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【Discussion Paper Series by ESRC-JSPS Research Project on Japan and the UK】

Has COVID-19 Pandemic Transformed Japan's GVCs? Tracking Changes by Applying RAS Technique to Multi-Regional Input-Output Tables

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1 Introduction

In the past twenty years, the global economy has been subject to a series of shocks which include global financial and economic crisis in the late 2000s, European sovereign debt crisis, Great East-Japan Earthquake, Brexit, and the U.S.-China trade friction in the 2010s, and COVID-19 pandemic in the early 2020s.[2] Each time, not only economies directly involved but also others linked with those economies through international trade were greatly affected. External shocks also posed a challenge to the global value chains (GVCs) which have been established on the premise that international trade would not be disrupted easily.[3]

Value chains have been created by unbundling the production process to a number of stages and allocating each of the stages to the firms most fit to undertake the task. Some of the firms may be domestic ones, but with opportunities expanding in a more liberalized and globalized world, many of the firms would be foreign ones which include subsidiaries of domestic firms. When a production process involves crossing border for more than twice, it is called a GVC (Antras 2020; Antras and Chor 2022). While taking part in a GVC raises economy's productivity and per capita income, it would naturally rely on sound and stable international trade. Any change to the soundness and stableness of international trade may require a transformation of the GVC.[4]

When faced with a shock which may have a lasting impact on trade, or which may show itself repeatedly, a GVC can adapt to the new environment in a number of ways. While the details will be discussed in section 2, options suggested include the following.

If a firm would like to avoid any disruption of its production, depending on the location of the shock, it may choose to shift the supplier of intermediate inputs to a foreign country (offshoring), to the home country (onshoring), or to spread the suppliers to different countries (diversification). When the firm takes one of these options, it would come up as a change in the pattern of trade across borders.

Alternatively, if a firm prefers to have the ability to resume production promptly even when it faces disruption due to a shock, it may strengthen relationship with the current

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[2] Future shocks that could be perceived include those related to climate change, geoeconomic tensions, and digital disruptions (Baldwin et al. 2023).

[3] At the same time, GVCs are considered to contribute in transmitting and/or magnifying the impact of shocks. See Acemoglu et al. (2012), Acemoglu and Tahbaz-Salehi (2020), Coveri et al. (2020), Kejzar et al. (2022), Elliot et al. (2022), Inoue and Todo (2023b), and Bai et al. (2024)

[4] Blanchard et al. (2023) suggests that GVCs have important influence in shaping trade policy by encouraging governments to liberalize trade. On the other hand, Bown (2018) argues that import protection of intermediate inputs had increased between 2010 and 2016, a period even before the U.S.-China trade friction.

intermediate input suppliers so that stoppage can be overcome collaboratively. If these options are taken by firms, the change may not be obvious by just looking at international trade.

Instead of affecting the suppliers upstream, a shock may affect the customer downstream as well. If the firms want to avoid depending only on domestic customers, it may want to sell its product abroad (foreign marketing). On the other hand, if the firm prefers to reduce the sales abroad, it may decide to cultivate domestic market for its product (domestic marketing). In each of the cases, diversifying customers may also be a solution.

Which of the options has been chosen in response to the shocks? Many empirical analyses have been conducted in relation to the shocks taking place, but the results are somewhat mixed. The situation with the still limited number of researches on the changes arising from COVID-19 pandemic is no exception. It is partly due to the different approaches that have been taken, but is also due to the limited data availability and insufficient tools to analyse transformation.

In terms of data, they typically use data on international trade. While they are suggestive of any changes that have taken place, it is difficult to judge whether they are due to changes in GVCs or to changes in more traditional trade. That is because data on international trade does not by itself show the input and output relationship that is critical to the analysis dealing with GVCs. It is also difficult to determine whether any changes are due to decisions made by the firms and/or the government. It is because international trade is also affected by many other factors including economic responses by the firms to technological change and economic development.

With regards data, availability of multi-country input-output table is important. It enables researchers to track input sources and output markets of a given industry in a given economy across borders. An important contribution in this regard is the Inter-Country Input-Output Table (ICIO) compiled and published by the Organisation of Economic Co-operation and Development (OECD). It is a multi-country input-output tables covering 76 countries (plus rest of the world) and 45 industries. It has been widely used to analyse the features of and the changes taking place in GVCs. However, the most recent edition (2023 edition) covers only the period up to 2020 (from 1995) so that it is not enough to fully analyse the impact of COVID-19. Furthermore, ICIO is only available in current prices which reflects not only changes in volumes but also in prices. It is desirable to have a multi-country input-output table that covers more recent years and is also in constant prices.

Equally important is the methodology to analyse the impact of shocks on GVCs. Even

if we have a multi-country input output table that satisfies these requirements, a methodology that allows the researcher to identify the transformation of the GVCs due to discretionary decisions made by the firms and/or the government separately from those changes due to other factors. It implies that, at least, the changes due to economic incentives that result from technological change and economic development need to be removed from any changes that may have taken place in the input-output relationship. Analysis that has been done already using OECD's ICIO, for instance, has made significant contribution in understanding the implications of GVCs on individual economies, but the distinction between the two changes mentioned above has not been made.

The aim of this paper is to analyse the impact of the most recent shock, the COVID-19 pandemic, on Japan's GVCs. In order to answer the research question, an alternative set of multi-country input-output tables, namely, Multi-Regional Input-Output (MRIO) compiled and published by the Asian Development Bank (ADB) is used. MRIO provides tables for the period up to 2022 whose value is in constant CY2010 prices.

The methodology applied to these tables is RAS technique. It is a technique usually used to estimate unknown input coefficients when only partial information is available. In this paper, it will be used as a technique that will decompose the changes in input coefficients and output coefficients so that we will be able to distinguish between coefficient changes due to reactions to economic incentives and those due to discretionary policy actions.

The rest of the paper is organized as follows. Section 2 surveys the literature on the GVCs' responses to shocks. Section 3 describes the basic structure of ADB's MRIO. It will be followed by Section 4 which explains how the RAS technique can be applied to decompose the actual changes taking place in the MRIO. Section 5 presents the policy-induced effects that are obtained by the RAS procedure, and Section 6 discusses how the actual changes taking place in the MRIO can be explained by the results. Concluding remarks are provided in Section 7.

2 Literature

2.1 Supply disruption

Facing the COVID-19 pandemic, a number of options that GVCs may adopt in response to the shock have been suggested by economists and international organizations (OECD, 2020; UNCTAD, 2020; WTO 2023). Once the information on the vulnerability

of GVCs are known, the firms need to review their risk management measures and take necessarily action, if any, to minimize the damage when another shock occurs in the future.[5] The following are the options that are often suggested on the basis of the lessons learned from previous shocks.[6] They are mainly options to deal with disruptions in the supply of intermediate goods and services.

First is to shift suppliers of intermediate goods to less-risker geographical locations (Javorcik 2020; Todo 2022; White House 2023). This option includes what is often called "reshoring" or "onshoring" the new supplier is in the same economy as the purchaser of the inputs, and "offshoring" when the if the new supplier is in a foreign economy. In the case of the latter, it may be further classified to "nearshoring", "friendshoring", or "regionalization" depending on the proximity of the new supplier to the purchaser in terms of geography and/or political principles.

Second is to secure multiple suppliers of intermediate goods (Hayakawa and Mukunoki 2021a; Todo and Inoue 2021; Shepherd 2021; CEA 2022; Todo et al. 2023; OECD 2023).[7] The proposal to "diversify" sources of inputs to suppliers in different geographical locations corresponds to this option. Diversification is considered to be superior than onshoring because the latter increases the risk by relying solely on domestic suppliers (OECD 2021; Bonadio et al. 2021) so that onshoring should take place only as a result of other factors (Bacchetta et al. 2021). Note that the inputs supplied by different suppliers in this case should be different in principle (implying that each of the inputs are "single-sourced"). If they supply identical inputs, it would be included in the next option.

Third is to maintain a multiple number of actual or potential suppliers of same inputs and/or to hold precautionary inventories of inputs (Brandon-Jones et al. 2014; Martins de sa et al. 2019; Shih 2020; McKinsey Global Institute 2020). On the one hand, having multiple suppliers requires that the inputs supplied by different suppliers need to be standardized so that they can be "substitutable" (IMF 2022). Multiple sourcing could also make use of redistributed manufacturing that builds on additive manufacturing and micro-factories (Phillips et al. 2022). On the other hand, the suggested change in stock management implies that "just-in-time" inventory-saving principle should be replaced by

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[5] Collecting sufficient information on the GVC beyond the first-tier suppliers, making them visible, and sharing them among the participants in the GVC are preconditions for any action that should be taken. Governments can also support the private-sector's efforts by collecting and disseminating information related to possible shocks to the private sector.

[6] The current state of the literature on GVCs is summarized in Fernandez-Stark and Gereffi (2019), Antras and Chor (2022), and Inomata (2019).

[7] Chopra and Sodhi (2014) and Boehm et al. (2019) among others suggest the importance of diversifying suppliers of intermediate inputs on the basis of the U.S. experience at the time of Great East-Japan earthquake in 2011.

"just-in-case" inventory-holding principle to avoid stock-outs and production discontinuation (Carreras-Valle 2021; Ortiz 2022; Alessandria et al. 2023). These options are usually characterized as "redundancy" because they would remain idle when there are no shocks and would increase cost in the short-term.

While these options are popular among the economists and in the policy arena, they are being criticized by other economists and scholars in the business administration who have been involved in risk management (Miroudot 2020a). The main concern for the critics is that the suggested options are emphasizing the need of "robustness": the need to maintain production even when they are subject to negative influence of the shock. The argument is based on the understanding that the current GVC structure should be an optimal result of firms' effort to maximize efficiency so that any deviation from it should reduce efficiency (IMF 2019; Baldwin and Freeman 2022). It should also be difficult for the firms to change because of the large sunk-cost that has been paid in establishing the current GVC (Baldwin 1988, Antras 2021).[8]

According to the critics, what should be pursued in this respect is not robustness, but "resilience": the ability to rapidly resume production even when the production has to cease for a short period of time (Ponomarov and Holcomb 2009; Behzadi et al. 2020; Miroudot 2020b).[9] From their perspective, single sourcing of inputs and enhancing long-term relationship with the suppliers lead to faster recovery of production when it is affected by shocks (Haraguchi and Lall 2015; Ando et al. 2021; Jain et al. 2022). The example of Japanese firms, which are known to have created a long-term relationship with their suppliers, are often referred to in this respect. They have shown that the relationship helped to shorten the time to resume production (Fujimoto 2021). It is argued that it becomes more important when the good produced is not a product of an open modular architecture but rather a product of an integral collaborative architecture. Understanding of this kind has led to suggestions of developing capabilities so that firms can swiftly switch from a competitiveness-first operation at normal times to a continuity-first operation at times of crisis (MacDuffie et al. 2021).

Until now, we have been surveying the *suggested actions* as to how GVCs should react to shocks. What, then, are the *actual actions* that have been taken by the firms and the governments during the COVID-19 pandemic?

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[8] Achieving optimality in terms of efficiency may not necessarily mean that the status quo of GVCs is optimal in a political sense. Antras (2021) notes that, if the negative consequences of globalization (such as widening inequality) are left uncontrolled, the induced policy reactions may force changes to the GVCs.

[9] Note that the term "resilience" in the literature is often used more broadly, including the features that is covered by the term 'robustness' as defined in this paper.

In economies other than Japan, there has been a rich accumulation of empirical studies on the actual changes that has taken place in response to the shock. However, the evidence on what were the changes in those economies are, so far, mixed.

While surveys on the firms indicate that redundancy, stockpiling, and reshoring are among the popular measures taken (BCI 2023), and some report that near-shoring and friend-shoring have taken place (Alfaro and Chor 2023, CEA 2024), other empirical analyses have found little evidence of onshoring (Brenton et al., 2022; WTO 2023), and any decoupling that took place has been partial (Ando et al. 2024).[10] As for the diversification of suppliers, there seems to be some evidence that it has increased (Todo 2022) so that the chances of survival of the firms has improved (Lebastard et.al., 2023).

Compared to the ample research done on other economies, the impact on COVID-19 on Japan's GVCs is yet to be analysed. The vulnerability of Japan's GVCs to shocks had been acknowledged (METI 2020) and the impact of COVID-19 was warned to be of a significant magnitude even at the early stages of infection (Inoue and Todo 2020; Inoue et al. 2021). Evidently, the warnings were justified by the reality: The Japanese economy was significantly hit by the pandemic (Hayakawa and Mukunoki, 2021b). It was not only because of the magnitude of the economic impact of the decline in economic activity due to the soft-lockdown introduced domestically, but also because of the acute stop of supplies from other economies, most notably from China, which were subject to harsher government intervention than Japan.

However, the decline in production recovered within in a relatively short period of time (Ando et al. 2021), a phenomenon similar to what had been observed when the GVCs were affected by the Great East-Japan earthquake (Fujimoto 2011; Todo et al. 2015; Todo 2018; Inoue and Todo 2019) and the great flood in Thailand (Haraguchi and Lall 2015). The resilience is considered to be a result of a number of factors, including the collective efforts of the firms to establish a long-term relationship with each other. There are also indications that having larger inventories helped when supply of inputs fell (Zhang and Doan 2023).

At the same time, firms' responses to the surveys show that there are many firms considering, in the medium-term, diversification of their suppliers in addition to enhancing collaborative relationship with other firms involved in GVCs. In contrast, only a few considered shifting of suppliers to other regions including Japan ("onshoring") (DBJ 2020; JBIC 2021, METI 2021). However, that does not mean that the firms are not

[10] As for the impact of the US-China trade friction, Freund et al. (2023), Wang and Hannan (2023), Fajgelbaum et al. (2023) find that trade diversion has taken place after the imposition of tariffs.

considering any shift to other destinations. In fact, in the long-term, there are indications that firms are planning to have more tighter relationship with ASEAN economies (because of the rise in labour cost in China) and India (because of the size of the market) (JBIC 2023; JETRO 2023). They may also consider expanding domestic production if geopolitical or economic security reasons become more urgent (METI, 2023).

2.2 Demand collapse

Compared to the discussions on the impact of supply disruption through GVCs, those on the impact of demand collapse through GVCs are limited. Decline in exports of intermediate inputs or final products emerged when employment falls and income declines in the destination economy (as seen during the European sovereign debt crisis); when demand for durables drops due to the "postpone-able" nature of these goods (as seen during the global financial and economic crisis); when international trade faces difficulty because of stringent trade finance (as seen during the global financial and economic crisis); when trade is restricted because of higher trade barriers (as seen during the US-China trade friction); or when consumption activities are constrained by voluntary and involuntary restraint (as seen during the COVID-19 pandemic) (Eaton et al. 2016; Baldwin and Tomiura 2020; Shingal and Agarwal 2023). In order to prepare for demand disruptions, therefore, exporting economies are recommended to diversify customers (Todo et al. 2023a).

However, the experience of COVID-19 pandemic tells us that negative demand shocks to certain goods or services may partly be offset by factors such as panic purchase of other goods and services (Hayakawa and Mukunoki 2021b), and by widespread use of e-commerce (Hayakawa et al., 2023). These offsetting factors may be behind the fact that empirical analysis of the impact of demand shocks to economies involved in GVCs finds limited evidence of significant negative impact on the exporting economies. While simulation exercise expected significant impact of demand shocks (Inoue and Todo 2020; Pichler et al. 2020; George et al. 2020), analysis of international trade data showed that the impact of demand shocks was insignificant (Hayakawa and Mukunoki 2020), short-lived (Hayakawa and Mukunoki, 2021b), or smaller than that of supply-shocks (Inoue and Todo, 2023a).

2.3 Reasons for the mixed results

Mixed results of the previous studies are partly a result of the lack of data that is

available for empirical studies to be made. However, it may also be a result of the following factors.

First is the difference between a macro approach and a micro approach. Some studies have been made on the basis of micro data on actions taken by firms in a certain industry, while others depend on more aggregated dataset that averages out the difference in firms' actions. An action taken in a firm/industry may not be the one taken by a different firm/industry.

Second is the difference between the options that have intentionally been taken by the firms and the actual outcome which may reflect, not only those intentional actions, but also the firms' actions reacting to economic incentive to maximize profits. For example, if the labour cost in a certain location is becoming attractive enough to increase purchase from suppliers in the location (e.g. increase in "offshoring"), what can be done by the firm to take into account the risk involved (e.g. increase in "onshoring") may be to keep the current supply mix as it is (e.g. no change in sourcing).

In the following, we will make use of a multi-regional input-output database which is explained in more detail in section 3. It implies that this paper will take a macro-approach to the issue so that the different actions that may be taken by different firms will be averaged out. In addition, because of the nature of the database, what is shown in the paper is the changes, if any, in the GVC that involve input sourcing and output marketing that crosses international borders. Therefore, the analysis is able to clarify whether there has been any onshoring, offshoring, or diversification, but not whether there has been a change in terms of redundancy, for example.

In terms of the distinction between the firms' actions that are made intentionally and actions that are reactions to economic incentive, the methodology employed in this paper, which will be explained in more detail in chapter 4, enables us to extract the two different changes. It should be able to show whether the intentional actions taken were consistent with or against the economic incentives that the firms/industries were subject to, and, if they were against the actions that should be taken in response to economic incentives, whether they were large enough to offset the changes due to economic incentives or not.

3 Data

As it was defined earlier, a global value chain is a production process which crosses international borders for more than twice, before the product is sold to satisfy final demand. Because of this nature, if a global value chain is to be analysed, an input-output table that covers the related economies is essential.

The basic framework of a multi-country input-output table is as shown in Figure 1. It is nothing conceptually different from input-output tables for a single economy except that it is now for the world as a whole so that different industries in different economies are identified separately. On the one hand, the values in each of the columns show the input structure of production by an industry in an economy, where the sources of intermediate inputs are identified as industries in different economies. On the other hand, the values in each of the rows show the output structure of production by an industry in an economy, where the destination of products as intermediate inputs and those meeting final demands are identified as industries and sectors in different economies.

<Figure 1>

This framework allows a researcher to trace the source of input across borders which is necessary if the structure of the GVCs is to be analysed. In particular, by looking at the input structure of industry *i* in economy *k*, upstream structure of the GVC in which this particular industry *i* in economy *k* is taking part can be identified. Similarly, by looking at the output structure of industry *j* in economy *l,* downstream structure of the GVC in which this particular industry is taking part will be revealed.

To compile such a multi-country input-output table, what is necessary is not only detailed bilateral international trade data for goods and services, but also domestic input-output tables of the relevant economies that are compatible with the international trade data.

Because of this demanding requirement, it took a while since the conception of an input-output table (Leontief 1936) to cover more than a single economy. After some pioneering work in this field by researchers using data collected by the Global Trade Analysis Project (GTAP), such as Koopman et al. (2014), a project funded by the European Commission and undertaken by a consortium of twelve research institutions headed by the University of Groningen, came up with the World Input-Output Database (WIOD). It is based on official data published by individual economies and international institutions, and is compiled in a consistent manner with the system of national accounts (SNA). It was first published in 2012 and has been updated until 2016: the last release provides tables for each year during the period 2000-2014, covering 43 economies and the rest of the world, each consisting of 56 industries. It contributed greatly in promoting the understanding of global value chains which can be seen in Antras and Gortani

(2020).[11]

One of the successors in providing international input-output tables for research is the Inter-Country Input-Output (ICIO) tables compiled by the Organisation of Economic Co-operation and Development (OECD). The work started in the 1990s and the latest 2023 edition provides data for each of the years in the period 1995-2020 covering 45 industries in 76 economies and the rest of the world.[12] ICIO has been used extensively to analyse trade in value-added (TiVA) which can be derived from the tables. Studies have also been made on the basis of ICIO to look into the changes that has taken place in the GVCs such as Baldwin et al. (2023).

However, ICIO at present is not sufficient to answer the research question of this paper for the following reasons. First, the tables provided are only up to 2020 which may be too short if the analysis intends to look into the impact of the COVID-19 pandemic which lasted until at least 2023.[13] Since it is natural to assume that any decision on the transformation of the GVCs, if any, would take some time, it is desirable to have data for some years after 2020. Second, values in the ICIO tables are in current prices which reflects not only changes in volumes but also in prices of intermediate input, value added, and final demand. Since the reactions of the GVCs to the shock which is of interest is volume changes in input and output, the tables need to be in constant prices so that changes in volume can be identified (Linden and Dietzenbacher 2000).

The analysis in this paper, therefore, is based on the Multi-Regional Input-Output (MRIO) Tables compiled and published by the Asian Development Bank (ADB), which is another successor of the WIOD. Its latest 2023 version provides data for the each of the years for the period 2000 and 2007-2022, which covers longer period after the outbreak of the COVID-19 pandemic. It covers 62 economies and the rest of the world which consist of 35 industries, which are somewhat smaller than the coverage of ICIO but is sufficiently detailed to undertake the analysis. Another advantage of using MRIO is that it offers data in constant prices. It is a kind of data that is not offered in other sources of international input-output tables. The studies that have made use of MRIO include ADB

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[11] Other earlier examples of compiling international input-output tables included the Asian International Input-Output Tables by the Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO), Eora MRIO by University of Sydney, EXIOBASE by EU-based consortium, FIGARO by Eurostat and the Joint Research Centre of the European Commission, Global MRIO Lab by University of Sydney, GTAP 10A MRIO by Global Trade Analysis Project (GTAP).

[12] This is for the shorter version of the 2023 edition of ICIO. The extended version has split tables for Mexico and China: it distinguishes between global manufacturing activities and activities excluding those in those economies.

[13] World Health Organization (WHO) declared that spread of COVID-19 is a Public Health Emergency of International Concern (PHEIC) on 30 January 2020 and that it is a pandemic in 11 March 2020. It was judged that the situation was no longer a PHEIC on 5 May 2023.

(2023).

The structure of the MRIO tables at constant CY2010 prices are summarized in Table 1. The covered economies show that the all of the 62 economies are either regional or nonregional members of the ADB. It does not explicitly cover some of the developed economies in the Asia-Pacific and Europe who are members of the OECD as well as ADB.[14] It also includes, as independently identified economies, no African, and only a few South American economies. These economies that are not independently identified are all aggregated into the "rest of the world." While it is admittedly unsatisfactory from the point of view of completeness, it should still be considered as a second-best source of data in analysing GVCs considering that the total GDP of the explicitly covered economies is about 93 percent of the world total in 2020 (ADB Homepage).

<Table 1 >

As for the industries covered, MRIO observes the International Standard Industrial Classification revision 3.1 (ISIC Rev.3.1). However, since the number of industries covered is only 35, it implies that some of the divisions of ISIC Rev.3.1 are aggregated.[15] The aggregation has been considered necessary in view of the availability of official data from the national statistics authorities.

In the analysis to follow, two coefficients derived from MRIO will be used extensively. One is the "input coefficient". An input coefficient of an input produced by industry *i* of economy *k* that is used in the production by industry *j* of economy *l* (a_{ij}^{kl}) is defined as a ratio of the amount of input used (z_{ij}^{kl}) to total output of the purchasing industry *j* of economy *l* (x_j^l), or

$$a_{ij}^{kl} = \frac{z_{ij}^{kl}}{x_j^l}.$$

It measures the contribution of the input to total output of the purchasing industry and will be used to show the upstream structure of the industry in the GVC.

The other is the "output coefficient". An output coefficient of an output produced by an industry *i* of economy *k* and purchased by industry *j* of economy *l* (b_{ij}^{kl}) is defined as a ratio of the amount of output purchased (z_{ij}^{kl}) to total output of the producing industry *i* of economy *k* (x_i^k), or

[14] For example, New Zealand and Spain do not appear separately as an economy in the tables.
[15] In ISIC Rev.3.1, industries are classified into 17 sectors, 62 divisions, 161 groups, and 298 classes.

$$b_{ij}^{kl} = \frac{z_{ij}^{kl}}{x_i^k}.$$

It measures the contribution of the sales to total sales of the producing industry and will be used to show the downstream structure of the industry in the GVC.

The two coefficients play an important role in the methodology which will be elaborated in the next section.

4 Methodology

When a shock strikes a GVC and is considered to have a serious enough implication on the GVC so that it has to be transformed, it should affect the choice of the source of inputs, the choice of the market of sales, or both. Whichever the case may be, it is going to change the input-output structure of industries which would be reflected on the input and output coefficients. Therefore, to track the changes in the GVC as a result of a shock it was subject to, change in input and output coefficients of MRIO should provide researchers with important information.

However, the problem is, input and output coefficients are also affected by technological change and economic development. On the one hand, technological change will affect the substitutability between different products or between same products produced in a different economy. In either case, it would be reflected in the changes in the input coefficients. On the other hand, economic development will affect the industrial composition which will be reflected in the changes in the output coefficients. The problem, therefore, is how to decompose the changes in input and output coefficients so that impact of technology change and economic development can be identified and removed in order to extract the impact of the shock on the coefficients. This task will be accomplished by applying RAS technique to the MRIO.

RAS technique is a popular tool used in input-output analysis mostly to estimate input coefficient matrix when there is only a limited information. More specifically, it is typically used in national input-output tables when the only available information is

- Input coefficient matrix at time 0, $\boldsymbol{A}(0)$,
- Vector of total gross output by industries at time t, $\boldsymbol{x}(t)$,
- Vector of total interindustry sales by industry at time t, $\boldsymbol{u}(t), and$
- Vector of total interindustry purchase by industry at time t, $\boldsymbol{v}(t)$.

The idea of RAS technique is to find a column vector $\boldsymbol{r}$ whose elements will be multiplied to each of the rows of $\boldsymbol{A(0)}$ (irrespective of purchasing industry and economy), and a row vector $\boldsymbol{s}$ whose elements will be multiplied to each column of $\boldsymbol{A(0)}$ (irrespective of producing industry and economy), so that the vector of sums of the rows and that of the columns will be equal to those given for time t, $\boldsymbol{u}(t)$ and $\boldsymbol{v}(t)$, respectively (UN 2018). The result of the RAS technique can be expressed as finding vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ so that a matrix $\widetilde{\boldsymbol{A}}(t)$ can be obtained by

$$\widetilde{\boldsymbol{A}}(t) = \hat{\boldsymbol{r}}\boldsymbol{A}(0)\hat{\boldsymbol{s}},$$

where $\widehat{\ }$ indicates that the vector has been diagonalized and $\widetilde{\boldsymbol{A}}$ is such that satisfies

$$\widetilde{\boldsymbol{A}}(t)\boldsymbol{x}(t) = \boldsymbol{u}(t) \text{ and } \boldsymbol{e}'\widetilde{\boldsymbol{A}}(t)\hat{\boldsymbol{x}}(t) = \boldsymbol{v}'(t).$$

The vectors $\boldsymbol{r}$ and $\boldsymbol{s}$ can be obtained by repeating the adjustment of rows and columns until the estimated sum of the rows and the columns converge to $\boldsymbol{u}(t)$ and $\boldsymbol{v}(t)$ within a reasonable range.[16]

Each of the obtained $\boldsymbol{r}$ and $\boldsymbol{s}$ are considered to have economic meaning (Stone 1961). Vector $\boldsymbol{r}$ can be considered to reflect the "substitution effects" which results from technological change so that some intermediate inputs are used instead of other intermediate inputs during the period, e.g., using more ICT-intensive parts than non-ICT intensive parts. Vector $\boldsymbol{s}$ can be considered as reflecting the "fabrication effects" which corresponds to the changes in the mix of produced output due to economic development, e.g., larger share of manufacturing compared to agricultural industries. Since both of the effects are consequences of firms' response to economic incentives, both of the effects combined will be called, in this paper, "economic-incentive effects."

As already mentioned, RAS technique has traditionary been used to forecast unknown input coefficients before they become available later (usually with a considerable lag). The performance of the RAS technique, however, turned out to be unsatisfactory: The estimated $\widetilde{\boldsymbol{A}}(t)$ did not match the actual $\boldsymbol{A(t)}$. It is because, input coefficients change over time not only because there are substitution and fabrication effects but also because

[16] The approach can be understood as a solution to the constrained minimum information distance problem. Except for such cases where the input coefficient matrix has too many zeros as elements, it is found that RAS approach converges to a solution (Miller and Blair 2009). However, note that ***r*** and ***s*** is unique only up to a scaler. In order to come up with a unique solution, additional assumption needs to be made. See also footnote 19.

there are cell-specific effects at play. That is,

Changes in input coefficient
= Substitution effects (common to all the cells on the same row)
+ fabrication effects (common to all the cells on the same column)
+ Cell-specific changes.

Cell-specific changes includes all other changes other than those that results from changes in economic incentives. Most importantly, since shocks affecting GVCs generally emerges in a certain sell (disruption of supply of a certain input to a certain producer or a decline in demand for a certain output by a certain customer), any action taken in response to shocks would also be reflected in the cell-specific changes. Most importantly, it should include changes that result from actions taken by firms and governments to address the higher risk perceived by natural disaster, economic crisis, political confrontation, and other shocks. This paper will focus on this aspect of the cell-specific effects, and will call this "policy-induced effects" to distinguish it from the "economic-incentive effects" defined above.[17]

The unsatisfactory performance of RAS technique may have been a problem as a forecasting methodology, but it suggests the its usefulness as a decomposing methodology. Once we know the actual input coefficients, $\boldsymbol{A}(t)$, by taking the difference between $\boldsymbol{A}(t)$ and $\widetilde{\boldsymbol{A}}(t)$, we are able to remove changes due to substitution and fabrication effects and extract cell-specific effects. Since the cell-specific effects reflect the policy-induced effects, we will be able to find whether the shocks have led to policy responses that has been effective enough to make changes that are different from changes due to economic factors such as substitution and fabrication effects.

In the following, we will make use of the RAS technique, not as a forecasting methodology of input coefficients, but as a methodology to decompose the change in input coefficients to extract policy-induced effects. The use of RAS technique as a decomposing method has been done in the pioneering studies by Linden and Dietzenbacher (2000) and Dietzenbacher and Hoekstra (2002). They analysed interregional input-output tables of the European Union, the former using tables in current prices and the latter in constant prices.[18] This paper should be the first to apply RAS

[17] Note that the term 'policy' refers to actions taken by both the governments and the firms.
[18] As already mentioned, the solutions of $\boldsymbol{r}$ and $\boldsymbol{s}$ are unique only up to a scaler. In order to come up with unique solutions of $\boldsymbol{r}$ and $\boldsymbol{s}$, therefore, Linden and Dietzenbacher (2000) and Dietenbacher and Hoekstra (2002) introduced an assumption that the sum of substitution effects equals zero. Since we do not attempt to estimate $\boldsymbol{r}$ and $\boldsymbol{s}$ individually, we do not assume such a condition to hold.

technique to ADB's MRIO and to use it to analyse the impact of shocks including the COVID-19 pandemic on GVCs with a focus on Japan.

5 Estimated results of the policy-induced effects

When an industry is involved in a GVC, it should have relationship with both industries in the upstream (through purchase of their inputs) and those in the downstream (through sales of their outputs). Therefore, any changes to GVCs brought about by shocks could take place in its upstream relationship or in its downstream relationships, or both. Consequently, the analysis to follow is done on both of these relationships based on the decomposition of changes in input coefficients obtained by applying RAS technique. The procedure is as follows.

(a) Obtain input coefficient matrix $\boldsymbol{A}(t)$ from MRIO for each of the years between 2007 and 2022.
(b) Apply RAS technique to input coefficient matrix of previous year, $\boldsymbol{A}(t-1)$ to obtain $\widetilde{\boldsymbol{A}}(t)$, with the exception of $\widetilde{\boldsymbol{A}}(2007)$ which is obtained by applying RAS technique to $\boldsymbol{A}(2000)$.
(c) Take the difference between $\boldsymbol{A}(t) - \widetilde{\boldsymbol{A}}(t)$ to obtain $\dot{\boldsymbol{A}}(t)$.

As explained earlier, $\widetilde{\boldsymbol{A}}(t)$ is the input coefficient that would be observed as a result of economic incentives such as substitution and fabrication effects. By subtracting $\widetilde{\boldsymbol{A}}(t)$ from the actual $\boldsymbol{A}(t)$, $\dot{\boldsymbol{A}}(t)$ should reflect the policy-induced effects which was taken in response to the shocks.

All input and output coefficient matrices shows some changes in all of its cells. Since we are interested in policy-induced effects that is significant, we focus on those changes that lie outside the range defined by "$\text{average} \pm 3$ standard deviation of the changes that took place in the coefficients each year".

Also, not all the industries in Japan have a large enough share in total production, and not all is extensively involved in GVCs. In terms of their contribution to gross domestic product (GDP), and their involvement in GVC, two of the most prominent industries in Japan are electrical and optical equipment (ELEC) industry and transportation equipment (TRAN) industry. Therefore, in the following, the focus will be given to these two industries.[19]

[19] Results for other industries is available on request from the author.

5.1 Electric and optical equipment industry

5.1.1 Policy-induced effects in input coefficients

Table 2 shows the significant policy-induced effects that has taken place in the input coefficients for Japan's electric and optical equipment industry (c14; ELEC) over the whole period. The industries in the rows are the source industries which, at least in one of the years during the period, saw significant policy-induced effects in input coefficients. The cells that correspond to the significant changes are shaded so that they can be distinguished from the others (positive changes are shown in red, and negative changes in green).

<Table 2>

Many changes have taken place in the input from industries within Japan, including the services industries. There are also changes in input from ELEC in other economies which suggests that there are changes taking place within the GVCs which the Japan's ELEC is involved in. As for the timing of the changes, significant number of industries saw changes simultaneously in 2010.

It is interesting to note that the table also shows that there were changes that alternate in signs (+ or -) in the following years. It implies that the change that took place earlier was a temporary change and it was reversed in the following years. Therefore, in order to identify permanent changes, we need to accumulate the changes over the years. Figure 2 shows the significantly accumulated changes during 2008-2022. It shows the industries which showed large swings during the period (top five industries that showed the largest positive or negative accumulated changes).[20]

<Figure 2>

It reveals that in 2009 and 2010, JPN's ELEC increased its dependence on intermediate input for Japan's other industries including c14 (ELEC), c12 (METL), c30 (RENT), and c20 (WHOL). At the same time, input of ELEC from Korea (KOR) and the Rest of the World (RoW) started to fall gradually. These changes lasted for about ten years until late 2010s when Japan's ELEC started to fall significantly and PRC's ELEC to

[20] If an industry is among the top five in both the industries with the largest positive *and* those with the largest negative accumulated changes, the number of industries shown would be less than ten.

steadily increase.

The result suggests that significant concentration of inputs from Japanese industries took place in response to the global financial and economic crisis in the late 2000s. However, it was accompanied, not by a decline in input from other industries in other economies, but by an increase in the sum of input coefficients. It implies that value added per output produced by Japan's ELEC declined. In this sense, the result of the policy-induced effects during the period should be called, not as a simple 'onshoring, but as "inefficient domestic input concentration."

The trend has since been reversed in response to the US-China trade friction and the COVID-19 pandemic: input from Japanese sources declined and input from China increased. It partially made up for the loss in value added per unit since 2007, but not completely. In that sense, the aim of the policy during this period could be called "efficient offshoring of input."

5.1.2 Policy-induced effects in output coefficients

Table 4 shows the significant changes that has taken place in the output coefficients during the period for ELEC. Please note that this time, different from Table 3, destinations of output are shown in columns, and the rows are for the years that showed changes. Here again, rather than showing all of the policy-induced effects, Table shows those industries which, in any of the years during the period, were subject to changes in a significant magnitude; those changes which were more than three standard deviations away from the mean in absolute terms. The significant changes are shaded in a similar way as explained before.

<Table 3>

The changes in the sales to Japan's industries are relatively more visible but there are changes taking place in sales to other industries in other economies as well. This time, there do not seem to be any specific year in which changes are concentrated.

The industries that showed significant accumulated changes during the period is shown in Figure 3. It shows that there was an increase in sales to JPN's ELEC and C19 (SALE) as well as ELEC in Taipei,China (TAP). They more than replaced the fall in sales to PRC's ELEC and RENT, and RoW's ELEC, c17 (POW), and RENT. Since mid- 2010s, increase in sales to PRC's ELEC picked up pace, and gradually replaced sales to JPN's ELEC and c15 (TRAN) and RoW's ELEC, POW, and RENT. It was followed by increases in PRC's RENT and TAP's ELEC in the late 2010s.

<Figure 3>

These changes suggest that, after the global financial and economic crisis, concentration of intermediate input sales to the domestic market within Japan took place. However, sales to China gradually increased, followed by a lagged increase of sales to Taipei,China so that, eventually, sales became increasingly concentrated to the Asian market other than Japan. All these were taking place while the industry increased its total sales of intermediate input rather than those to meet final demand. In that sense, the policy until the late 2010s could be called "domestic intermediate-input market concentration" while that after the late 2010s could be called "foreign intermediate-input market concentration".

5.2 Transport equipment industry

5.2.1 Policy-induced effects in input coefficients

We will now shift to the policy-induced effects taking place in the GVC of transport equipment industry (TRAN).

Table 4 shows the policy-induced effects in Japan's TRAN. A glance at the Table shows that, compared to what we saw for ELEC, there are less changes taking place among TRAN in the economies, and many of the changes have taken place within JPN's industries rather than with the industries in other economies. In terms of the timing of the changes taking place, again many are concentrated in 2010.

<Table 4>

The largest accumulated changes are shown in Figure 4. There was a significant increase in input from JPN's TRAN in 2010, when a more modest increase in input from other industries took place. In the following years, there were not much cell-specific changes taking place until 2015 when there was a significant negative change in RoW's TRAN.

<Figure 4>

The changes suggest that there has been a significant increase in input from Japanese industries to Japan's transportation equipment industry. However, it took place without

much decline in input from other industries in other economies. It implies that a concentration to Japanese inputs was accompanied by a decline in value added. In that sense, it should be considered, not as a simple "onshoring," but as an "inefficient domestic input concentration".

5.2.2 Policy-induced effects in output coefficients

The significant changes in output coefficients of Japan's transportation equipment industry is shown in Table 5. There are relatively more changes taking place within the Japanese industries than in other industries, but the concentration seems to be lower than in the case of input coefficients.

<Table 5>

The accumulated changes in industries which has seen a significant change is as shown in Figure 5. There is a significant increase in sales to JPN's TRAN in 2010. It has taken place without much decline in sales to other industries implying that sales of its product as intermediate goods increased (i.e., fall in sales to final demand). Another noticeable change during the period is the fall in sales to USA's c31 (PUB) and TRAN and RoW's TRAN since late 2010s.

<Figure 5>

The changes suggest that Japan's transportation equipment has been increasing its sales as intermediate input to domestic industries in the aftermath of global financial and economic crisis in the late 2000s. During the period under US-China trade friction and COVID-19 pandemic, it is accompanied by reduction of its sales to industries in foreign economies. Throughout the period, the industry is increasing its sales as intermediate input and reducing that to final demand. In this sense, it can be called "domestic intermediate-input market concentration."

6 Explaining the transformation of GVCs

The result of the estimation of the policy-induced effects by applying RAS technique to input coefficient matrix for the period 2007-2022 was presented in the previous section. Specific results were provided for Japan's electrical and optical equipment industry and transportation equipment industry, which are two of the most prominent industries of

Japan and those who are involved in GVCs in a significant way. The result showed that, for both industries, there were significant changes taking place after the global financial and economic crisis in the late 2000s and somewhat more modest changes since the late 2010s, which corresponds to the period of US-China friction and COVID-19 pandemic.

Some may find the result somewhat different from what has been expected or from what has been identified in the previous studies. The reasons for the apparent difference maybe twofold.

One is that the previous studies often discuss the transformation in GVCs for the economy as a whole rather than for the industries as was shown in the previous section.

The other is that the previous studies usually discuss the transformation in GVCs based on actual changes that has taken place, not on policy-induced effects as was shown in the previous section.

Therefore, in order to be able to compare the result of the previous studies with that of this paper, it should be useful to aggregate the industries for each of the economies so that is can be directly compared with the previous studies. It should also be useful to show the contributions of economic-incentive effects and policy-induced effects in achieving the actual changes in input and output coefficients. By doing so, we should have better understanding of whether Japan's GVCs have transformed or not, and if so, why they have transformed in a particular way.

6.1 GVCs in the electrical and optical equipment industry

6.1.1 Changes in input coefficients

Figure 6 shows the changes taken place in the input coefficients of Japan's electrical and optical equipment industry (ELEC) by period and by region. The years covered are grouped into four periods; the period after the global financial and economic crisis (2008-2010), the period after the Great East-Japan Earthquake (2011-2015), the period when tensions between U.S. and China intensified (2016-2019), and the period subject to COVID-19 pandemic (2020-2022). As for the regions, it has been grouped into five regions: China, other East Asia, Europe, North America, and others. China has been specified independently because of its importance in Japan's GVCs.

<Figure 6>

According to Panel A, the overall change in input coefficient over the period was to reduce domestic input with not much change in input from other sources. According to

Panel B, the changes in domestic input coefficients were due to economic-incentive effects that overwhelmed the policy-induced effects that tried to encourage use of domestic input. However, if we look at each period, we find that there are differences in the way they have changed. The actual change was to modestly increase domestic inputs after the global financial and economic crisis (Panel C), but it was to decrease them in other periods (Panels D, E, and F). The breakdown of the actual changes in input coefficient to those due to economic incentives and those due to policy implementation shows that, in some periods, actual changes are consistent with the changes due to policy implementations (Panels C and F), but in other periods, actual changes are to the contrary to policy-induced effects (Panels D and E). In the latter cases, policy-induced effects were overturned by economy-incentivised changes.

6.1.2 Changes in output coefficients

Figure 7 shows the changes of output coefficients of Japan's electrical and optimal equipment industry (ELEC). During most of the years in 2008-2022, economic incentive was to reduce sales of intermediate sales to domestic and foreign economies, and increase sales to final demand (Panel A). However, there were strong policy-induced effects to reverse the pressure and increase sales to China and other East Asia, as well as to the domestic market during the years (Panel B). As a result, there has been a concentration of intermediate input sales to the neighbouring region, China and other East Asia.

<Figure 7>

Breaking down to periods shows that there have been somewhat significant differences in the pattern of changes taking place. After the global financial and economic crisis (Panel C), the economic-incentive was to reduce the sales of intermediate input to all of the regions. However, there was a strong policy initiative to increase sales of intermediate input to the domestic market. Therefore, the period saw a increased concentration of domestic sales of intermediate input.

In the following period of the first half of the 2010s (Panel D), similar economic incentive existed. However, the policy-induced effects were to increase sales to foreign market instead of the domestic market. As a result, there were increase in sales of intermediate input to Europe and North America.

During the period of anti-globalization in the latter half of the late 2010s (Panel E), economic incentive of a similar nature continued, except the encouragement of sales to China which turned slightly positive during the period. Together with a strong positive

policy initiative to increase sales to China and East Asia. It led to a concentration of sales to China.

Finally, during the period under COVID-19 pandemic of the early 2020s (Panel F), economic incentive seems to have been neutral. However, there was a strong policy intension to increase sales to foreign market, especially to China and East Asia, instead of the domestic market. There has been, as a result, a strong regionalization of sales of intermediate inputs to China and other East Asia.

6.2 GVCs in the transportation equipment industry

6.2.1 Changes in input coefficients

Figure 8 shows the changes in input coefficients of Japan's transport equipment industry (TRAN). As Panel A shows, overall changes over the period was a decline in dependence on domestically produced intermediate input. It was a result of economic-incentive effects overwhelming the policy-induced effects which tried to maintain dependence on domestic sources (Panel B).

<Figure 8>

During the period of global financial and economic crisis (Panel C), there has been no major changes in the actual input coefficients because the economic incentive to reduce domestic dependence was almost completely offset by policy-induced effects.

In the following period of the first half of 2010s (Panel D), economic incentive to reduce domestic reliance and to increase input from rest of the world overwhelmed the policy-induced effect which tried to reverse such changes. As a result, dependence in domestic input declined.

Tensions between the U.S. and China in the late 2010s (Panel E) had an impact of reversing the changes that has taken in the previous periods. Economic incentive was to increase dependence on domestic input instead of input from the rest of the world and China. Although the policy-induced change worked in the opposite way, the outcome was to increase domestic sourcing of input.

Changes that took place in the second-half of the 2010s seems to have been short-lived. The period under the influence of the COVID-19 pandemic (Panel F) was subject to an economic incentive to reduce domestic dependence, which was further reinforced by the policy-induced effects that tried to reduce domestic dependence in exchange of increase in input from other regions.

6.2.2 Changes in output coefficients

Figure 9 shows the changes in output coefficient that took place over the whole period. The changes that took place over the period was to slightly reduce the sales of intermediate input to domestic market (Panel A). It was a result of a negative impact on sales to the domestic market by economic incentives partially offset by positive impact to increase domestic sales by policy initiatives (Panel B).

<Figure 9>

The changes that took place in the late 2000s (Panel C) increased dependence on the domestic market. During the period, there was a slight increase in the sales to domestic market which is a result of a policy-induced effects that exceeded economic-incentivized changes. It could be called a "domestic intermediate-input market concentration."

During the following period (Panel D), concentration to the domestic sales was reversed and saw a decline in domestic sales. The decline in domestic sales was a result of both economic-incentivized and policy-induced effects. The former also reduced sales to China. The latter increased sales to North America and to the rest of the world.

Tension between U.S. and China increased concentration of sales to domestic market which was a combined effect of economic-incentivized and policy-induced effects (Panel E). Both of the effects also increased sales to China and other East Asia. On the other hand, while economic-incentive effects encouraged sales to North America and to the rest of the world, they were more than offset by policy-induced effects so that dependence on both regions fell during the period.

Finally, the period under the influence of COVID-19 (Panel F) witnessed a large decline in sales to the domestic market and a more modest decline in sales to almost all other regions, excluding other East Asia and Europe. It was mainly a result of economic-incentive effects that reduced the sales to the regions except North America.

6.3 Transformation of GVCs under the COVID-19 pandemic

The aim of this paper is to examine whether Japan's GVC has been transformed by the COVID-19 pandemic. The analysis explained above is summarized to answer this research question (Table 6).

<Table 6>

6.3.1 Electrical and optical equipment industry

During the pandemic, semi-conductors, for example, faced a shortage of supply because of the close-down of production sites in China, to which Japan depended on in a significant way. This experience would suggest that the dependence on Chinese producers would be reduced to lower the risk of another supply constraint. The possibility is a diversification of sources to Japanese suppliers ("onshoring") and/or to foreign suppliers other than the Chinese.

However, the actual change that took place in the sources of input was an increase in input from foreign suppliers, particularly those in China. The decline in domestic sources is partially due to economic-incentive effects, but it was also reinforced by the policy-induced effects which reduced domestic sourcing and increased sourcing from China and other East Asian economies. Rather than diversification out form China and/or onshoring, the intention of the poicies seems to have been to promote further outsourcing from foreign economies including China. The risk of another supply constraint in China does not seem to have been high enough to put a break to outsourcing to China. All the changes have contributed in increasing value added per unit of production which is reflected in the decline in the sum of input coefficients.

Regarding output destination, the actual change in output coefficients shows that domestic sales of output as intermediate input was reduced and, in its place, sales to China and other Asian economies have increased. This, however, seems to be against economic incentives: economic-incentive effects were to basically maintain current pattern of sales of intermediate inputs. It means that intensifying sales to the China and other East Asian economies was due to the policy-induced effects. As a result, total sales of intermediate inputs were maintained during the period.

6.3.2 Transportation equipment industry

The sources of input to the transportation equipment industry has been increasingly outsourced: reducing purchase from domestic sources, and increasing input purchased from foreign sources including China. It is a result of both economic-incentive effects and policy-induced effects. Both of the effects contributed in reducing domestic input. The difference between the two was their impact on input from other sources. Only the policy-induced effects increased input from other economies. These changes together increased value-added per unit produced by the industry.

As for the sales of their output, the actual change of sale coefficients was to reduce sales to domestic and Chinese markets. It is different from the direction of the policy-

induced effects that aimed to maintain the existing composition of sales of intermediate inputs. It is overwhelmed by the economic-incentive effects that reduced sales to domestic and Chinese markets. The result of the changes is to reduce the sales of intermediate inputs and increase those that meet final demand. The industry seems to have shifted more towards the downstream of the GVC.

7 Concluding remarks

The objective of this paper is to analyse whether any significant changes has been brought about by the COVID-19 pandemic in the global value chains that Japan is involved in. In order to answer the research question, RAS technique, which is usually used to estimate unknown input coefficient when only partial information is known, is applied to Multi-Regional Input-Output (MRIO) tables published by the Asian Development Bank (ADB) to decompose the changes in input and output coefficients. Estimated input coefficient by RAS can be considered to be the input coefficient that would have resulted if the economy is subject only to "economic-incentive effects" that are brought about by technological change and economic development. By taking the difference between these effects and the actual changes enables us to extract the "policy-induced effects" that result from actions taken by the firms and the governments.

The result of the analysis for the changes taking place in the input coefficients during 2020-2022, the period subject to COVID-19 pandemic, shows that, in both electrical and optical equipment industry and transportation equipment industry, "outsourcing" in input took place, and "onshoring", as some expected, did not take place during the period. The outsourcing was consistent not only with economic incentives but also with policy intensions. The analysis also shows that outsourcing made it possible for these industries to raise the share of value-added produced per unit of output.

As for the output destination, both industries showed a decline in the sales of intermediate goods to the domestic market. In the electrical and optical equipment industry, increase in sales of intermediate products to China and other East Asian economies took place at the same time. In the transport equipment industry that was not the case. Therefore, for the electrical and optical equipment industry, the change can be characterized as "foreign marketing" of their sales while, for the transportation equipment industry, the changes can be characterized as "reducing domestic market dependence." Interestingly, "foreign marketing" of the electrical and optical equipment industry was a result of policy intension that overwhelmed the reactions to economic incentives that tried to maintain current composition. In the case of the transportation equipment industry, it

was a result of changes due to economic incentives while policy intension was to maintain the market composition.

As the results show, applying RAS methodology to MRIO has enabled us to shed new light into the changes taking place in the GVCs under various shocks including the COVID-19 pandemic. It suggests that the methodology could be developed further to understand better the GVCs that have become important players of global production.

Before concluding, a number of areas for future research can be mentioned.

First, the RAS approach to analyse transformation of GVCs introduced in this paper could be applied to other economies to check its usefulness in understanding the impact of COVID-19. In particular, applying the approach to U.S. and China to see the impact of U.S.-China trade friction, and to U.K. to see the impact of Brexit will be of interest.

Second, the robustness of the result of the analysis needs to be checked as new data becomes available. In particular, the Multi-Regional Input-Output tables are expected to be revised and/or refined as new information on input-output structure of various industries in various economies arrive. Therefore, similar analysis needs to be done on the new dataset as they are published.

Third, the five periods that was identified in this paper was selected in somewhat arbitrary manner. Different years could be grouped to form a different set of periods. Therefore, the implications of the results need to understood carefully.

Fourth, the relationship between the changes in the input and output coefficient and the external shocks need to be more carefully modelled and analysed. For example, the paper assumed that any changes taking place during the period 2020-2022 was due to the COVID-19 pandemic. However, the changes may also be due to delayed changes taking place in response to tensions between U.S. and China: It is natural to think that any changes that need to be made on GVC needs some time because they require careful designing and enough time for its preparation. Therefore, future analysis needs to consider ways to disentangle the concurrent changes that are taking place during the same period.

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Table 1: Basic Structure of a Multi-Country Input-Output Table

			Intermediate Demand			Final Demand			Total Output
			Economy 1	--- Economy l ---	Economy N	Economy 1	--- Economy g ---	Economy N	
			Ind. 1---Ind. M	--- Ind. j ---	Ind. 1---Ind. M	F.d. 1---F.d. K	--- F.d. f ---	F.d. 1---F.d. S	
Source of Intermediate Input	Economy 1	Ind. 1 --- Ind. M	$Z = \begin{bmatrix} z_{11}^{11} \cdots z_{1M}^{1N} \\ \vdots \quad z_{ij}^{kl} \quad \vdots \\ z_{M1}^{N1} \cdots z_{MM}^{NN} \end{bmatrix}$			$F = \begin{bmatrix} F_{11}^{11} \cdots F_{1S}^{1N} \\ \vdots \quad F_{if}^{kg} \quad \vdots \\ F_{M1}^{N1} \cdots F_{MS}^{NN} \end{bmatrix}$			$x = \begin{bmatrix} x_1^1 \\ \vdots \\ x_j^i \\ \vdots \\ x_M^N \end{bmatrix}$
	--- Economy k ---	--- Ind.i ---							
	Economy N	Ind. 1 --- Ind. M							
Value Added+Taxes less Subsidies			$y' = \left[y_1^1 \cdots y_j^l \cdots y_M^N \right]$						
Total Output			$x' = \left[x_1^1 \cdots x_j^l \cdots x_M^N \right]$						

(Source) Prepared by the author.

Table 1 Economies and Industries Covered by ADB MRIO

Economies	Code	Economies	Code	Industries	Code
Australia	AUS	Romania	ROM	Agriculture, hunting, forestry, and fishing	c1
Austria	AUT	Russia	RUS	Mining and quarrying	c2
Belgium	BEL	Slovakia	SVK	Food, beverages, and tobacco	c3
Bulgaria	BGR	Slovenia	SVN	Textiles and textile products	c4
Brazil	BRA	Sweden	SWE	Leather, leather products, and footwear	c5
Canada	CAN	Türkiye	TUR	Wood and products of wood and cork	c6
Switzerland	SWI	Taipei,China	TAP	Pulp, paper, paper products, printing, and publishing	c7
China, People's Republic of	PRC	United States	USA	Coke, refined petroleum, and nuclear fuel	c8
Cyprus	CYP	Bangladesh	BAN	Chemicals and chemical products	c9
Czech	CZE	Malaysia	MAL	Rubber and plastics	c10
Germany	GER	Philippines	PHI	Other nonmetallic minerals	c11
Denmark	DEN	Thailand	THA	Basic metals and fabricated metal (METL)	c12
Spain	SPA	Viet Nam	VIE	Machinery, nec	c13
Estonia	EST	Kazakhstan	KAZ	Electrical and optical equipment (ELEC)	c14
Finland	FIN	Mongolia	MON	Transport equipment (TRAN)	c15
France	FRA	Sri Lanka	SRI	Manufacturing, nec; recycling	c16
United Kingdom	UKG	Pakistan	PAK	Electricity, gas, and water supply (POWR)	c17
Greece	GRC	Fiji	FIJ	Construction	c18
Croatia	HRV	Lao People's Democratic Republic	LAO	Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel (SALE)	c19
Hungary	HUN	Brunei Darussalam	BRU	Wholesale trade and commission trade, except of motor vehicles and motorcycles (WHOL)	c20
Indonesia	INO	Bhutan	BHU	Retail trade, except of motor vehicles and motorcycles; repair of household goods	c21
India	IND	Kyrgyz Republic	KGZ	Hotels and restaurants (HOTL)	c22
Ireland	IRE	Cambodia	CAM	Inland transport	c23
Italy	ITA	Maldives	MLD	Water transport	c24
Japan	JPN	Nepal	NEP	Air transport	c25
Korea, Republic of	KOR	Singapore	SIN	Other supporting and auxiliary transport activities; activities of travel agencies	c26
Lithuania	LTU	Hong Kong, China	HKG	Post and telecommunications	c27
Luxembourg	LUX	Rest of the World	RoW	Financial intermediation	c28
Latvia	LVA			Real estate activities	c29
Mexico	MEX			Renting of M&Eq and other business activities (RENT)	c30
Malta	MLT			Public administration and defense; compulsory social security (PUB)	c31
Netherlands	NET			Education	c32
Norway	NOR			Health and social work	c33
Poland	POL			Other community, social, and personal services	c34
Portugal	POR			Private households with employed persons	c35

(Source) Asian Development Bank, Multi-Regional Input-Output Table

Table 2: Policy-induced effects in Input Coefficients of Japan's ELEC Industry

(cells showing significant effects)

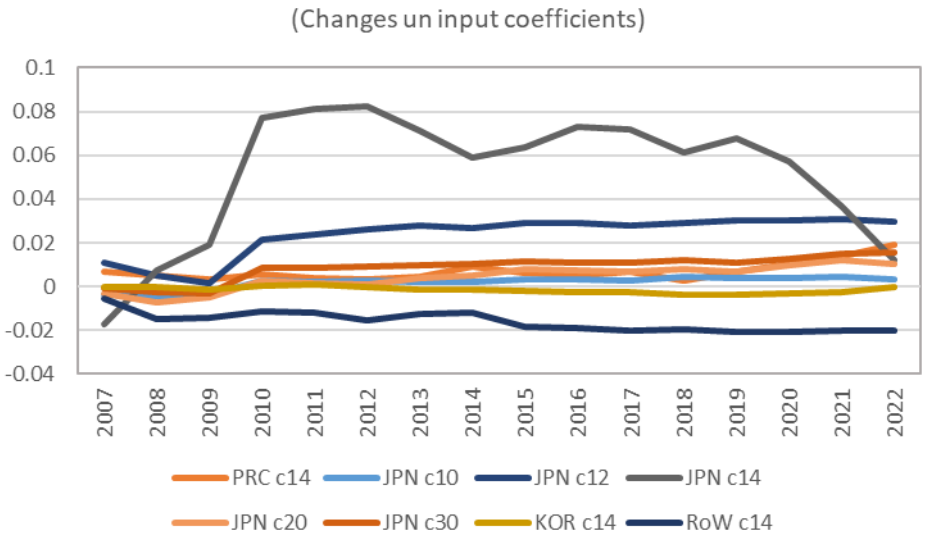
Economies Code	Industries Code	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
PRC	c12	0.00035049	-0.000118	-0.0003437	0.0006629	-3.02E-05	-0.0003759	3.87E-05	0.000234	-0.0001629	-1.82E-05	9.23E-05	-4.84E-05	0.00096419	-0.000986	0.00017762	0.0002453
PRC	c14	0.00688534	-0.0019612	-0.001487	0.0023644	-0.001986	-0.0004588	0.00109209	0.0044493	-0.0026875	-0.0013949	0.00207874	-0.0039322	0.00398269	0.0033934	0.00326556	0.0052295
JPN	c7	0.00156577	-0.0003467	0.00024407	0.0034765	-0.00027	0.00011021	0.00015048	0.0001397	0.00043306	-0.0002671	-3.72E-05	0.00029228	-0.0004319	0.0001168	0.00051691	3.73E-05
JPN	c9	0.0007743	0.0001772	-0.0001422	0.0035049	-0.000318	0.00035154	-0.0004632	-0.0003223	0.000562	0.00013845	-0.0001089	-0.0009801	-0.0006239	0.0002758	-0.0005373	-0.0010378
JPN	c10	-0.0037885	-0.0004774	0.000369	0.0068668	-0.000599	0.00030223	-0.0003753	-0.0002181	0.00095884	0.00028455	-0.0008258	0.00189852	-0.0007114	-3.31E-05	0.00062901	-0.0011936
JPN	c11	0.00273234	0.00015831	-0.0011785	0.0028502	0.000324	0.00015535	-0.0001667	0.0003358	0.00042562	-2.22E-05	-0.00019	7.67E-06	-0.0002673	0.0006218	-5.03E-05	0.0001072
JPN	c12	0.01087904	-0.0058419	-0.0033768	0.0195292	0.00266	0.00222537	0.00171055	-0.0010472	0.00251919	1.43E-05	-0.0015749	0.0015335	0.0007987	0.0001627	0.0006042	-0.0014358
JPN	c13	5.82E-05	6.93E-05	0.00042172	0.0013772	-0.000103	0.00016132	-0.0003408	-0.0004279	-0.000203	0.00032351	-8.04E-05	0.00026294	0.00038522	0.0006991	1.87E-05	-0.0004994
JPN	c14	-0.017275	0.02494254	0.01164836	0.0575738	0.004067	0.00165969	-0.0111312	-0.0126334	0.00448913	0.00972595	-0.0015469	-0.0104411	0.00658403	-0.010486	-0.0207118	-0.0245536
JPN	c15	0.00108914	0.00017871	-4.24E-05	0.001037	-0.000176	-8.96E-05	-0.0001466	-8.39E-05	-6.06E-05	0.00017287	-0.0003192	0.00021669	0.00028409	0.0004019	2.11E-05	-0.0001028
JPN	c17	0.00096664	-0.0002003	-0.0003626	0.0043139	0.000427	0.00017834	0.00034921	0.0003184	0.00037889	-0.0007039	4.78E-05	0.00040635	-0.0003941	0.0006401	0.00067821	0.0005147
JPN	c18	0.00065923	-1.13E-05	-0.000137	0.001064	0.000223	6.82E-05	0.00012562	0.000104	9.41E-05	-0.0001678	2.03E-05	0.000204	-0.0001259	0.0001561	0.00021653	0.0001633
JPN	c19	0.00127871	-0.0001319	-0.0003822	0.0027924	6.54E-05	0.00012432	0.00022996	0.0002059	0.00020516	-0.0003797	2.77E-05	0.00021892	-0.0002029	0.0002893	0.00034839	0.0004281
JPN	c20	-0.0030821	-0.0044607	0.00248199	0.0076332	-0.00103	-0.0004429	0.00277489	0.0011826	0.00303321	-0.0005288	-0.0006469	0.00110759	-0.0015136	0.0030926	0.00237097	-0.0017292
JPN	c21	0.00105505	-0.0002964	0.00014797	0.0017443	-5.74E-05	2.00E-05	0.0001872	0.0001505	0.00028413	-0.000152	-5.64E-05	0.00040346	-0.0002247	0.0003648	0.00041907	3.70E-05
JPN	c22	-0.0004439	-0.0003364	-7.53E-05	0.0030491	0.000113	9.98E-05	0.00024353	0.0001505	0.00046431	-0.0002949	1.77E-05	0.00061643	-0.000382	0.0004112	0.00038125	6.96E-05
JPN	c23	0.00112629	-0.0003588	0.00013422	0.0027215	0.000104	0.00011447	0.00022575	5.87E-05	0.00065698	-0.0002401	-6.82E-05	0.00033572	0.00010997	0.0006498	0.00051115	7.33E-05
JPN	c27	0.00027719	-0.0001185	-5.08E-05	0.0012647	1.41E-05	3.21E-05	7.13E-05	7.07E-05	0.00015711	-0.0001361	-1.03E-05	0.00035082	-0.0001884	0.000233	0.00028125	0.0001067
JPN	c28	0.00172416	-0.0003527	-2.11E-05	0.0031525	0.00019	0.00010196	0.00020804	0.0001809	0.00038184	-0.0003789	4.57E-06	0.00037361	-0.0003435	0.0004255	0.00055596	0.00026
JPN	c30	-0.0005808	-0.0019156	-0.0007524	0.0117937	3.06E-05	0.00035311	0.00093315	0.0006124	0.00119541	-0.0010212	3.30E-06	0.00154077	-0.0011951	0.0018635	0.00194313	0.000659
JPN	c35	0.00062295	-0.0001291	-2.24E-05	0.0010002	3.14E-05	3.87E-05	7.24E-05	5.60E-05	0.00011374	-9.41E-05	-5.94E-06	0.00013792	-7.81E-05	0.0001046	0.00012595	5.94E-05
KOR	c14	-0.0004839	0.00027624	-0.0012283	0.0015256	0.001002	-0.0013358	-0.0013867	-1.82E-05	-0.0001741	-0.0006687	-0.0001743	-0.0012228	0.00032937	0.0006677	0.00025585	0.0023822
TAP	c14	-0.000389	-4.98E-06	0.00094431	0.003869	-0.003195	0.00028325	0.00032567	0.0014131	-0.000558	-0.000435	0.00012198	-0.0005571	0.00076611	-0.005942	0.00160857	0.0017338
USA	c14	-0.0015112	-0.0003151	-0.0011208	0.0014865	-0.000854	-0.0006058	-7.27E-06	8.37E-05	-4.17E-05	-0.0001489	6.43E-05	0.0034361	-0.0010374	0.0004955	8.74E-05	0.0002264
MAL	c14	-0.0001662	0.00060464	-0.0016446	0.0005966	4.80E-05	-2.76E-05	0.00046476	0.0004121	3.71E-05	-0.0003345	0.00058453	-0.0009709	-0.0024484	0.0007415	0.00026807	0.0010031
PHI	c14	0.00194847	0.00028446	-0.0017639	0.0009235	0.000886	-0.0006292	0.00014317	0.0010347	0.00048606	0.00013812	0.00037766	-0.003264	0.00049624	0.000592	0.00177987	-0.0002884
VIE	c14	0.0009592	0.00069002	-0.0005507	0.0005655	0.00039	0.00035705	0.00028958	4.67E-05	-0.0010084	-0.0003289	0.00014598	-0.001134	3.72E-05	0.000172	-0.0005258	0.0009495
SIN	c14	0.00100106	0.00088022	-0.0005806	0.0010831	0.001194	0.00020413	0.00048355	-0.0004574	-0.0012394	-0.0006492	0.00171116	3.31E-05	-0.0025427	-0.000155	0.00043911	0.0008166
SIN	c20	-0.0009498	4.25E-05	-1.51E-05	9.94E-05	1.06E-05	-1.95E-05	-3.53E-05	0.0001282	4.54E-05	2.83E-05	0.00023837	0.00071307	-0.0006455	0.0002706	-0.0004126	0.0003027
RoW	c12	-0.0014872	-0.0003216	0.00023645	-6.93E-06	-0.000187	-2.51E-05	0.00020206	-0.0001817	-2.04E-07	-0.0001185	0.00011594	0.00226318	-0.0019623	-0.000187	0.00144421	0.001249
RoW	c14	-0.0057739	-0.0088232	0.00014554	0.0029545	-0.000537	-0.0034875	0.00282987	0.0010051	-0.006429	-0.000608	-0.0012449	0.0004309	-0.0013258	3.93E-05	0.00058092	0.0002494
RoW	c22	-0.0022595	-4.70E-05	0.00010526	0.0008298	-0.000998	0.00013939	0.00031359	0.0002572	-0.0012425	-0.0001064	-0.0002963	8.28E-05	-0.0001565	1.72E-05	0.00019975	-4.55E-05
RoW	c30	-0.0012544	-2.75E-05	4.16E-05	0.000211	-0.000274	1.86E-05	0.00012488	4.64E-06	-8.07E-05	-6.32E-05	-1.15E-05	6.31E-05	-7.18E-05	8.39E-06	-2.36E-05	6.25E-05
Sum of all changes		-7.475E-10	-4.379E-10	-1.743E-10	0.1680814	1.13E-09	2.9301E-10	1.5006E-15	-3.344E-09	1.0466E-09	1.9441E-10	1.3355E-09	-6.064E-16	1.0222E-09	-1.04E-09	9.0559E-16	-2.483E-10
Average of all changes		-3.39E-13	-1.986E-13	-7.907E-14	7.623E-05	5.13E-13	1.3288E-13	6.8053E-19	-1.517E-12	4.7464E-13	8.8168E-14	6.0565E-13	-2.75E-19	4.636E-13	-4.73E-13	4.107E-19	-1.126E-13
Standard deviaition of all changes		0.00050582	0.00058927	0.00027721	0.0013581	0.000144	0.0001046	0.00025981	0.0002922	0.00020686	0.0002143	8.504E-05	0.00027992	0.00020084	0.000284	0.00045778	0.0005456
Upper threshhold for significant changes		0.00151745	0.00176782	0.00083162	0.0041505	0.000433	0.0003138	0.00077943	0.0008765	0.00062057	0.00064291	0.00025512	0.00083975	0.00060252	0.0008521	0.00137333	0.0016369
Lower threshhold for significant changes		-0.0015174	-0.0017678	-0.0008316	-0.003998	-0.000433	-0.0003138	-0.0007794	-0.0008765	-0.0006206	-0.0006429	-0.0002551	-0.0008397	-0.0006025	-0.000852	-0.0013733	-0.0016369

(Notes)

1. For the codes for the economies and the industries, see Table 1.

2. Columns are the industries that showed significant changes in, at east, one of the years during the period. Significant changes are defined as changes that are more than three standard deviations away from the mean on both sides.

Figure 2 Accumulated Policy-induced effects in Input Coefficients of Japan's ELEC Industry (sectors showing significant accumulated effects)



(Note) 1. For the codes for the economies and the industries, see Table 1.

2. Industries selected are those which showed five largest positive or negative accumulated changes among the industries that was selected in Table 2. There are only eight lines because JPN c14 and JPN c20 are among the top five in both positive and negative accumulated changes.

Table 3 Policy-induced effects in Output Coefficients of Japan's ELEC Industry
(cells showing significant effects)

Economies Code	PRC	PRC	PRC	PRC	PRC	GER	INO	IRE	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN
Industries Code	c13	c14	c18	c30	c34	c14	c14	c14	c12	c13	c14	c15	c18	c19	c31	c33
2007	0.0031398	0.0258733	0.00225568	0.0018855	0.0007533	8.64E-05	1.88E-05	-6.19E-05	-0.004083	-0.002413	-0.017275	-0.0029992	0.0010856	0.002519	-9.41E-05	0.00237545
2008	-0.000282	-0.000715	-0.000476	-0.000916	-4.79E-05	-0.000848	0.0005423	-6.79E-05	1.81E-05	0.0028339	0.0249425	0.00271023	0.0004153	0.001711	0.0001435	0.00058517
2009	-0.000883	-0.006109	-0.0008088	-0.000974	-0.00014	-0.000285	3.46E-05	-5.10E-05	0.0022817	0.0027815	0.0116484	0.00115882	0.0014292	0.000976	0.0005739	0.00041813
2010	0.0004141	-0.001971	0.00074732	0.0004599	0.0001414	0.0009319	0.0006387	3.22E-05	0.0009577	0.0068914	0.0575738	0.0077217	0.0057964	0.007276	0.0052082	0.00404059
2011	-0.000426	-0.003222	-0.0005174	-0.000388	-5.21E-05	0.0004553	5.45E-05	1.42E-06	0.0012889	-6.57E-05	0.0040672	-0.0001141	-0.000207	0.000705	0.0004051	0.0001012
2012	-0.00033	-0.000628	-0.0005115	-0.000274	-3.26E-05	-6.40E-05	1.87E-05	7.80E-06	2.93E-05	8.73E-05	0.0016597	0.00117281	-2.08E-05	0.000508	-3.50E-05	8.32E-05
2013	1.83E-05	0.0008002	-1.03E-05	7.33E-06	-1.92E-05	0.0008053	-0.000205	0.0002248	-0.0009861	-0.001438	-0.011131	-0.0021201	-0.001695	-0.00112	-0.000594	-0.0004449
2014	0.0010755	0.0087375	0.00087146	0.0010354	0.000265	0.0006667	0.0003099	0.0007449	-0.0009535	-0.001466	-0.012633	-0.0027457	-0.001319	-0.00159	-0.000716	-0.0007889
2015	-0.000151	0.0002005	-0.0001979	0.0002196	-2.44E-05	-0.000168	0.0004029	0.0002111	-2.53E-05	0.0008214	0.0044891	0.00255101	-7.37E-05	0.000645	4.27E-05	-4.57E-05
2016	-0.000604	0.0021882	-0.0022178	-0.000367	-0.000213	-0.000873	-0.001238	-0.000182	0.0011227	0.0013407	0.009726	0.00079371	0.0012883	0.000687	0.0006216	0.00056574
2017	0.0002771	0.0024026	0.00026226	0.0004944	7.16E-05	0.0006673	0.0002118	-0.000698	-2.70E-05	-0.000172	-0.001547	0.00192467	-7.87E-05	0.000321	-3.29E-05	-6.32E-05
2018	-3.26E-05	0.0222887	-0.0008612	0.0025592	0.0021854	0.0001312	-5.07E-05	-0.000805	-0.0009471	-0.002431	-0.010441	-0.0051992	-0.002062	-0.0009	-0.00096	-0.0004258
2019	0.0002963	-0.002449	0.00048559	-0.000442	-0.000182	-0.00118	-7.79E-05	-8.37E-05	0.0006405	0.0009007	0.006584	-0.0001622	0.0011712	0.000161	0.0005636	0.00058228
2020	0.0035009	0.0344505	0.00013291	0.0012054	-4.47E-05	0.0005696	-0.000256	1.40E-05	-0.0010401	-0.002227	-0.010486	-0.004818	-0.00183	-0.00093	-0.00115	-0.0007237
2021	0.0003729	0.0008714	0.00280342	0.0079144	0.001233	-8.76E-05	0.0004779	0.0001381	-0.0016087	-0.003672	-0.020712	-0.0047561	-0.002958	-0.00128	-0.00184	-0.0012198
2022	0.004146	0.0442237	0.00210477	0.0094987	0.0011959	-0.000171	0.0011128	-3.49E-05	-0.0020077	-0.003732	-0.024554	-0.0049021	-0.002763	-0.00152	-0.001957	-0.0012842

Economies Code	KOR	MEX	TAP	USA	USA	USA	USA	USA	USA	USA	USA	MAL	PHI	VIE	SIN	HKG
Industries Code	c14	c14	c14	c14	c15	c18	c20	c27	c30	c31	c33	c14	c14	c14	c14	c20
2007	-0.005067	0.0016802	-0.002286	-0.0024249	-0.000844	-4.76E-06	-0.000383	0.0002416	-2.21E-05	-0.0002064	-9.65E-05	-0.0009281	0.00431152	-0.0002409	-0.0020286	5.73E-07
2008	-0.00035	-0.001749	0.0009248	-0.0002875	-0.000105	-0.000174	3.55E-05	-0.000137	-0.00018	-2.26E-05	-3.53E-06	-2.34E-05	0.00013351	0.00033906	0.00049949	2.39E-05
2009	-0.000915	-8.31E-05	0.0042988	-0.0004506	-8.83E-05	-0.000242	-3.25E-05	0.0001041	-0.000106	-0.0001803	-3.12E-05	0.0006167	-0.0015906	0.0013876	-0.0001736	6.36E-05
2010	0.0034712	0.0008906	0.0038149	0.0010662	0.0005421	0.0007153	0.000201	0.0006532	0.0010491	0.00090563	0.0001211	0.0007514	-0.00047951	-1.07E-05	0.00070412	9.63E-05
2011	0.0019265	-0.000445	-0.001699	-0.0001347	7.38E-05	1.03E-05	4.78E-05	0.0001412	-0.000155	-9.85E-05	-6.98E-06	8.37E-05	0.00096678	6.83E-05	0.00073753	4.10E-05
2012	0.0023795	0.0001516	0.0010707	0.0004628	0.0002599	0.0003051	-7.06E-05	0.0001299	0.0001761	0.00027936	7.24E-06	-0.00023	-0.00034413	0.00029063	-0.0006182	-1.86E-05
2013	0.0001129	0.0001039	0.0026807	0.0017031	0.0019674	0.0005682	0.0003164	0.0015922	0.001672	0.0015517	0.0001677	-0.0004915	-4.31E-05	3.54E-05	-0.0005509	7.12E-05
2014	0.0002933	-0.000649	-0.000974	0.0003658	0.0002984	0.0002398	1.18E-05	-0.000176	1.97E-05	-0.0001393	3.30E-05	-6.69E-05	-8.57E-05	-9.63E-05	0.005427	0.0023214
2015	0.0010613	0.0002184	0.0024897	3.62E-05	0.0003049	-2.03E-05	2.42E-05	0.0001412	0.0001887	1.84E-05	1.89E-05	1.43E-05	0.00033962	0.00058942	-0.0058813	-0.0021278
2016	-0.00217	1.62E-05	0.0006461	-0.0004014	-0.000745	-0.000433	-9.68E-05	-0.000268	-0.000553	-0.0005561	-0.0001145	-0.0011267	-0.00010264	-0.0001364	0.00017707	-0.0001527
2017	-0.001302	0.0009481	0.0004851	-0.0001652	0.0009091	-0.000787	0.0005078	0.0004356	0.0006908	0.00037316	0.0009629	0.0005372	0.000227119	-3.39E-05	-0.0005085	1.43E-05
2018	-0.001513	0.0009294	-0.001265	-0.0002903	-0.000103	4.04E-05	-2.00E-05	0.000733	0.0001039	0.00246786	-0.0007651	0.0029025	0.00047842	5.12E-05	0.00135308	0.0002356
2019	0.0024509	-0.000363	0.0004986	7.88E-05	0.000421	0.0002693	8.90E-05	-0.000343	0.0001447	-0.0107868	0.0001339	0.0019956	0.000366189	0.00028566	0.00134931	4.07E-05
2020	-0.004927	-0.001208	0.0020278	0.0006503	-0.000855	-0.000728	0.0001641	-0.000401	-0.000233	-0.000757	-0.0001815	-0.0054812	0.00129394	-0.0015963	-0.0004875	0.0004075
2021	0.0085369	0.0014686	0.0032391	0.000466	0.000841	0.0010249	0.0003284	0.0007466	0.0024991	0.001342	0.0003665	0.0001883	0.00701343	-0.0002747	0.00526346	-0.0001545
2022	0.0009378	-0.001494	0.0067361	-0.0011393	-0.003457	-0.000634	-0.00138	-0.001625	-0.003733	-0.0015039	-0.000386	0.003083	0.00215053	-0.0001772	-0.0035368	-0.0004262

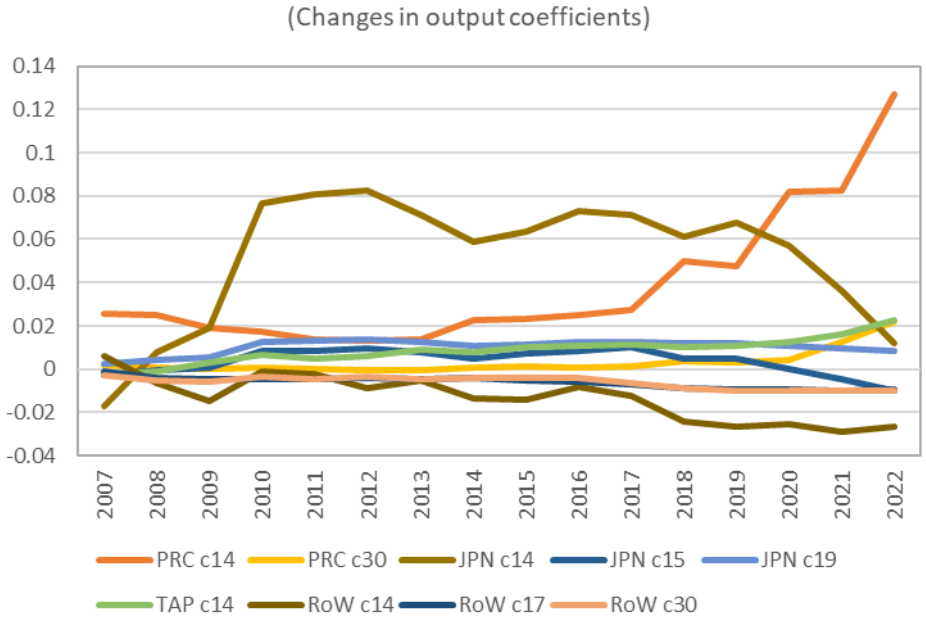
Economies Code	RoW	RoW	RoW	RoW	RoW	RoW	RoW	RoW	Sum of all changes	Average of all changes	Standard deviation of all changes	Upper threshold of significant changes	Lower threshold of significant
Industries Code	c2	c13	c14	c17	c18	c27	c30	c34					
2007	-0.0010325	0.00089556	0.0062086	-0.0010812	-0.00105	-0.0027239	-0.003099	-7.69E-06	3.01E-04	1.36E-07	0.000733	0.002199	-0.0022
2008	-0.0007835	-0.001426	-0.0126611	-0.0026912	-0.001585	-0.0007882	-0.001829	5.43E-05	-7.13E-05	-3.24E-08	0.000613	0.001838	-0.00184
2009	-0.0008275	2.23E-05	-0.0082817	-0.0011077	-0.00097	0.0002436	-0.001059	-0.0007154	-3.90E-04	-1.77E-07	0.000365	0.001095	-0.0011
2010	0.00054755	-0.0003826	0.0135098	0.0004682	0.0006611	0.0007636	0.0024143	0.00030575	1.64E-01	7.43E-05	0.001312	0.004011	-0.00386
2011	-0.0002592	0.00055676	-0.0007637	-0.0001278	0.0001537	-0.001032	-0.00097	-0.0001239	-2.35E-04	-1.07E-07	0.000139	0.000416	-0.00042
2012	0.00015666	-0.0004723	-0.0069082	0.0003386	0.0003013	0.0001428	0.000863	0.00020448	-5.21E-04	-2.36E-07	0.000169	0.000506	-0.00051
2013	-0.0005593	-0.000184	0.0036509	-0.0006231	-0.000213	-0.0002797	-0.001084	-0.0002069	4.99E-04	2.26E-07	0.000284	0.000853	-0.00085
2014	0.00029799	8.55E-05	-0.0082255	0.0005366	0.0011114	0.0004747	0.000846	0.00019712	-2.49E-04	-1.13E-07	0.000407	0.001222	-0.00122
2015	0.00015594	0.00025056	-0.0005496	-0.0007763	-0.001365	-0.0007668	-0.000316	-0.0002636	3.88E-04	1.76E-07	0.00019	0.00057	-0.00057
2016	-0.0006859	-0.0004605	0.0056401	-0.0005829	-0.000168	0.0001609	9.31E-05	3.31E-05	2.17E-05	9.86E-09	0.000268	0.000803	-0.0008
2017	-0.0005614	-0.0009341	-0.0040887	-0.0013479	-0.001531	-0.0009251	-0.002499	-0.0006664	9.07E-05	4.11E-08	0.000152	0.000456	-0.00046
2018	-0.0003674	-0.0012037	-0.0116004	-0.00163	-0.001226	-0.0005821	-0.002036	-0.000424	-8.32E-05	-3.77E-08	0.000617	0.001851	-0.00185
2019	-0.0004605	-0.0006218	-0.0023053	-0.0009169	-0.001471	-0.0003231	-0.001269	-0.0002365	-3.95E-04	-1.79E-07	0.0003	0.0009	-0.0009
2020	4.52E-07	-1.98E-07	0.0008454	-8.04E-05	-7.31E-05	3.32E-05	0.0001468	1.75E-06	3.01E-04	1.37E-07	0.000805	0.002415	-0.00242
2021	-1.06E-05	-0.0002053	-0.0032735	-8.17E-05	-4.82E-05	-0.000169	-0.00043	-9.85E-05	1.68E-04	7.63E-08	0.000565	0.001695	-0.00169
2022	1.83E-05	0.00037383	0.0020088	0.0001173	0.000174	7.57E-05	0.0003162	3.70E-05	6.14E-06	2.79E-09	0.001139	0.003418	-0.00342

(Notes)

1. For the codes for the economies and the industries, see Table 1.

2. Columns are the industries that showed significant changes in, at east, one of the years during the period. Significant changes are defined as changes that are more than three standard deviations away from the mean on both sides.

Figure 3 Accumulated Policy-induced effects in Output Coefficients of Japan's ELEC Industry (sectors showing significant accumulated effects)



(Note) 1. For the codes for the economies and the industries, see Table 1.

2. Industries selected are those which showed five largest positive or negative accumulated changes among the industries that was selected in Table 2. There are only nine lines because JPN c14 is among the top five in both positive and negative accumulated changes.

Table 4: Policy-induced effects in Input Coefficients of Japan's TRAN Industry

(cells showing significant effects)

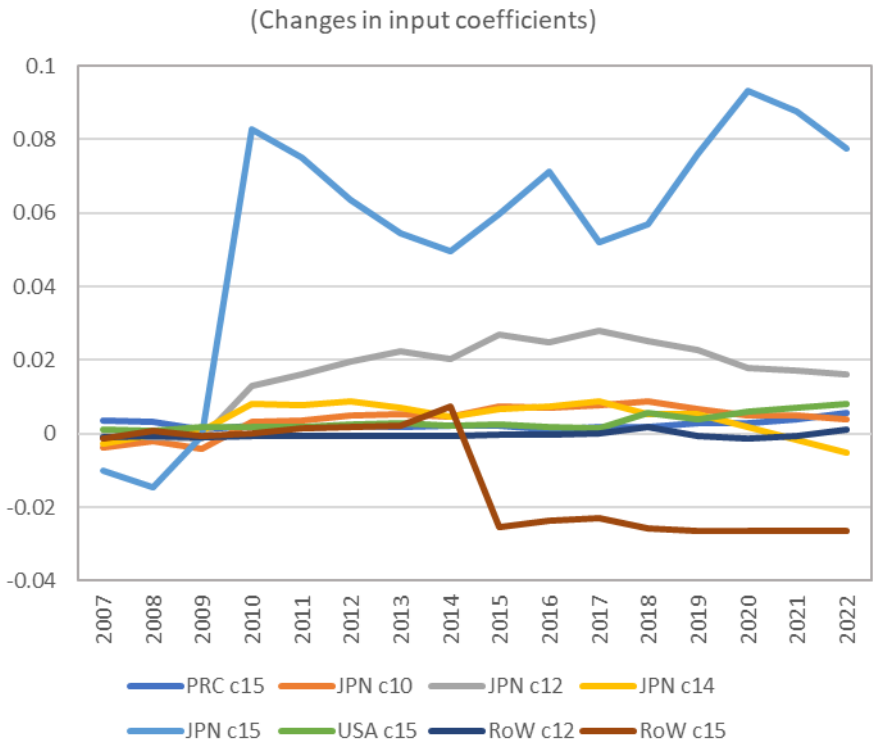
Economies Code	Industries Code	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
PRC	c15	0.003462	-0.000157	-0.002083	0.000881	-0.000496	0.000418	-8.64E-05	0.000368	-0.000215	-0.000783	0.000437	0.000232	0.00088	0.000158	0.000964	0.00154
JPN	c10	-0.003647	0.001809	-0.002248	0.00738	0.000403	0.001138	0.000335	-0.000476	0.002854	-0.000629	0.001008	0.000793	-0.002083	-0.001752	0.000254	-0.00116
JPN	c12	-0.000637	-0.000456	-4.10E-05	0.01421	0.003016	0.003578	0.002736	-0.001944	0.006656	-0.002139	0.002967	-0.002721	-0.002372	-0.005005	-0.000758	-0.000904
JPN	c14	-0.002756	0.00241	0.001125	0.007185	-0.000104	0.00107	-0.001935	-0.002504	0.00216	0.000657	0.001544	-0.003419	-0.000103	-0.003549	-0.003412	-0.00358
JPN	c15	-0.009856	-0.004599	0.013695	0.083506	-0.007818	-0.011403	-0.008969	-0.004777	0.00988	0.011692	-0.019437	0.004887	0.019214	0.017271	-0.005556	-0.010025
JPN	c17	0.001161	0.000228	-0.000396	0.002602	0.000689	0.00037	0.00046	9.76E-05	0.001039	-0.000923	0.00096	-0.000461	-0.000889	-0.000531	0.000224	0.000454
JPN	c20	0.001279	-0.001502	0.0014	0.00548	0.000608	0.000264	0.002923	0.000784	0.004324	-0.001381	0.001462	-0.001537	-0.003171	-0.000559	0.001119	-0.001194
JPN	c23	0.000548	0.00036	-0.000225	0.002365	0.000359	0.000255	0.000274	-0.000209	0.0013	-0.000586	0.000685	-0.000426	-0.000496	-0.000342	0.000245	0.000171
JPN	c30	0.00234	0.000561	-0.002564	0.006632	0.000415	0.000754	0.000945	0.000242	0.00227	-0.001451	0.00183	-0.000898	-0.002169	-0.001407	0.00048	0.000602
USA	c15	0.001049	-0.000125	0.001092	-0.000188	-1.04E-05	0.000853	0.000345	-0.000766	0.00016	-0.000495	-0.000245	0.004042	-0.001922	0.002376	0.000916	0.001114
RoW	c12	-0.000812	0.000184	-0.000378	0.000403	0.000152	-3.40E-06	-0.000168	0.000173	5.77E-05	8.15E-05	0.000322	0.00177	-0.002279	-0.000719	0.000443	0.001787
RoW	c15	-0.001236	0.001933	-0.001314	0.000694	0.001432	0.000476	9.02E-05	0.005176	-0.032475	0.001746	0.000534	-0.002762	-0.00075	-5.00E-05	3.10E-05	6.69E-05
Sum of all changes		-4.32E-11	-3.86E-11	-9.82E-10	1.57E-01	5.46E-11	-7.61E-10	-3.69E-17	-1.4E-10	8.3E-10	-1.87E-10	1.21E-09	8.84E-16	-2.14E-10	5.83E-10	-1.36E-15	-9.51E-10
Average of all changes		-1.96E-14	-1.75E-14	-4.45E-13	7.11E-05	2.48E-14	-3.45E-13	-1.67E-20	-6.35E-14	3.76E-13	-8.46E-14	5.47E-13	4.01E-19	-9.72E-14	2.64E-13	-6.18E-19	-4.31E-13
Standard devialtion of all changes		0.000267	0.000135	0.000313	0.00183	0.000184	0.00026	0.000216	0.000169	0.000751	0.000263	0.000426	0.000196	0.000432	0.000401	0.000148	0.000243
Upper threshhold for significant changes		0.000801	0.000405	0.000939	0.00556	0.000553	0.000779	0.000648	0.000507	0.002253	0.00079	0.001277	0.000588	0.001295	0.001203	0.000445	0.00073
Lower threshhold for significant changes		-0.000801	-0.000405	-0.000939	-0.005418	-0.000553	-0.000779	-0.000648	-0.000507	-0.002253	-0.00079	-0.001277	-0.000588	-0.001295	-0.001203	-0.000445	-0.00073

(Notes)

1. For the codes for the economies and the industries, see Table 1.

2. Columns are the industries that showed significant changes in, at east, one of the years during the period. Significant changes are defined as changes that are more than three standard deviations away from the mean on both sides.

Figure 4 Accumulated Policy-induced effects in Input Coefficients of Japan's TRAN Industry (sectors showing significant accumulated effects)

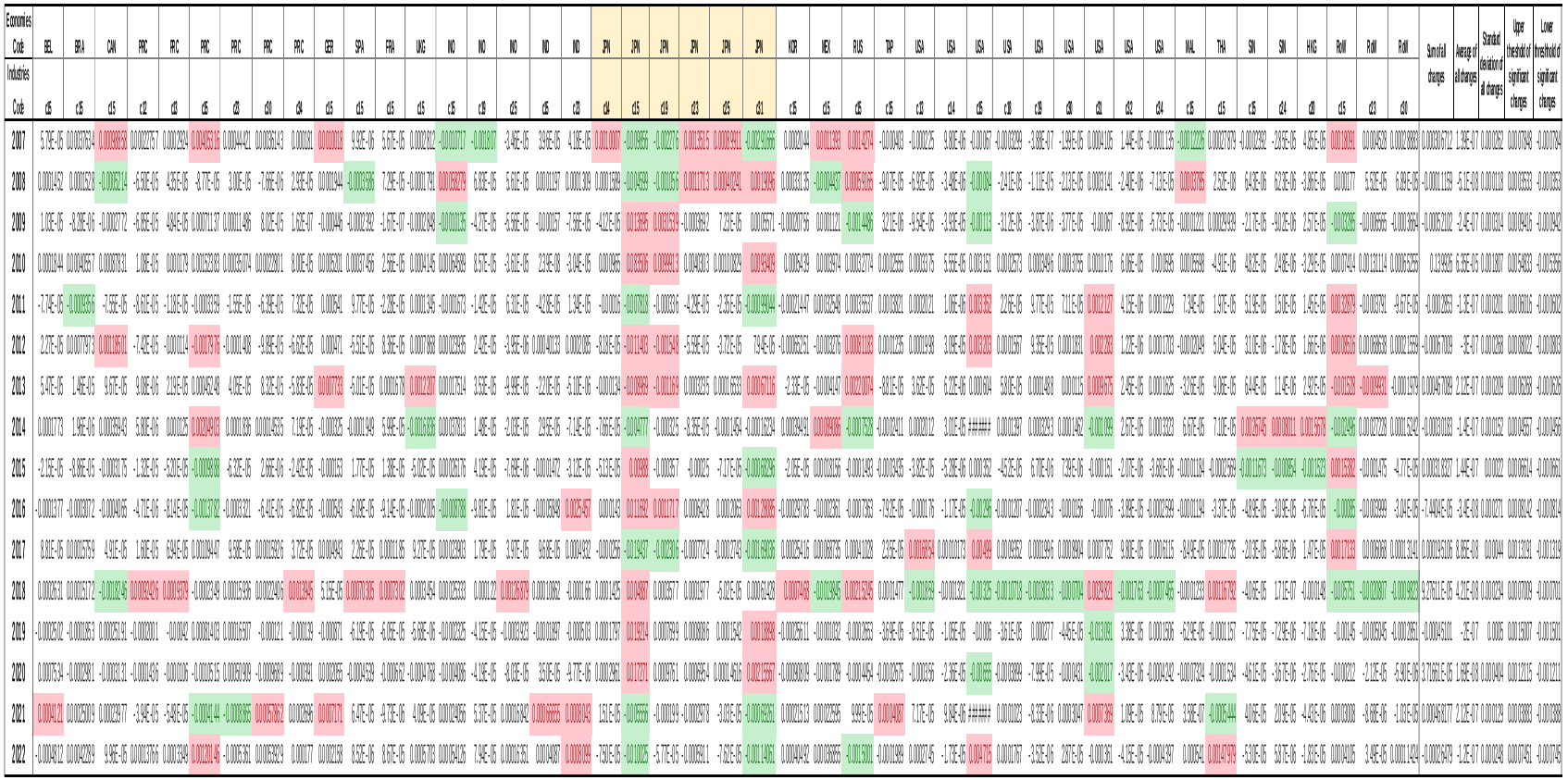


(Note) 1. For the codes for the economies and the industries, see Table 1.

2. Industries selected are those which showed five largest positive or negative accumulated changes among the industries that was selected in Table 2. There are only eight lines because there are only eight sectors selected in Table 4/

Table 5: Policy-induced effects in Output Coefficients of Japan's TRAN Industry

(cells showing significant effects)

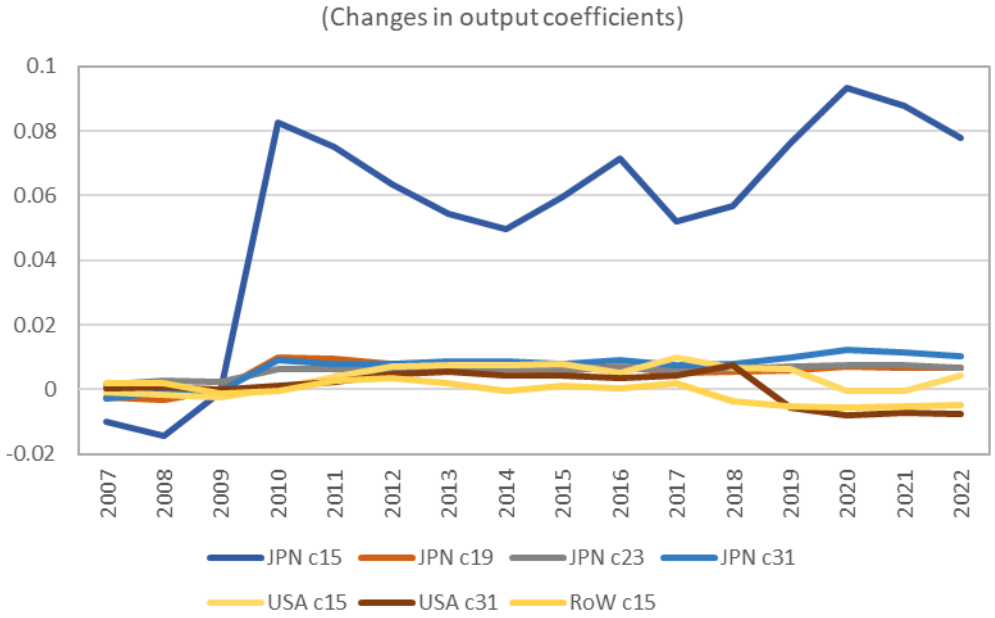


(Notes)

1. For the codes for the economies and the industries, see Table 1.

2. Columns are the industries that showed significant changes in, at east, one of the years during the period. Significant changes are defined as changes that are more than three standard deviations away from the mean on both sides.

Figure 5 Accumulated Policy-induced effects in Output Coefficients of Japan's TRAN Industry (sectors showing significant accumulated effects)



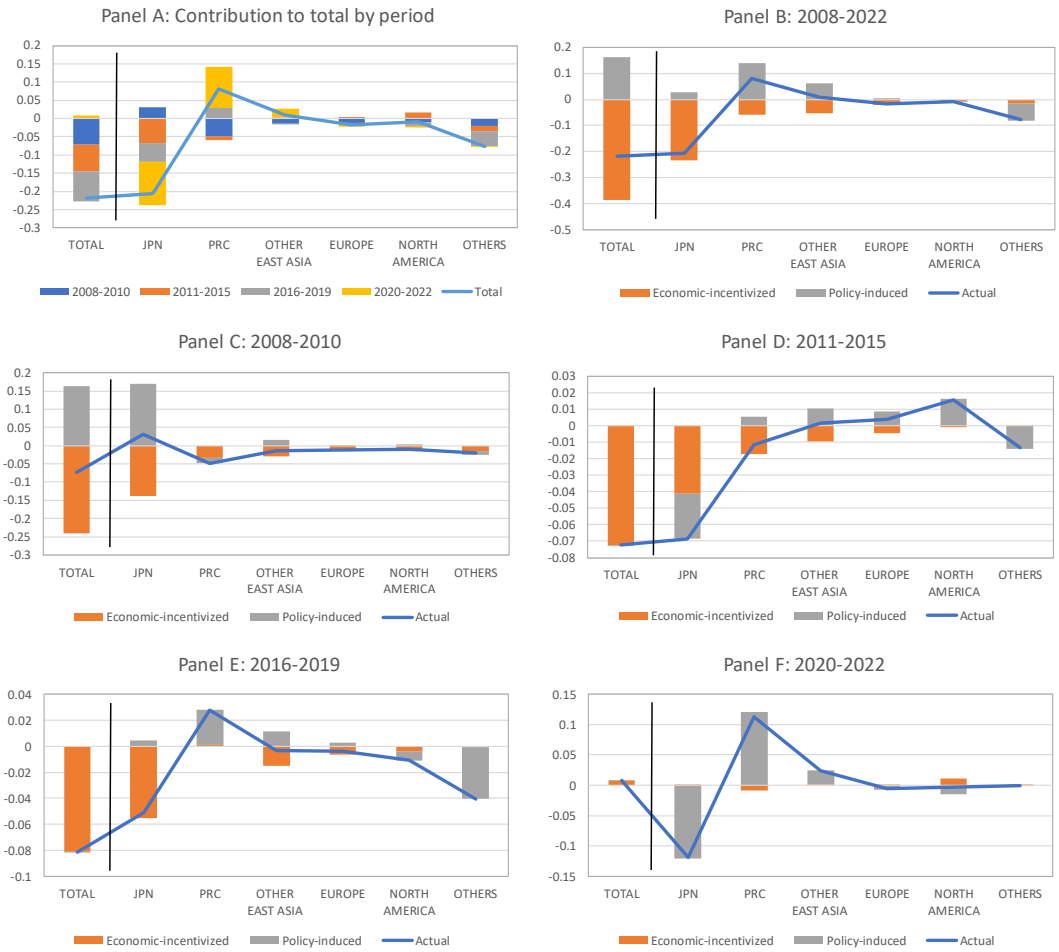
(Note) 1. For the codes for the economies and the industries, see Table 1.

2. Industries selected are those which showed five largest positive or negative accumulated changes among the industries that was selected in Table 2. There are only seven lines because JPN c19, JPN c19, and JPN c31 are among the top five in both positive and negative accumulated changes.

Figure 6 Changes in Actual Input Coefficients of Japan's ELEC and Its Breakdown

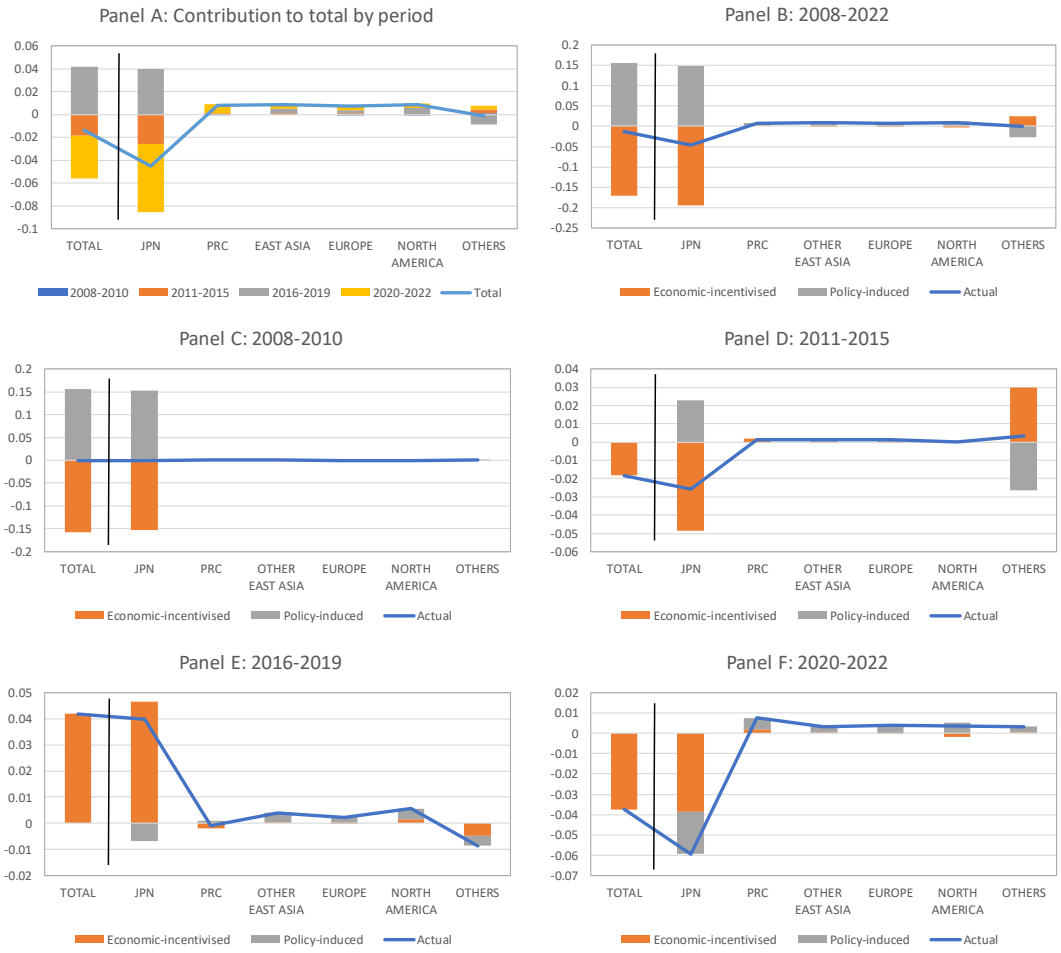
(Source) Prepared by the author.

Figure 7 Changes in Actual Output Coefficients of Japan's ELEC and Its Breakdown



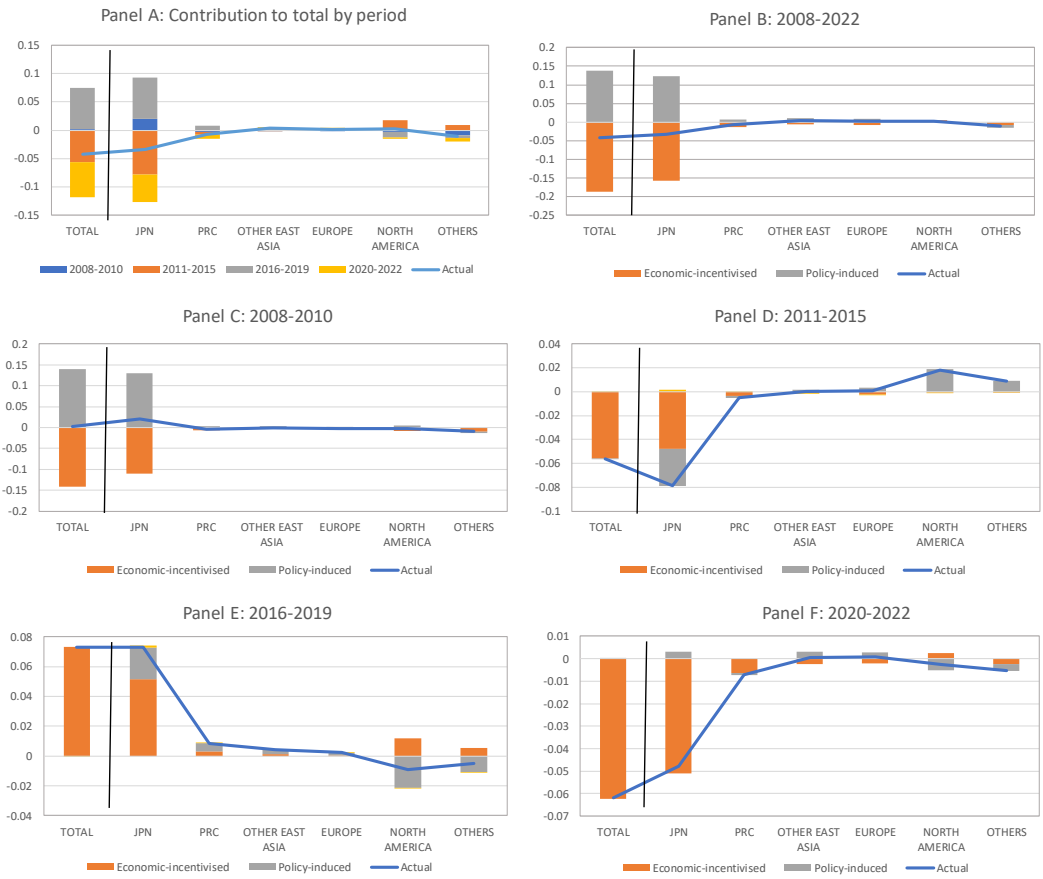
(Source) Prepared by the author.

Figure 8 Changes in Actual Input Coefficients of Japan's TRAN and Its Breakdown



(Source) Prepared by the author.

Figure 9 Changes in Actual Output Coefficients of Japan's TRAN and Its Breakdown



(Source) Prepared by the author.

Table 6: Changes in Japan's GVC under the COVID-19 pandemic

	Nature of changes	Electric and Optical Equipment Industry (ELEC)	Transportation Equipment Industry (TRAN)
Input sourcing	Actual	Reduce domestic sourcing and increase outsourcing to China and other East Asia ==>Reduce intermediate inputs and increase value added	Reduce domestic sourcing and increase outsourcing to China and other East Asia ==> Reduce intermediate inputs and increase value added
	* Economic-incentive effects	Reduce domestic sourcing	Reduce domestic sourcing
	* Policy-induced effects	Reduce domestic sourcing and increase outsourcing to China and other East Asia	Reduce domestic sourcing and increase outsourcing to China and other East Asia
Output sales	Actual	Reduce sales to Japan and increase sales to China and other East Asia ==> Maintain total sales of intermediate inputs	Reduce sales to Japan and China ==> Reduce total sales of intermediate inputs
	* Economic-incentive effects	Maintain total sales of intermediate inputs	Reduce sales to Japan and China ==> Reduce total sales of intermediate inputs
	* Policy-induced effects	Reduce sales to Japan and increase sales to China and other East Asia ==> Maintain total sales of intermediate inputs	Maintain total sales of intermediate inputs

(Source) Prepared by the author.