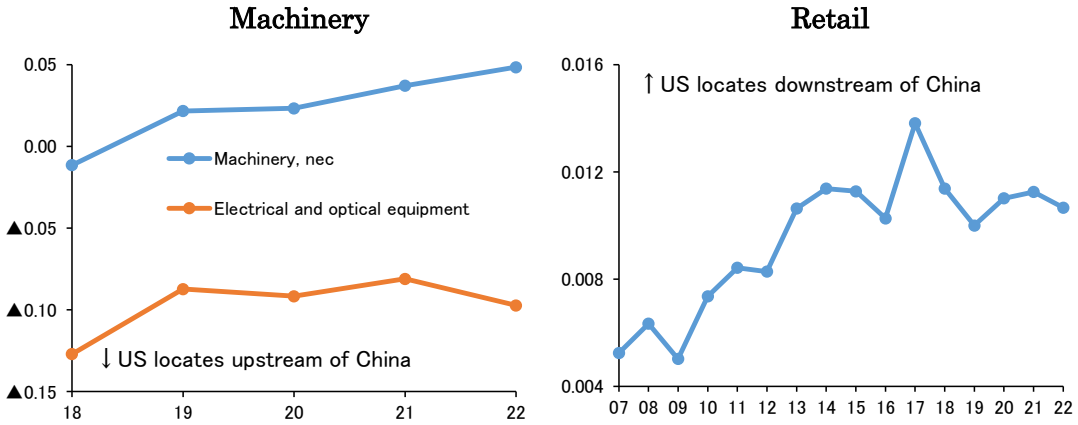
Source: ADB

[Figure 38] Position of the US on GVC toward China



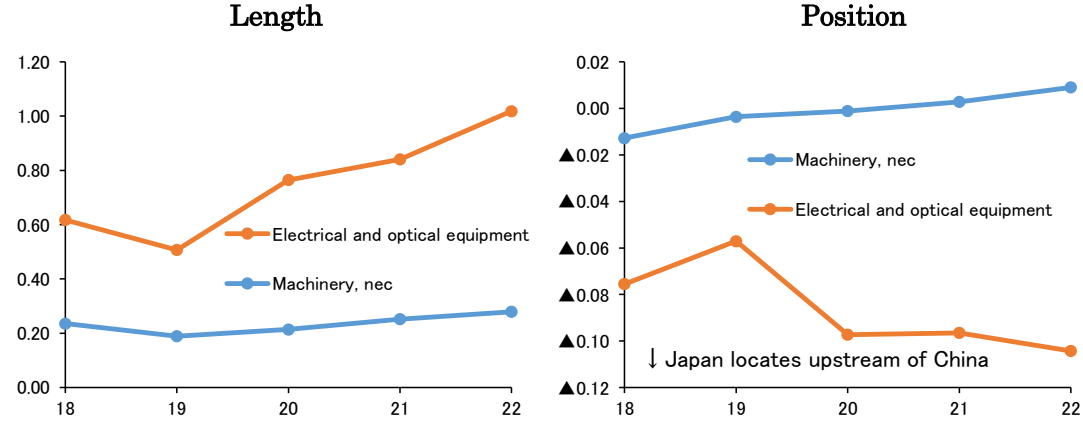
Source: ADB

[Figure 39] Position of the US on GVC toward China



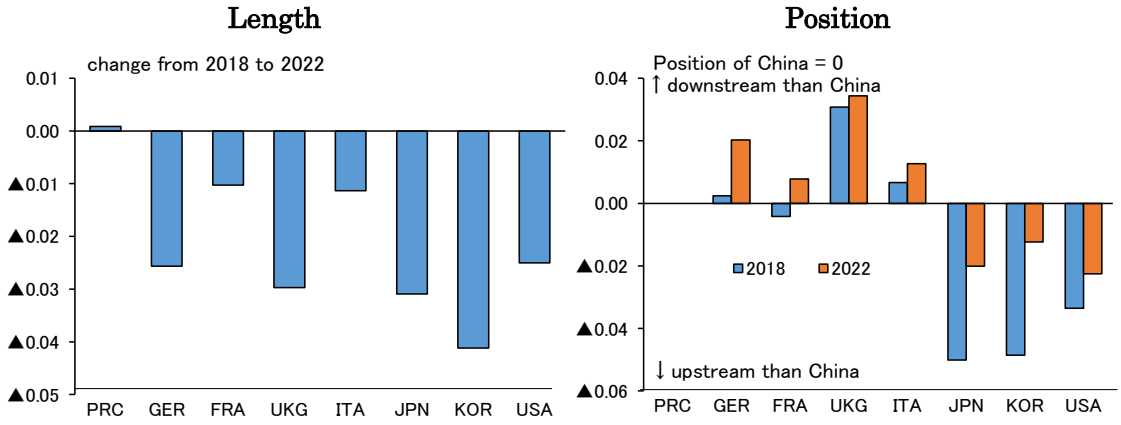
Source: ADB

[Figure 40] Length of / Position on Japan GVC toward China



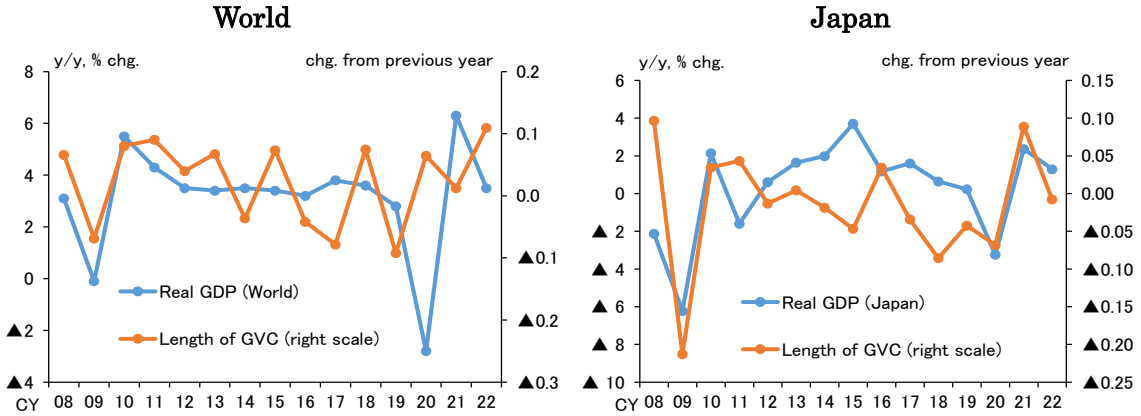
Source: ADB

[Figure 41] Length of / Position on GVC
(Electrical and optical equipment to transport equipment)



Source: ADB

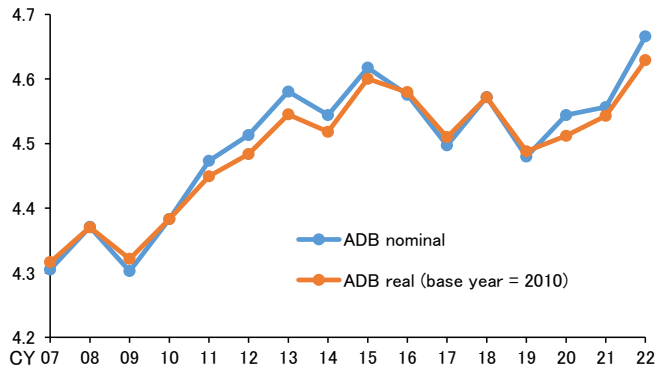
[Figure 42] Real GDP and length of GVC



Note: USD denominated base.

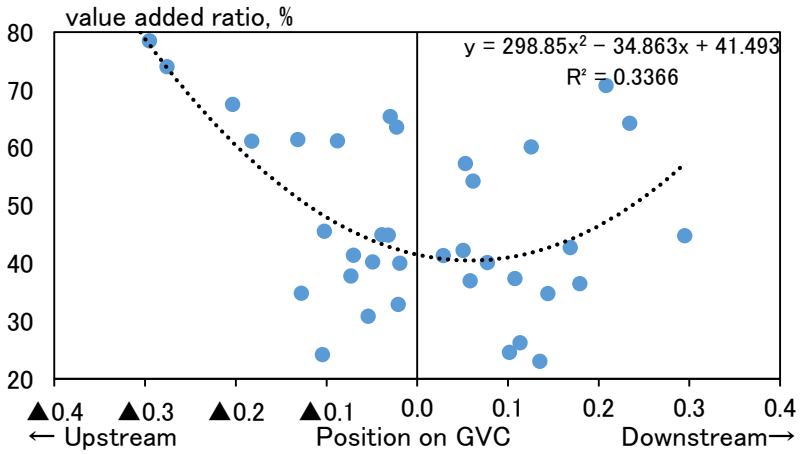
Sources: ADB、IMF

[Figure 43] Length of GVC (World, Nominal and Real)



Source: ADB

[Figure 44] Smile curve (Japan, 2008)



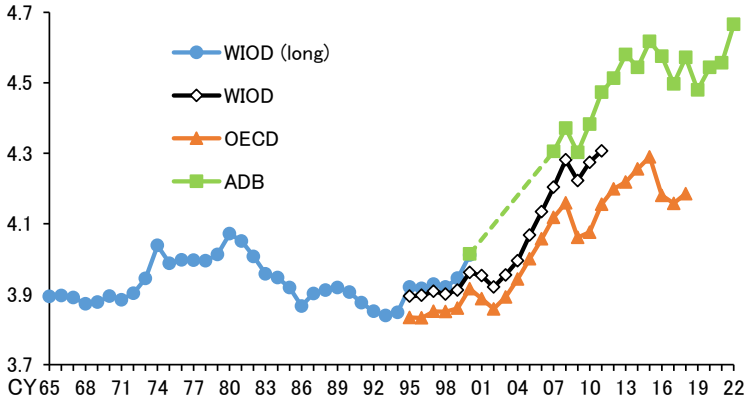
Source: OECD

Appendix 1. Comparison of the global input-output table.

As discussed in section 2.1, several organisations now publish global input-output tables. These differ in terms of the number of countries and industrial categories included, although they share a common currency in that they are denominated in US dollars.

This paper uses these global input-output tables to calculate the upstream and downstreamnesss and to compare the 'length of GVCs (upstream plus downstream)' on a global basis.

Figure A-1 Length of GVC (World)



Source: ADB, OECD, WIOD

Figure A-1 shows that, although there are some differences in the sense of level, the movements in the length of GVCs calculated from all the global input-output tables are similar. In other words, from the 1960s to the 1990s, there were slight fluctuations, but the movement remained within the range between 4 and 4, and these changes were considered to be due to price factors such as oil shocks, so that in reality there was little change in GVC length.

In the 2000s, however, the values calculated from both linkage tables show that the 'length of GVCs' increased, indicating that a major structural change occurred. In the 2010s, on the other hand, both ADB and OECD "length" remained flat, suggesting that its growth stagnated in step with slow trade.

Appendix 2. Concept of Upstreamness

As discussed in Section 2.2.2, upstreamness and downstreamnesss are calculated by the Ghosh and Leonchev inverse matrices, respectively. In the following, we explain the concept of upstreamness originally proposed by Antras and Chor (2013) and then follow the process to see that it eventually becomes a Ghosh inverse matrix, as expressed in Ito and Vezina (2015). For details of the proof, see Suganuma (2016).

$$Y_i = F_i + Z_i = F_i + \sum_{j=1}^{n} a_{ij} = F_i + \sum_{j=1}^{n} d_{ij} Y_j \quad \text{ただし、} d_{ij} = \frac{a_{ij}}{Y_i}$$

$$\Leftrightarrow\ Y_i = F_i + \sum_{j=1}^{n} d_{ij} F_j + \sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j + \sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{ik} d_{kl} d_{lj} F_j + \cdots$$

$$\Leftrightarrow \quad 1 = \frac{F_i}{Y_i} + \frac{\sum_{j=1}^{n} d_{ij} F_j}{Y_i} + \frac{\sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j}{Y_i} + \frac{\sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{ik} d_{kl} d_{lj} F_j}{Y_i} + \cdots$$

Antras and Chor (2013) defined the following equation as 'upstreamness', with each term on the right-hand side of the above equation weighted according to the distance to final demand.

$$U_i = 1 \cdot \frac{F_i}{Y_i} + 2 \cdot \frac{\sum_{j=1}^{n} d_{ij} F_j}{Y_i} + 3 \cdot \frac{\sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j}{Y_i} + 4 \cdot \frac{\sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{ik} d_{kl} d_{lj} F_j}{Y_i} + \cdots$$

$$\Leftrightarrow U_i = \frac{1}{Y_i}\left(1 \cdot F_i + 2 \cdot \sum_{j=1}^{n} d_{ij} F_j + 3 \cdot \sum_{j=1}^{n}\sum_{k=1}^{n} d_{ik} d_{kj} F_j + 4 \cdot \sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n} d_{ik} d_{kl} d_{lj} F_j + \cdots \right)$$

After bundling the upstreamnesss of each industry in a vector, a further development of the equation proves that the it is calculated as a Ghosh inverse matrix, as shown in section 2.2.2.

$$\vec{U} = \mathbb{Y}^{-1} \cdot [I + 2M + 3M^2 + \cdots]\vec{F} \ where\ \mathbb{Y} = \begin{bmatrix} Y_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & Y_n \end{bmatrix}\ M = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & d_{nn} \end{bmatrix}$$

$$\Leftrightarrow \vec{U} = \mathbb{Y}^{-1} \cdot [I - M]^{-1}[I + M + M^2 + \cdots]\vec{F}$$

$$\Leftrightarrow \vec{U} = \mathbb{Y}^{-1} \cdot [I - M]^{-2} \cdot \vec{F}$$

$$\Leftrightarrow \vec{U} = \mathbb{Y}^{-1} \cdot [I - M]^{-1} \cdot \vec{Y}$$

$$\Leftrightarrow \vec{U} = [\mathbb{Y} - M\mathbb{Y}]^{-1} \cdot \mathbb{Y} \cdot \vec{1}$$

$$\Leftrightarrow \vec{U} = [I - \mathbb{Y}^{-1}A]^{-1} \cdot \vec{1} \ \ where\ A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

$$\Leftrightarrow \vec{U} = [I - B]^{-1} \cdot \vec{1} \ \ where\ B = \mathbb{Y}^{-1}A = \begin{bmatrix} \frac{a_{11}}{Y_1} & \cdots & \frac{a_{1n}}{Y_1} \\ \vdots & \ddots & \vdots \\ \frac{a_{n1}}{Y_n} & \cdots & \frac{a_{nn}}{Y_n} \end{bmatrix}$$

Appendix 3. Definitions of upstreamness and downstreamness: infinite geometric series

As indicated in section 2.2.2 and Appendix 2, the upstreamness and downstreamnesss are represented by inverse matrices. Suganuma (2016) explains this point using the fact that the inverse matrix is the sum of an infinite geometric series (Equations (4-1) and (4-2)). This is actually a more intuitive way to understand the concepts of upstreamness and downstreamnesss.

Taking upstreamness as an example, when the output of one industry is used in the production of another industry, it manifests itself as a series of stages (B), (B^2), (B^3), and so on, in an attenuated but continuous manner. Adding these up, the upstreamness is finally calculated as "the average number of processes that the output of the good undergoes before arriving at the final good".

Such equation expansion also makes it possible to analyse whether changes in the upstreamness (downstreamness) of an industry are due to an increase in the use of the first stage. Suganuma (2016) shows that the expansion of upstreamness in the manufacturing industry is basically due to the first stage, while in some non-manufacturing industries, the second stage is the largest, indicating that the expansion of indirect use contributed to the expansion of upstreamness.

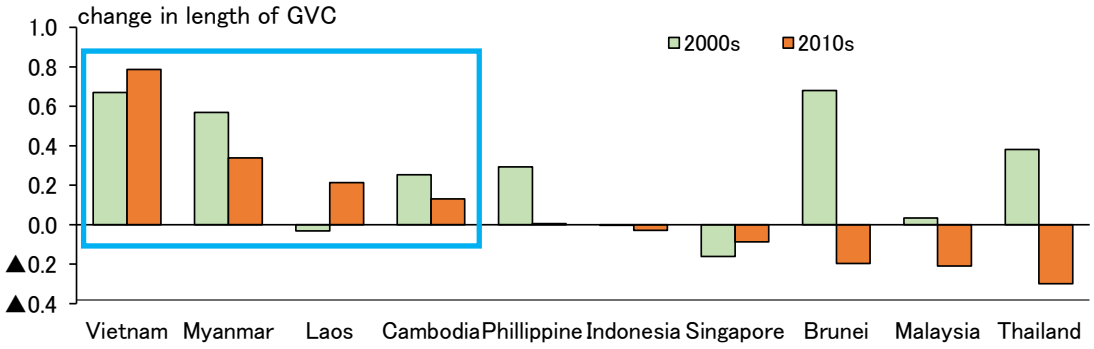
$$\vec{U} = [I - B]^{-1} \cdot \vec{1} = [I + B + B^2 + B^3 + \cdots] \cdot \vec{1} \quad (4-1)$$

$$\vec{D} = [I - G]^{-1} \cdot \vec{1} = [I + G + G^2 + G^3 + \cdots] \cdot \vec{1} \quad (4-2)$$

Appendix 4. GVCs in South East Asia

The paper showed that the length of GVCs remained largely unchanged over this period in South-East Asia as a whole. However, a country-by-country breakdown showed that there was a contrast in movement, particularly in the 2010s.

Figure A-3 Changes in the length of GVCs in Southeast Asian countries



Source: OECD

Figure A-3 shows the change in the length of GVCs in the South-East Asian countries, by country. It can be seen that in the four 'CLMV' countries on the left-hand side, GVCs continued to grow even in the 2010s, when global GVCs as a whole slowed down.

As for the background to these developments, in China, which became the 'factory of the world' in the 2000s, the subsequent rise in labour costs and increased business risks led to a widespread move by companies to diversify their production sites to these 'China plus one' countries. Even as the growth of GVCs stagnated in the world as a whole, these countries are thought to have increased their length as they were integrated into GVCs.