RIETI Policy Discussion Paper Series 22-P-024

Resilient and Innovative Supply Chains: Evidence-based policy and managerial implications

TODO, Yasuyuki
RIETI

The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Policy Discussion Paper Series 22-P-024

September 2022

Resilient and Innovative Supply Chains: Evidence-based Policy and Managerial Implications*

Yasuyuki TODO

Research Institute of Economy, Trade and Industry and Waseda University

Abstract

The aims of this paper are threefold. First, we discuss how resilient and innovative supply chains and knowledge networks can be constructed, mostly based on papers from current and previous projects at RIETI. The role of geographic diversity across partner countries in supply chains and knowledge networks is particularly emphasized. Second, we overview the recent policies affecting global supply chains and trends in the supply chains of major countries from the viewpoint of diversity. It is particularly observed that the reliance on China in imports of intermediate products to many countries in Asia has increased substantially. Although the reliance of Japan on China recently declined to some extent, it is still high compared with that of the United States and European countries. Finally, policy and managerial suggestions are provided based on the academic evidence in the first part and the current observations in the second part. It is suggested that Japan should lower its reliance on China in supply chains and diversify supply chains internationally to countries without national security concerns (i.e., "friend-shoring") for resilience, and it should also expand knowledge networks among such countries to increase innovation.

Keywords: global supply chains, resilience, innovation, diversity, national security, disasters

JEL classifications: F13, L14, O33

* This study is conducted as a part of the Project entitled "Research on relationships between economic and social networks and globalization" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). This article is a substantially extended version of the author's section in the monograph edited by Gong Xue and published by S. Rajaratnam School of International Studies (RSIS), Nanyang Technological University (MN37), titled "Regional Economic Integration in the Post-Pandemic Era," adding a number of academic studies in the literature review, the latest data, and new policy and managerial implications. The author is grateful for helpful comments and suggestions by seminar participants at RSIS and RIETI. The author is also grateful for the financial support of JSPS Kakenhi Grant No. JP18H03642. The opinions expressed and arguments employed in this paper are the sole responsibility of the author and do not necessarily reflect those of RIETI, Waseda University, or any institution with which the authors are affiliated or those of coauthors of studies cited in this paper.

1. Introduction

Recently, global supply chains have been substantially reorganized. One major reason for this reorganization is the adoption of policies in the United States, Japan, and European countries toward decoupling from the Chinese economy for national security concerns and protectionism policies in China to counterattack these decoupling policies. Another reason is that many countries have experienced a disruption in supply chains and resulting reductions in domestic production during the COVID-19 pandemic. Moreover, the Russia-Ukraine War is currently lowering exports of natural gas, minerals, and cereals from the two countries, exacerbating concerns about risks of supply chain disruption.

Under these circumstances, the aims of this article are threefold. First, we discuss how resilient and innovative supply chains can be constructed, mostly based on papers from current and previous projects at RIETI. The role of geographic diversity in supply chain partners is particularly emphasized. Second, we overview the recent policies affecting global supply chains and trends in the characteristics of the supply chains of major countries from the viewpoint of diversity. It is particularly observed that the reliance on China for imports of intermediate products has increased substantially among many countries, while the United States and Japan have recently lowered their reliance on China. Finally, policy and managerial suggestions are provided mostly from the perspective of Japan, based on the academic evidence in the first part and current observations in the second part. It is suggested that Japan should lower its reliance on China in supply chains, diversify supply chains internationally to countries without national security concerns (i.e., "friend-shoring") for resilience and expand knowledge networks among such countries for innovativeness.

2. Characteristics of Resilient and Innovative Supply Chains

Role of geographic diversity in resilience

In the wake of the COVID-19 pandemic, because of policies to prevent infections, such as lockdowns, the world economy has experienced the propagation of negative production shocks through supply chains. The propagation can be both upstream, i.e., from customers to suppliers because of shortages of demand, and downstream, i.e., from suppliers to customers because of supply shortages. Trade data showed that COVID-19 infection in a country decreased exports from other countries that utilized inputs imported from the infected country, confirming downstream propagation (Hayakawa and Mukunoki, 2021).

Before the pandemic, some economic studies had already examined the propagation of economic shocks through supply chains in detail and found their large effects (Barrot and Sauvagnat, 2016; Boehm, et al., 2019; Carvalho, et al., 2021). For example, a simulation study using supply chain data for nearly 1 million companies in Japan found that the indirect effect of the Great East Japan earthquake in 2011 on domestic production by supply chain shock propagation was 100 times as large as its direct effect (Inoue and Todo, 2019). According to a similar simulation study that predicted the effect of the disruption of imports of intermediates on production in Japan, a two-month disruption to 80% of imports that amounts

to 6 trillion yen would spread outward to a production reduction of 92 trillion yen in total (Inoue and Todo, 2022).

This substantial propagation is partly enhanced by the difficulty of substituting disrupted suppliers with others. Inoue and Todo (2019) showed that the propagation effect would be minimal in hypothetical supply chains in which suppliers are perfectly substitutable, while it would persist for a long time and result in a large production loss when inputs are quite specific to each customer and thus are not substitutable. Another similar simulation study that incorporated international trade, Inoue and Todo (2022), shows that the economic effect of the disruption of intermediate imports can be largely mitigated when intermediates can be procured from domestic firms even when the production capacity of domestic suppliers remains the same. These results imply that promoting substitutability among suppliers is key to resilient supply chains. This conclusion is also supported by an econometric study by Barrot and Sauvagnat (2016) using long-term data for the United States.

In practical examples, Toyota Motor realized the importance of supplier substitutability from its experience in the Great East Japan earthquake and has created a database of its direct and indirect suppliers called RESCUE so that it can easily find substitutes for disrupted suppliers once any shock occurs (Toyota 2016; Fujimoto et al. 2016). This database helped Toyota minimize the length of the period of supply chain disruption in subsequent disasters, including the COVID-19 pandemic (Nikkan Kogyo Shinbun 2020).

In addition to building such databases, another way to promote supplier substitutability is geographic diversification, particularly international diversification, of supply chain partners. If a company is linked with suppliers and customers in only one country, a large economic shock that hits the partner country can largely affect the company because it is difficult to replace the disrupted partners with new partners in other countries that are not hit by the shock. In contrast, if the company is linked with partners in various countries, the shock can be mitigated by substitution of suppliers and customers in other countries for disrupted ones.

This presumption is supported by a study using data for global supply chains of major companies in the world (Kashiwagi, et al., 2021). The study finds that Hurricane Sandy, which hit the US east coast, including New York, in 2012, lowered sales of US companies linked with companies in the affected region through supply chains. However, the hurricane did not substantially affect sales of companies linked with the affected region if they were located outside the US or located in the US but linked additionally with overseas companies. This evidence implies that companies that have diverse partners internationally can mitigate the propagation of economic shocks because they can find substitutes relatively easily by selecting from their existing partners or using their international information network.

This implication has held during the COVID-19 pandemic. One study using trade data at the country-product level found that the spread of COVID-19 in a country reduced exports of machinery from another country that imports machinery parts from the infected country, confirming the propagation of the economic effect of COVID-19 through global supply chains (Ando and Hayakawa, 2021). They further found that the negative indirect effect of COVID-19 in suppliers of parts on exporters of

machinery was alleviated more when the exporting countries imported parts from more countries. Among the 35 exporting countries examined in the study, the diversity in imports of parts is the largest for Germany and the smallest for Singapore. Because of the difference in the degree of supplier diversity between the two countries, the effect of COVID-19 outbreaks in supplier countries on Singapore was 1.7 times larger than that on Germany.

Another study using company-level data collected in ASEAN countries and India during the COVID-19 pandemic reached the same conclusion (Todo, et al., 2021). They defined resilient companies as those that faced a decline in the transaction amount with a supplier or customer during the pandemic but increased the amount with another. Although the share of resilient companies in the sample was 7%, companies are 4-8% more likely to be resilient when their suppliers are located in more than one country than when they are located in only one country.

Diversity also promotes innovation

Furthermore, it should be emphasized that geographically diversified supply chains are more innovative because companies can learn new technologies, knowledge, and information from their foreign partners. The literature on international economics has shown empirical evidence of productivity improvement through exporting, importing, and inflows and outflows of foreign direct investment (FDI) (Atkin, et al., 2017; Keller and Yeaple, 2009, among many others). In the case of Japan, Kimura and Kiyota (2006) found a positive effect of exporting and FDI outflows on productivity. Todo and Shimizutani (2007) and Todo (2006) showed productivity improvement in Japanese firms because of FDI outflows and inflows, respectively, particularly when FDI is associated with research and development (R&D) activities in the host country.

Todo et al. (2016) also found that Japanese companies linked with suppliers and customers outside the prefecture increased sales, sales per worker, and the number of patent applications compared to those linked with suppliers and customers in the same prefecture. Although their study focuses on domestic supply chains in Japan, their results suggest that companies can obtain new knowledge through links with distant partners, including foreign partners, and improve their productivity and innovativeness.

In addition to supply chains, or networks of enterprises through transactions of materials and parts, knowledge networks, such as research collaboration networks, are quite helpful for learning and innovation (Chen, et al., 2019), as the literature on open innovation has shown (Chesbrough, 2003). In particular, Iino et al. (2021), using patent data, found that by engaging in international research collaboration, companies can increase the number of citations per patent, a measure of the quality of innovation, by 27%. Moreover, the effect of international research collaboration is substantially higher than the effect of domestic collaboration (5.5%). These findings confirm the importance of international linkages to learning new knowledge and promoting innovation.

International research collaboration was also quite effective during the COVID-19 pandemic. OECD (2021) stated that "(c)ollaboration lies at the heart of science, technology and innovation response to COVID-19, where national and international collaborative platforms for technology are

revolutionizing vaccine design and production" (p. 122). Among the medical publications related to COVID-19 authored by US-based scientists from January to November 2020, 16% involved international collaboration: 5.5% were with China, and 4.7% were with the United Kingdom.

In summary, supply chains and knowledge networks geographically diversified across countries are the key to their resilience and innovativeness.

3. The Current Situation of Global Supply Chains

This section provides an overview of the current situation of global supply chains that have changed rapidly in recent years, particularly focusing on the Asia-Pacific region.

US–China decoupling and its impact on trade

One major force of the changes in global supply chains is US–China decoupling. The US government has restricted exports and technology transfer of high-tech products and technologies to some Chinese companies, most notably Huawei, but many other companies as well, since 2019 because of national security concerns. In addition, the US has heavily regulated FDI inflows in high-tech sectors since 2018, targeting FDI from China. More recently, the US government announced the importance of building resilient supply chains for strategic products, such as semiconductors, large capacity batteries, and pharmaceuticals, for national security (White House 2021, 2022a; USDC et al. 2022). For this purpose, the CHIPS and Science Act passed the US Congress in July, 2022 and was signed by President Biden in August, 2022. The Act aims at attracting production plants of TSMC, Samsung, and Intel, the global giants in the semiconductor industry, to the US and promoting research and development (R&D) activities in strategic industries, using the total budget of 280 billion US dollars (White House 2022b).

The Japanese government followed the strategies of the US, restricting exports of information and communication technologies (ICT) and military-related products in 2019 and FDI inflows in 2020. The government provided subsidies for "onshoring" to companies producing essential products that locate their production plants in Japan (METI 2022) or set up their production facilities in ASEAN for supply chain diversification (JETRO 2022). The Japanese government also attracted TSMC's production plant to Japan. The modified budget for fiscal year 2021 allows the government to provide subsidies of up to 620 billion yen to attract semiconductor plants (Reuters 2021, November 23). Using the budget, the Japanese government attracts TSMC's production plant to Japan and financially supports investment of new plants of Kioxia and Western Digital (Nikkei XTECH 2022).

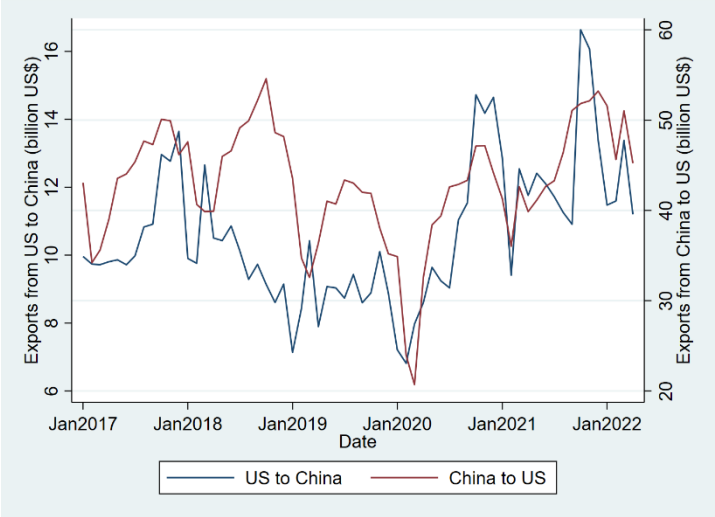
European countries also followed the US. The UK and the European Union (EU) initiated respective policies, the 5G Network Diversification Strategy with a budget of 250 million GBP (UK Government 2020) and the European Chips Act with 43 billion euros (EU 2022). The purpose of these policies was to construct resilient supply chains of high-tech products that do not rely on Asia, particularly China.

China reacted to these policies of the US, Japan, and European countries by setting up its export control law in 2020 to strengthen controls of exports and technology transfer of sensitive products from

China (National People's Congress 2020). In addition, the Chinese government has provided a large amount of subsidies to high-tech sectors, 40 billion RMB (6 billion US dollars) in 2015 and 100 billion RMB (15 billion US dollars) in 2020, according to METI (2022), since even before the US–China decoupling period.

However, it should be emphasized that despite these decoupling policies, trade volumes between them did not necessarily shrink. As shown in Figure 1, exports from the US to China and from China to the US both showed a decreasing trend in 2018 and 2019, most likely because of the restrictions mentioned earlier. However, both showed an increasing trend after March 2020, when trade volumes sharply dropped because of the spread of COVID-19 and associated lockdowns in China. Exports from the US to China reached a record high in October 2021, whereas exports from China to the US were the second highest in November 2021.

Figure 1: Trade between the US and China (monthly, January 2017-March 2022)



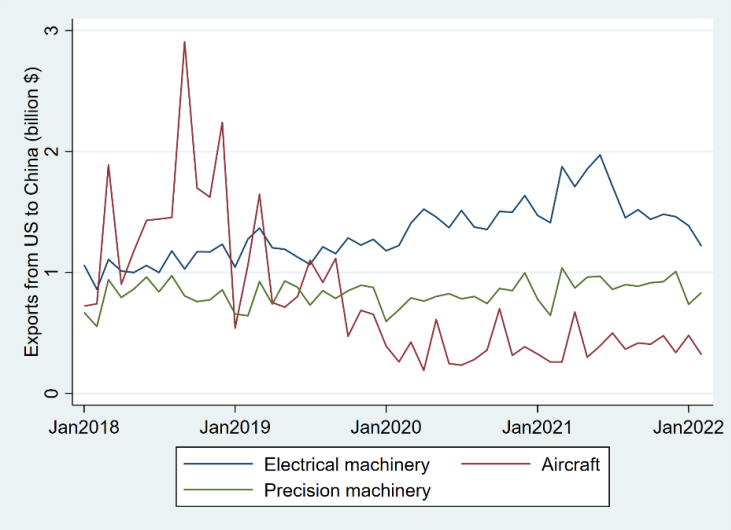
Source: United Nations (2022)

Figure 2 specifically presents high-tech exports from the US to China using more disaggregated classifications, i.e., the harmonized system (HS) code at the two-digit level. Exports of electrical machinery and equipment, including parts (HS code: 85), which are the major target of the US–China decoupling, have been increasing drastically since 2018, whereas exports of another target, precision instruments and parts including optical and medical instruments (90), are stable. In contrast, exports of aircraft, spacecraft and parts (88) have been clearly decreasing since 2019. However, this decrease should be interpreted with caution because it may be due to a decrease in demand for aircrafts during the COVID-19 pandemic.

Figure 3 exhibits exports of further disaggregated product categories, focusing on products of HS codes at the four-digit level; the word "semiconductor" is defined at the six-digit level. Again, exports of most products are either increasing or stable. However, we do observe a declining trend for some categories, i.e., machine tools including those for dry-etching patterns on semiconductor materials (8456)

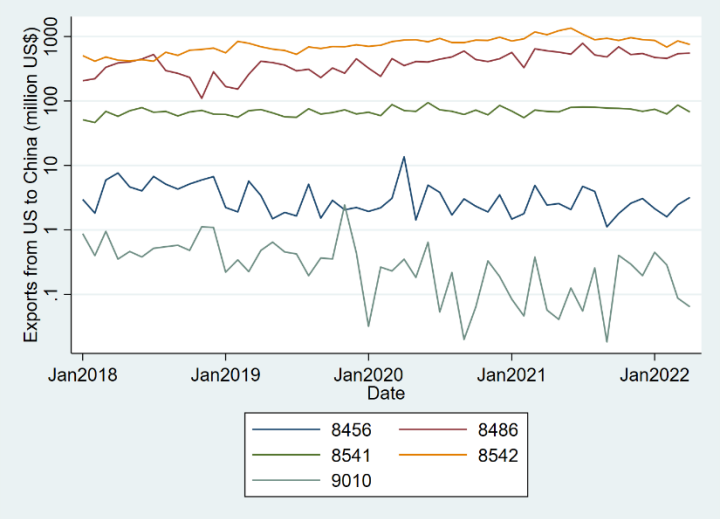
and the apparatus for photographic laboratories including that for semiconductor materials (9010).

Figure 2: High-Tech Exports from the US to China



Source: United Nations (2022)

Figure 3: Exports Related to Semiconductors from the US to China

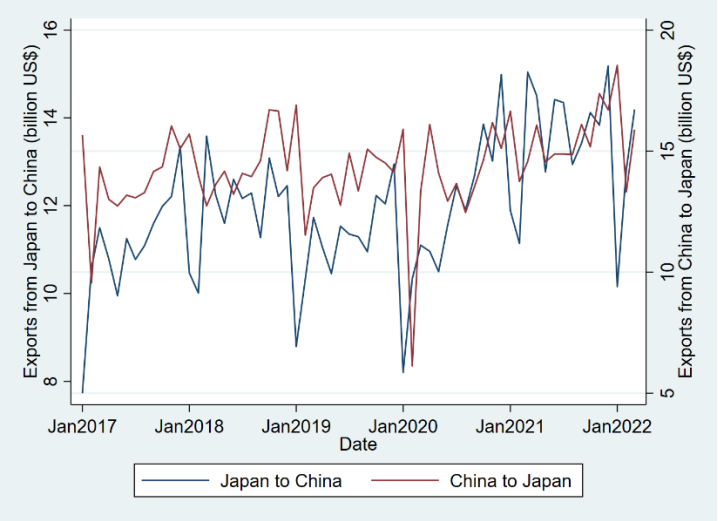


Source: United Nations (2022)
Note: The vertical axis is in log. The numbers in the legend indicate HS codes at the 4-digit level. 8456: machine tools for working any material by laser etc. 8486: machines used for the manufacture of semiconductor devices, etc. 8541: semiconductor devices. 8542: electronic integrated circuits. 9010: apparatus for photographic laboratories.

Figures 4-6 are corresponding figures for trade between Japan and China. Trade values in both directions between Japan and China show a recent increasing trend compared to those between the US and China (Figure 4). Similar to exports from the US, Japanese exports of high-tech products to China have been increasing (electrical machinery [85]) or stable (automobiles [87] and precision machinery [90]), as shown in Figure 5. Moreover, exports of any of the products related to semiconductors did not

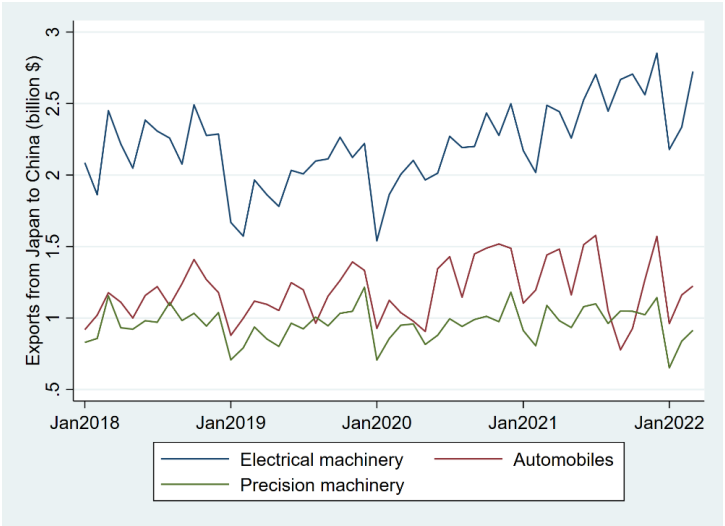
decrease during the US–China decoupling period (Figure 6).

Figure 4: Trade between Japan and China (monthly, January 2017-March 2022)



Source: United Nations (2022)

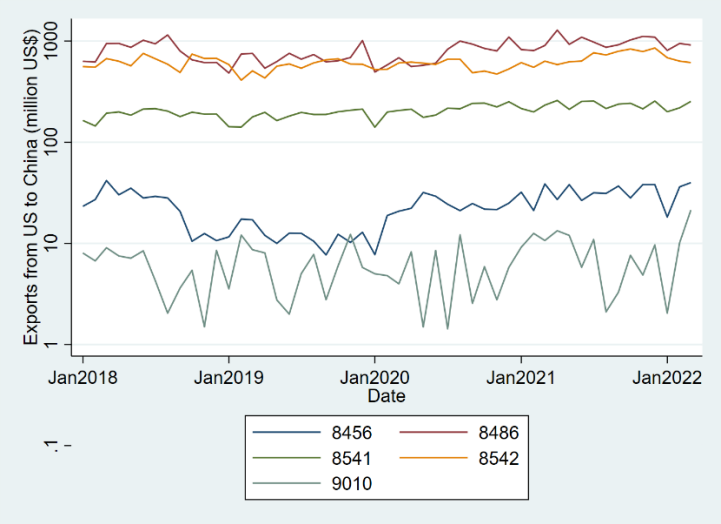
Figure 5: Exports of Major Products from Japan to China



Source: United Nations (2022)

All these figures show that although the US and Japan have imposed a number of restrictions to decouple the Chinese economy, trade volumes with China did not decline in general. Instead, US–China decoupling is occurring in limited industries and technology fields that are critical to national security, such as machine tools for dry-etching patterns on semiconductor materials and apparatuses for semiconductor materials (Figure 3). The minimal effect of the export restrictions by the US is most likely because both the Trump and Biden Administrations tried to balance the national security and economic interests of the US and thus allowed exports from US companies to Huawei of over $60 billion despite their restrictions on US exports to Huawei (Congressional Research Service 2022).

Figure 6: Exports of Semiconductor-related Products from Japan to China



Source: United Nations (2022)
Note: The vertical axis is in log. The numbers in the legend indicate HS codes at the 4-digit level.

Trends in geographic diversification of suppliers

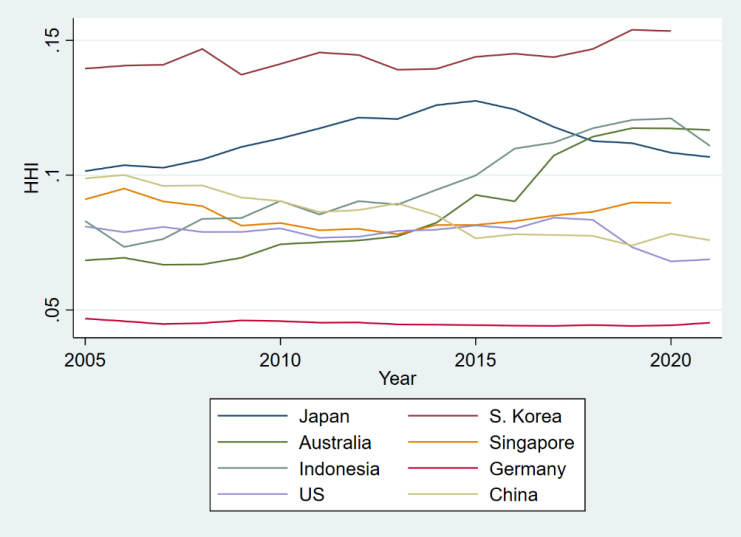
We now turn to the degree of geographic diversification of suppliers in global supply chains for selected countries in the Asia-Pacific region and Germany for comparison to evaluate their resilience. Figure 6 illustrates the Herfindahl-Hirschman Index (HHI) of imports of parts and components for each country. The HHI is defined by the sum of the squared share of each trade-partner country in the focal country's total imports. It takes a value between 0 and 1, and a larger HHI indicates a higher concentration or lower diversification of trade partners. Parts and components are defined by 22 (processed industrial supplies not elsewhere specified), 42 (parts and accessories of capital goods), and 53 (parts and accessories of transport equipment) of the Broad Economic Categories (BEC) of the United Nations. Figure 7, constructed from the UN Comtrade Database (United Nations 2022), shows the share of China in imports of parts for each country because China is currently a major hub in global supply chains.

Several findings are worth noting. First, South Korea, Australia, and Indonesia have raised their reliance on China and accordingly the geographic concentration of suppliers of parts measured by the HHI for the last decade. This increasing trend was not changed by the US–China decoupling starting in 2019 or the COVID pandemic starting in 2020, except for a reduction for Indonesia.

Second, Japan's reliance on China and its HHI were quite high in 2015, comparable to those of South Korea, but have declined slightly since then. This finding implies that Japanese companies lowered their reliance on China as part suppliers a few years before the US–China decoupling and the COVID-19 pandemic and continued this procurement strategy during these events. One possible reason for the change before the decoupling and pandemic is a recent increase in wages in China that encourages Japanese companies to relocate their parts plants in China to countries with lower wages, such as those

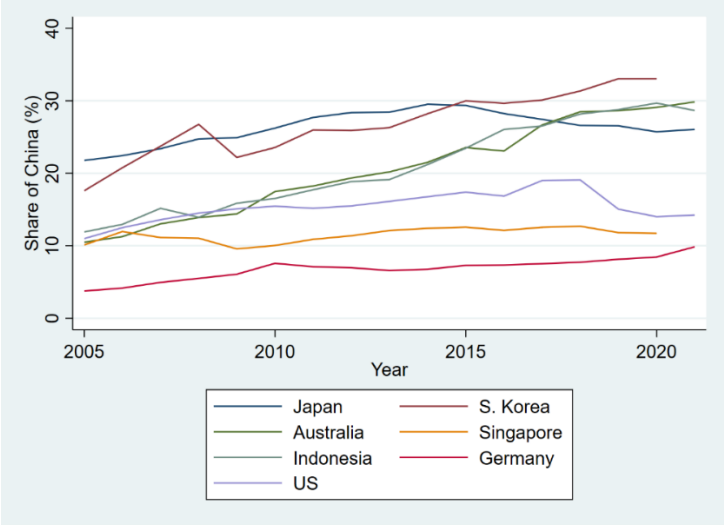
in ASEAN and India. Another reason may be that because disputes between Japan and China over the Senkaku Islands escalated in 2012 and the associated anti-Japan movement in China, Japanese companies realized the risks of trade and investment links with China. In addition, the decline in the share of China may be partly generated by an increase in the share of the EU, as shown in Figure 9, because of the Japan-EU economic partnership agreement (EPA) signed in 2018.

Figure 7: Herfindahl-Hirschman Index of Imports of Parts (2005-2021)



Source: United Nations (2022)

Figure 8: Share of China in Imports of Parts (2005-2021)

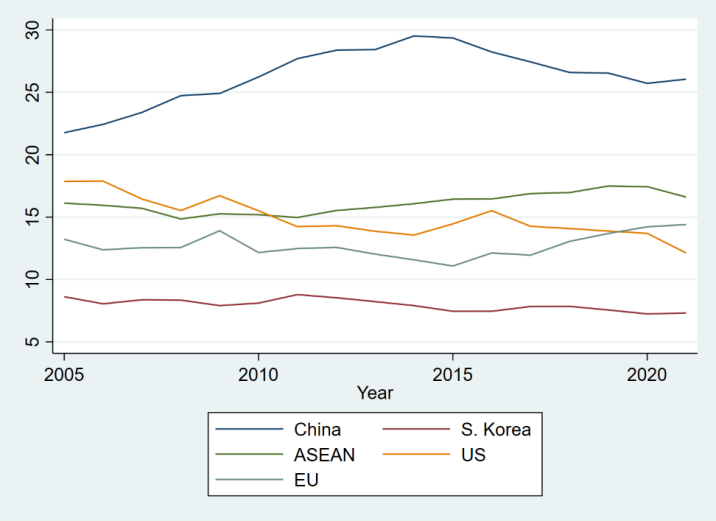


Source: United Nations (2022)

Third, the US has also lowered its HHI and its reliance on China since 2019, the initial year of US–China decoupling. Although we saw in Figure 1 that the total imports of the US from China did not change substantially, Figure 8 shows that the share of China in total imports of parts declined by 5

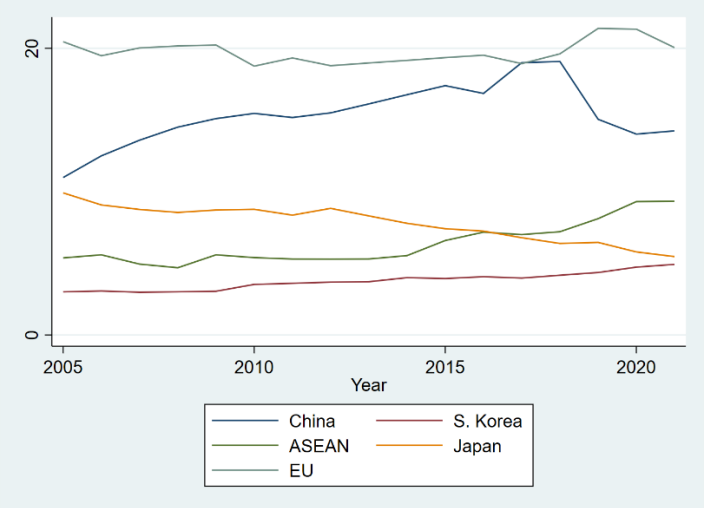
percentage points. This evidence confirms our findings that US–China decoupling does not occur in general but affects trade in some specific fields. Figure 10 further shows that the decrease in the share of China is associated with an increase in the shares of ASEAN, South Korea, and, to a smaller extent, the EU, suggesting that suppliers of the US companies are becoming increasingly diversified.

Figure 9: Share of Exporter Economies in Imports of Parts to Japan (2005-2021)



Source: United Nations (2022)

Figure 10: Share of Exporter Economies in Imports of Parts to the US (2005-2021)



Source: United Nations (2022)

Fourth, China drastically reduced its HHI from 0.099 in 2005, a value similar to Japan's in the same year, to 0.075 in 2021, the lowest value among the selected Asian countries in the same year. This evidence implies that China successfully diversified its supply chains geographically, while other countries intensified their reliance on China. This was possible mostly by reducing the share of Japan in China's imports of parts from 18% in 2005 to 9.5% in 2021. At the same time, China's supply chains

expanded to various regions in the world, most notably to ASEAN countries, whose share increased from 12.6% in 2005 to 17.9% in 2021.

Finally, although Germany is also increasing its reliance on China, its HHI remains substantially lower than the HHI for any of the selected countries in the Asia-Pacific region. This suggests that the level of geographic concentration of supply chains in the Asia-Pacific region is far greater than in Europe, although this finding can partly be explained by the fact that most of Germany's supply chain partners are European countries that are relatively small. The share of EU countries in Germany's intermediate imports is stable between 57-60% during the period 2005-2021.

Now, we evaluate these features of supply chains in the Asia-Pacific region based on the claim in the previous section that more geographically diversified supply chains are more resilient and innovative. First, Japan and the US recently lowered their reliance on China as suppliers and thus the degree of supply chain concentration. In the same period, their overall trade volume with China, particularly their exports to China, is not shrinking but shows an increasing trend. Therefore, we can conclude that the recent changes of Japan and the US are favorable to supply chain resilience and economic growth in that the two countries have lowered the risk of supply chain disruption without losing benefits from trade. In the US, these favorable changes may have been promoted by policies because the reduction of the reliance of the US on China coincides with the US's policies restrictive to China. In contrast, the role of policies in improving the supply chain diversity of Japan is not clear because the change in Japan started a few years before the changes in policies.

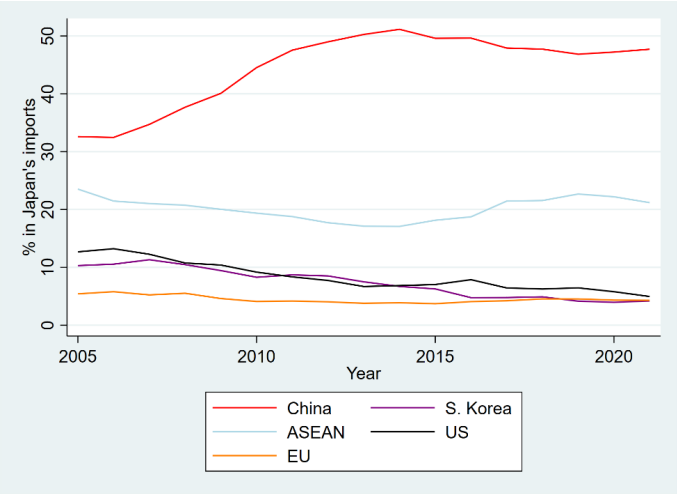
Second, despite the recent favorable change, Japan's reliance on China and level of concentration in supply chains are still high in absolute terms. Although it is difficult to determine the "best" HHI for resilient and innovative supply chains, the HHI for South Korea, Australia, Indonesia, and Japan are too high compared with that for Germany, China, Singapore, and the US. Japan's reliance on China is particularly large for some industries. For example, the share of China in imports of electronics to Japan shows a declining trend but is still close to 50% (Figure 11). The share of China in imports of parts of automobiles has increased for the most recent 4 years during the US–China decoupling and COVID-19 pandemic period and was at 37% in 2021, substantially higher than the share of China in imports of all kinds of parts, at 26%. Because risks of supply chain disruption are increasing due to global climate changes and national security concerns, it is suggested that Japanese manufacturing industries, particularly those relying heavily on China, improve supply chain diversity to deal with the risks.

Current situation of international knowledge networks

As we mentioned the importance of international knowledge networks to innovation, we provide an overview of their current situation, particularly focusing on Japan. Iino et al. (2021) show that the R&D activities of Japanese companies are less internationalized than those of companies in other developed countries and China. For example, the share of international co-invention in all patent applications in Japan during the period 2012-15 is 1.3%, compared with 3.6% for South Korea, 5.7% for China, 10.0% for the US, and 10.4% for the EU countries (OECD 2017). Because the effect of international research

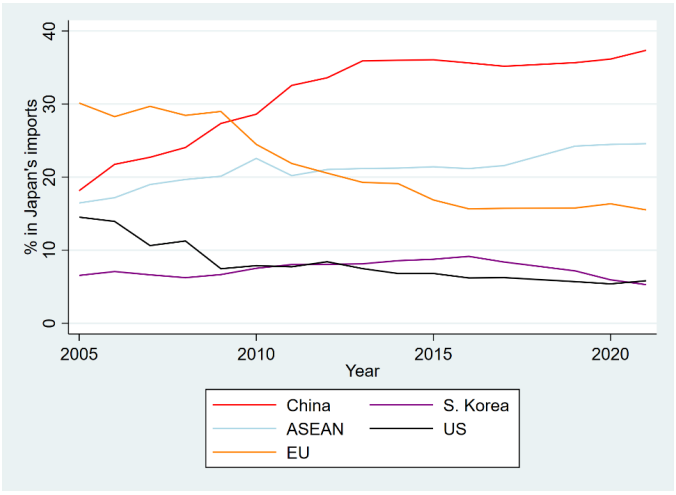
collaboration on innovation is quite large (Section 2 and Iino, et al., 2021), a lack of international collaboration may be one of the major causes of prolonged economic stagnation in Japan.

Figure 11: Share of Exporter Economies in Imports of Electronics to Japan (1999-2010)



Source: United Nations (2022)

Figure 12: Share of Exporter Economies in Imports of Parts of Automobiles to Japan (1999-2021)

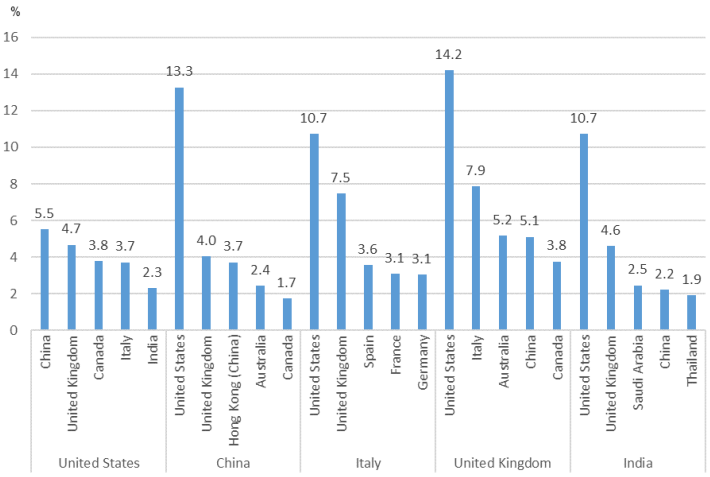


Source: United Nations (2022)

The low levels of international research collaboration and innovation did not change much during the COVID-19 pandemic. According to the OECD (2021), in terms of the number of biomedical publications related to COVID-19 in 2020, Japan ranked 15th. This low rank may be attributed to inactive international collaboration in COVID-19 research because Japan ranked 18th in the number of publications written in international collaboration. Figure 13 presents the top 5 countries in the number of publications in COVID-19 research and their top 5 partner countries of collaboration. Surprisingly, collaboration between the US and China was quite active amid the US–China decoupling. In contrast,

Japan does not appear in the figure, either as a top 5 country or as a top 5 partner.

Figure 13: Share of international scientific collaboration on COVID-19 medical research by partner economy, January to November 30, 2020



Source: OECD (2021), Figure 5.1.

4. Policy and Managerial Suggestions for More Resilient and Innovative Supply Chains

Based on the empirical evidence of resilient and innovative supply chains and knowledge networks in Section 2 and the current situation of global supply chains and international research networks in Section 3, we now provide several policy and managerial suggestions.

Not onshoring but diversifying supply chains across countries

First, some of the current policies are intended to attract supply chains to the domestic economy, using a large amount of subsidies. The proposed amount of subsidies for "onshoring" or “reshoring” semiconductor plants is 52 billion US dollars for the US, 43 billion euros (43 billion US dollars) for the EU, and 620 billion yen (4.5 billion US dollars) for Japan (although part of the budget will be used for R&D activities, as we will discuss later). However, large-scale onshoring/reshoring is harmful to the resilience of supply chains because the concentration of supply chains in the domestic economy is opposed to diversification and thus raises risks of supply chain disruption. In particular, in the case of Japan, major industrial regions are expected to be hit by severe natural disasters in the near future, such as a Nankai megathrust earthquake, an earthquake in the capital city of Tokyo, or the eruption of Mt. Fuji. Moreover, it is observed that after the Great East Japan earthquake in 2011, domestic suppliers of Japanese companies became more concentrated geographically by avoiding suppliers in the regions affected by the earthquake (Kawakubo and Suzuki, 2022). Therefore, confining supply chains within Japan may cause a devastating economic effect once a severe disaster hits Japan.

In addition, companies have spread supply chains across countries, using international trade and

investment, to achieve the maximum efficiency in production, particularly in the Asia-Pacific region (Baldwin, 2016; Wignaraja, 2016). Some companies produce or procure parts abroad to seek low wages or input costs, while others seek advanced technologies or large markets. Distorting the private incentive to international sourcing lowers efficiency.

In the past, large subsidies for the relocation of production plants did not necessarily promote productivity growth in the target region. For example, subsidies for the relocation of plants in the high-tech sectors to less industrialized regions in Japan in the 1980s and 1990s were found to attract only low-productivity plants (Okubo and Tomiura, 2012). The reason is that while high-productivity plants enjoy productivity spillovers and thick labor markets for skilled labor in industrialized regions and are not incentivized to relocate even with subsidies, low-productivity plants that cannot survive without a subsidy are willing to relocate. The current subsidies for reshoring may also attract semiconductor plants using outdated technologies, while plants using frontier technologies remain in their home countries, such as Taiwan and South Korea.

Therefore, policies should not focus exclusively on onshoring/reshoring to the domestic economy but instead, focus more on the geographic diversification of supply chain partners across countries. One obstacle to supply chain diversification is information costs for searching for appropriate partners abroad (Besedeš, 2008). To overcome this obstacle, public support for sharing information about foreign markets and business matching among domestic and foreign companies by export and investment promotion agencies, such as the Japan External Trade Organization (JETRO), is found to be effective (Kim, et al., 2018; Makioka, 2021; Martincus and Molinari, 2007; Van Biesebroeck, et al., 2016). Therefore, this type of policy should be utilized more than relocation subsidies.

Furthermore, diversified supply chains should be expanded to countries with lower risks to national security, aiming at "friend-shoring," because the risk of supply chain disruption because of national security issues has increased recently. Therefore, information sharing and business matching are suggested to utilize the current multilateral frameworks among such countries, such as the Quadrilateral Security Dialogue (QUAD) among Australia, India, Japan, and the US, the Supply Chain Resilience Initiative (SCRI) among Australia, India, and Japan, the Free and Open Indo-Pacific (FOIP), and the Indo-Pacific Economic Framework (IPEF).

In fact, some of these policies, notably public support for information sharing and business matching, have been actively implemented by the Japanese government. More recently, the government has provided subsidies to companies that relocate their production plants to ASEAN member nations for supply chain diversification (JETRO 2022). Therefore, it is encouraged that the private sector should fully utilize these existing policies to diversify its supply chain partners across countries without any national security threat. Although the cost of diversification is high, private companies should recognize that the benefit of diversification is becoming larger as the risk of supply chain disruption from national security issues becomes higher.

No industry targeting

Second, another concern is the current policies' narrow targeting of industries, particularly focusing on the semiconductor industry. The targeting policy is supported by the resurgence of industrial policy as an effective means of economic growth in the policy-making arena and in academia. However, we need to carefully interpret the reevaluation of industrial policy in economic research because the definition of "industrial policy" varies. Industrial policy narrowly defined as targeting a particular industry and trying to promote it by protectionism measures is not supported even by the current pro-industrial policy arguments in economics. For example, Aiginger and Rodrik (2020), one of the most influential articles on the "rebirth of industrial policy," state that "the industrial policy of the future is unlikely to look like the economist's traditional conception of it: top-down policymaking, targeting pre-selected sectors, and employing a standard list of subsidies and incentives" and that "(t)he contemporary conception and practice of industrial policy is much less about top-down incentives and much more about establishing a sustained collaboration between the public and private sectors around issues of productivity and social goals" (p. 192).

The pro-industry policy arguments are often founded on China's high growth that seems to be promoted by its industrial policy. However, it is quantitatively found that industry targeting alone did not promote growth in China but did promote growth when combined with competition policy (Aghion, et al., 2015). It is also documented in a detailed case study that China's industrial policy, particularly that for integrated circuits and robotics, could not contribute to industrial growth (Marukawa, 2020). Aiginger and Rodrik (2020) also conclude that South Korea, China, and Taiwan have been successful because they "tend to prioritize sectors and define important technologies" but "also include market forces, such as open economies, special zones, or favorable conditions for multinational enterprises" (p. 202). In addition, Tian (2020) warns that "only a limited government can lead to an efficient market and provide effective industrial policies" after reviewing the industrial policies and related debate in China. In the US where large subsidies to the semiconductor industry are going to be provided based on the CHIPS and Science Act, some argue that such interventions may not be efficiently implemented (Sykes 2022).

These arguments and empirical findings suggest that the current "industrial policy" targeting the semiconductor industry through protectionism measures, including subsidies for onshoring, may not be effective. Instead, targeting the semiconductor industry should be at least associated with policies to promote openness and competition. Therefore, as suggested previously, the focus of policies for resilient semiconductor supply chains must be on diversification, rather than onshoring, through information sharing and business matching. In addition, targeting the semiconductor industry itself may lead to inefficiency through misallocation of resources away from currently unnoticeable industries with greater potentials. To avoid inefficiency, policies for supply chain diversity should cover broader industries and promote competition among industries and companies.

Alleviating national security concerns

Third, although we have thus far discussed the importance of diversification of supply chain partners and reduction of reliance on China for resilience and economic growth, it does not necessarily mean that Japan, the US, European countries, or any other country should decouple China. Rather, it should also be emphasized that China is an important trade and knowledge partner for any country so that trade and knowledge links with China should not be eliminated.

However, it is quite risky for Japanese, US, and European companies to link with China currently because of national security concerns and future possible economic restrictions on China. As we saw in Figures 1-6, trade volumes of Japan and the US with China are generally increasing while shrinking in limited product categories. However, there are large geopolitical risks that trade restrictions by the US or Japan instituted for national security will be suddenly imposed on more products and considerably affect their exporters and importers. China may also widen its target products to strengthen exports. Because of these risks, companies outside China hesitate to trade with, conduct research collaboration with, and invest in China.

To alleviate these risks, we need transparent international rules to define which products are subject to trade restrictions and which industries are subject to regulations on inward FDI due to national security concerns. Currently, such national security exceptions are defined by the World Trade Organization (WTO), but its definition in GATT Article 21 is quite vague and has rarely been discussed in its Dispute Settlement Body (Boklan and Bahri, 2020). Therefore, it is suggested that the WTO clearly define a list of products and industries for possible export and inward FDI restrictions. For this purpose, we could learn from the Wassenaar Arrangement that specifies and annually updates a detailed list of target products for export controls to prevent transfers of conventional arms and dual-use goods and technologies (Wassenaar Arrangement 2021). Although export controls in the Wassenaar Arrangement are not legally enforceable, national security exceptions that the WTO would define should be claimed through a dispute settlement mechanism. Then, private companies can reduce geopolitical risks to a large extent by following the WTO's rule and thus can determine how they should reorganize their supply chains and innovation networks.

An obvious major problem of this suggestion is that the WTO is not functioning well recently. Therefore, these international rules are expected to be alternatively initiated by other bi or multilateral trade frameworks, such as the Trade Agreement between Japan and the US, CPTPP, and Regional Comprehensive Economic Partnership (RCEP), political frameworks, such as the G7, the QUAD and FOIP, or even a new international framework for this purpose. It is particularly expected that the Japanese government will play a major role in this rule-making process.

In addition, Japan enacted an economic security law in May 2022. It aimed to construct resilient supply chains of “critical products” by providing financial support to producers of these products and asking them to provide reports about their procurement and production. According to the law, critical products will be specified later, and thus, it is quite important that this selection process be based on clear

rules that are transparent to the private sector. It should also be transparent to the international community because how the Japanese government specifies the “critical products” may influence future international rules.

From the private sector’s perspective, it is crucial to collect information about what product and technology categories are likely to be the target of restrictions to protect national security. Therefore, it is suggested that private companies collectively negotiate with the government to acquire such information in an efficient manner.

Promoting knowledge networks

Finally, contemporary global supply chains, i.e., networks of companies through transactions of materials and parts, are often associated with networks through transactions of knowledge, e.g., research collaboration. In the world where technologies are extremely complex, research collaboration between companies and between companies and universities, which can be labeled "open innovation," is an important channel of innovation by learning from each other. Recent policies to promote industrial clusters in Japan are found to be effective because, unlike earlier policies, they promoted innovation networks among companies, research institutions, and universities (Nishimura and Okamuro, 2011a, 2011b). A study using large-scale data for patent-producing companies in the world shows that both domestic and international research collaboration stimulate innovation, while the latter has a far larger effect (Iino, et al., 2021). Widening tax deductions for open innovation in Japan is found to increase research collaboration and research outsourcing (Ikeuchi, 2022). Therefore, policies to support such collaboration are effective and should be encouraged (OECD, 2021). More generally, policies to promote innovation are needed to maximize social welfare (Romer, 1990), and empirical evidence on the positive effect of policies on innovation is thick (Bloom, 2019). Accordingly, the importance of innovation policy is often emphasized in both pro- and anti-industrial policy arguments (Aiginger and Rodrik, 2020; Gerstel and Goodman, 2020; Reinsch, 2021).

In practice, promoting R&D activities and international research collaboration in high-tech sectors, including the semiconductor industry, is already incorporated into the recent policy packages of Japan, the US, and European countries. For example, the budget of 280 billion US dollars of the CHIPS and Science Act of the US includes not only 39 billion dollars to construct resilient supply chains of semiconductors but also 11 billion dollars for R&D activities in the semiconductor industry, 500 million dollars for international cooperation in the industry, and 200 billion dollars for R&D activities in other frontier technology fields, such as artificial intelligence, quantum computing, and biotechnology (US Senate, 2022). Japan successfully attracted not only TSMC's plants for semiconductor production but also its R&D center to Japan for research collaboration with Japanese companies and research institutions (TSMC, 2022). In addition, it is reported that Japan and the US are planning to set up a research collaboration center for frontier semiconductor by the end of 2022 (Reuters 2022).

In the long run, more emphasis should be placed on such innovation policies to construct competitive domestic industries than on protectionism policies. Particularly important is supporting

research collaboration networks among countries with low risks to national security, or knowledge friend-shoring, by information sharing and business matching in the frameworks of the QUAD, FOIP, and IPEF, as in the case of friend-shoring of supply chains. As mentioned just above, the importance of international research collaboration among "friends" for national security has been recognized, but the government and private companies should strengthen this direction further and expand international knowledge networks more.

5. Summary and Conclusion

This policy discussion paper can be summarized as follows.

1.1 Geographically diversified supply chains across countries are resilient because of the relatively easy substitution of suppliers. They are also a source of innovation because of the possibility of learning from foreign countries.

1.2 Geographically diversified knowledge networks of companies across countries are also a source of innovation because of international knowledge spillovers.

2.1 Despite the policies of Japan and the US decoupling from China for national security, their trade volume with China has been increasing since March 2020 in total, except for limited product categories.

2.2 Japan and the US recently decreased their reliance on China as suppliers and as a significant share of the supply chain without harming overall trade with China, while South Korea, Australia, and Indonesia have failed to diversify their supply chains. However, the level of the reliance of Japan on Chinese suppliers is still high; compared with the US and European countries, Japan still has room to lower its reliance further for resilience.

3.1 Current policies for reorganizing supply chains focus largely on reshoring and onshoring, which may enlarge the risks of supply chain disruption and inefficient resource allocation. Geographic diversification across countries should be targeted more by policies that support information sharing and business matching, possibly through international frameworks, such as the CPTPP, QUAD, and FOIP.

3.2 Current policies are particularly targeting the semiconductor industry. Because targeting is more likely to distort the economy, particularly when it is combined with protectionism policies, governments should aim at the diversification of supply chains across countries and cover broad industries.

3.3 To lower geopolitical risks for private companies, international rules to clarify national security exceptions in international trade, technology transfer, and investment should be formed.

3.4 Policies to promote international collaboration in innovation should be associated with policies for the reorganization of supply chains, possibly through international frameworks, such as the CPTPP, QUAD, and FOIP.

References

Aghion, P., Cai J., Dewatripont M., Du L., Harrison A., and Legros P. (2015). Industrial policy and competition. *American Economic Journal: Macroeconomics, 7*, 1-32.

Aiginger, K., and Rodrik D. (2020). Rebirth of industrial policy and an agenda for the twenty-first century. *Journal of Industry, Competition and Trade, 20*, 189-207.

Ando, M., and Hayakawa K. (2021). Does the import diversity of inputs mitigate the negative impact of COVID-19 on global value chains? *The Journal of International Trade & Economic Development*, 1-22.

Atkin, D., Khandelwal A. K., and Osman A. (2017). Exporting and firm performance: evidence from a randomized experiment. *The Quarterly Journal of Economics, 132*, 551-615.

Baldwin, R. (2016). *The Great Convergence: Information Technology and the New Globalization*. Boston: Harvard University Press.

Barrot, J.-N., and Sauvagnat J. (2016). Input specificity and the propagation of idiosyncratic shocks in production networks. *The Quarterly Journal of Economics, 131*, 1543-1592.

Besedeš, T. (2008). A search cost perspective on formation and duration of trade. *Review of International Economics, 16*, 835-849.

Bloom N., Van Reenen J., Williams H. (2019). A toolkit of policies to promote innovation. Journal of Economic Perspectives, 33, 163-184.

Boehm, C. E., Flaaen A., and Pandalai-Nayar N. (2019). Input linkages and the transmission of shocks: Firm-level evidence from the 2011 Tōhoku earthquake. *Review of Economics and Statistics, 101*, 60-75.

Boklan, D., and Bahri A. (2020). The first WTO's ruling on national security exception: Balancing interests or opening Pandora's box? *World Trade Review, 19*, 123-136.

Carvalho, V. M., Nirei M., Saito Y. U., and Tahbaz-Salehi A. (2021). Supply chain disruptions: Evidence from the Great East Japan earthquake. *Quarterly Journal of Economics, 136*, 1255-1321.

Chen, K., Zhang Y., and Fu X. (2019). International research collaboration: An emerging domain of innovation studies? *Research Policy, 48*, 149-168.

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*: Harvard Business Press.

Congressional Research Service (2022). U.S. Restrictions on Huawei Technologies: National Security, Foreign Policy, and Economic Interests. CRS Report, vol. R47012. Congressional Research Service. https://www.everycrsreport.com/files/2022-01-05_R47012_65c5c54827b8fef912a19079f10e144b3b88d009.pdf (accessed July 5, 2022)

European Union (2022), European Chips Act: Communication, Regulation, Joint Undertaking and Recommendation. https://digital-strategy.ec.europa.eu/en/library/european-chips-act-communication-regulation-joint-undertaking-and-recommendation (accessed February 11, 2022)

Fujimoto, T., Kato Y., and Iwao S. (2016). Chotatsu Toyota Way to Supply Chain Management Kyoka no

Torikumi -Toyota Jidosha Chotatsu Honbu Chotatsu Kikaku/TNGA Suishinbu Koda Hiroaki Shi Kojutsu Kiroku- (in Japanese). MMRC Discussion Paper Series, No. 487. http://merc.e.u-tokyo.ac.jp/mmrc/dp/pdf/MMRC487_2016.pdf (accessed February 11, 2022)

Gerstel, D., and Goodman M. P. (2020). From industrial policy to innovation strategy: Lessons from Japan, Europe, and the United States. Center for Strategic & International Studies. https://www.csis.org/analysis/industrial-policy-innovation-strategy-lessons-japan-europe-and-united-states (accessed February 14, 2022)

Hayakawa, K., and Mukunoki H. (2021). Impacts of COVID-19 on global value chains. *The Developing Economies, 59*, 154-177.

Ikeuchi, K. (2022). Nihon ni okeru 2015 Kenkyu Kaihatsu Zeisei no Seido Henko no Koka Bunseki: Open Innovation Gata no Kakuju to Kurikosi Kojo Seido no Haishi no Eikyo. RIETI Discussion Paper, No. 22-J-027. Research Institute of Economy, Trade and Industry.

Iino, T., Inoue H., Saito Y. U., and Todo Y. (2021). How does the global network of research collaboration affect the quality of innovation? *Japanese Economic Review, 72*, 5-48.

Inoue, H., and Todo Y. (2019). Firm-level propagation of shocks through supply-chain networks. *Nature Sustainability, 2*, 841-847.

Inoue, H., and Todo Y. (2022). Propagation of Overseas Economic Shocks through Global Supply Chains: Firm-level Evidence. RIETI Discussion Paper, No. 22-E-062, Research Institute of Economy, Trade and Industry.

Japan External Trade Organization (2022). "Kaigai Supply Chain Tagenka to Shien Jigyo (in Japanese)," https://www.jetro.go.jp/services/supplychain/ (accessed July 9, 2022).

Kashiwagi, Y., Todo Y., and Matous P. (2021). Propagation of economic shocks through global supply chains: Evidence from Hurricane Sandy. *Review of International Economics, 29*, 1186-1220.

Kawakubo, T., and Suzuki T. (2022), Supply Chain Dynamics and Resilience of the Economy during a Crisis. RIETI Discussion Paper, No. 22-E-070, Research Institute of Economy, Trade and Industry.

Keller, W., and Yeaple S. (2009). Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States. *Review of Economics and Statistics, 91*, 821-831.

Kim, Y. R., Todo Y., Shimamoto D., and Matous P. (2018). Are seminars on export promotion effective? Evidence from a randomized controlled trial. *The World Economy, 41*, 2954-2982.

Kimura, F., and Kiyota K. (2006). Exports, FDI, and Productivity: Dynamic Evidence from Japanese Firms. *Review of World Economics, 142*, 695-719.

Makioka, R. (2021). The impact of export promotion with matchmaking on exports and service outsourcing. *Review of International Economics, 29*, 1418-1450.

Martincus, C. V., and Molinari A. (2007). Regional business cycles and national economic borders: what are the effects of trade in developing countries? *Review of World Economics, 143*, 140-178.

Marukawa, T. (2020). The evolution of China's industrial policy and 'Made in China 2025'. In A. S. Ding and Panda, J. P. (Eds.), *Chinese Politics and Foreign Policy under Xi Jinping* (pp. 131-149): Routledge.

Ministry of Economy, Trade and Industry (2022a), Supply Chain Taisaku no tameno Kokunai Toshi Sokushin Jigyohi Hojokin (in Japanese). https://www.meti.go.jp/covid-19/supplychain/index.html (accessed July 9, 2022).

Ministry of Economy, Trade and Industry (2022b), White Paper on International Economy and Trade 2022. https://www.meti.go.jp/english/report/data/gIT2022maine.html (accessed July 13, 2022).

National People's Congress (2020). Export Control Law of the People's Republic of China. http://www.npc.gov.cn/englishnpc/c23934/202112/63aff482fece44a591b45810fa2c25c4.shtml (accessed July 13, 2022). https://www.jetro.go.jp/ext_images/_Reports/01/e92a59e82865d470/20210034_03.pdf （日本語）

Nikkan Kogyo Shinbun (2020). "Tier 3 no Kadai made Araidasu Toyota no Shunen (in Japanese)," August 7, 2020, reprinted in Newsitch at https://newswitch.jp/p/23329 (accessed July 6, 2022).

Nikkei XTECH (2022). Kioxia and WD received support of at most 92.9 billion dollars from the Ministry of Economy, Trade and Industry. July 27, 2022. https://xtech.nikkei.com/atcl/nxt/news/18/13386/ (accessed August 11, 2022).

Nishimura, J., and Okamuro H. (2011a). R&D productivity and the organization of cluster policy: An empirical evaluation of the Industrial Cluster Project in Japan. *Journal of Technology Transfer, 36*, 117-144.

Nishimura, J., and Okamuro H. (2011b). Subsidy and networking: The effects of direct and indirect support programs of the cluster policy. *Research Policy, 40*, 714-727.

OECD (2017). *OECD Science, Technology and Industry Scoreboard*. Paris: OECD Publishing.

OECD. (2021). *OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity*. Paris: OECD Publishing.

Okubo, T., and Tomiura E. (2012). Industrial relocation policy, productivity and heterogeneous plants: Evidence from Japan. *Regional Science and Urban Economics, 42*, 230-239.

Reinsch, W. A. (2021). Forget Industrial Policy. It's Now Innovation Policy. Center for Strategic & International Studies. https://www.csis.org/analysis/forget-industrial-policy-its-now-innovation-policy (accessed February 14, 2022)

Reuters (2022). U.S., Japan to cooperate on semiconductors as part of new economic dialogue. July 30, 2022. https://www.reuters.com/technology/us-japan-set-agree-joint-research-semiconductors-media-2022-07-29/

Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy, 98*, S71-102.

Sykes, A. O. (2022). Stanford's Al Sykes on the $280 Billion Chips and Science Act, Government Intervention, and Trade. Stanford Law School Blogs. https://law.stanford.edu/2022/08/02/stanfords-al-sykes-on-the-280-billion-chips-and-science-act-government-intervention-and-trade/ (accessed August 12, 2022).

Tian, G. (2020). From industrial policy to competition policy: A discussion based on two debates. *China Economic Review, 62*, 101505.

Todo, Y. (2006). Knowledge Spillovers from Foreign Direct Investment in R&D: Evidence from Japanese Firm-Level Data. *Journal of Asian Economics, 17*, 996-1013.

Todo, Y., and Shimizutani S. (2007). Overseas R&D Activities and Home Productivity Growth: Evidence from Japanese Firm-Level Data. *Journal of Industrial Economics, 56*, 752-777.

Todo, Y., Matous P., and Inoue H. (2016). The Strength of Long Ties and the Weakness of Strong Ties: Knowledge Diffusion through Supply Chain Networks. *Research Policy, 45*, 1890-1906.

Todo, Y., Oikawa K., Ambashi M., Kimura F., and Urata S. (2021). Robustness and Resilience of Supply Chains During the COVID-19 Pandemic: Findings from a Questionnaire Survey on the Supply Chain Links of Firms in ASEAN and India. ERIA Discussion Paper Series, No. 407, Economic Research Institute for ASEAN and East Asia.

Todo, Y., and Shimizutani S. (2007). Overseas R&D activities and home productivity growth: Evidence from Japanese firm-level data. *Journal of Industrial Economics, 56*, 752-777.

Toyota Motor (2016). Five Years on: Toyota's Efforts to Build a Disaster Resilient Future. March 11, 2016. https://global.toyota/en/detail/11373994 (accessed on February 8, 2022)

TSMC (2022). TSMC Japan 3DIC R＆D Center Completes Clean Room Construction in AIST Tsukuba Center. Latest News. https://pr.tsmc.com/japanese/news/2942 (accessed August 12, 2022).

United Kingdom Government (2020), 5G Supply Chain Diversification Strategy. https://www.gov.uk/government/publications/5g-supply-chain-diversification-strategy (accessed February 11, 2022)

United Nations (2022), UN Comtrade Database. https://comtrade.un.org/data/ (accessed February 8, 2022)

United States Census Bureau (2022), Foreign Trade. https://www.census.gov/foreign-trade/balance/c5700.html (accessed February 8, 2022)

U.S. Department of Commerce and U.S. Department of Homeland Security (2022), Assessment of the Critical Supply Chains Supporting the U.S. Information and Communications Technology Industry. https://www.dhs.gov/sites/default/files/2022-02/ICT%20Supply%20Chain%20Report_2.pdf (accessed July 28, 2022).

U.S. Senate (2022), View the CHIPS+ Legislation, Press Releases, July 29, 2022. https://www.commerce.senate.gov/2022/8/view-the-chips-legislation (accessed August 11, 2022).

Van Biesebroeck, J., Konings J., and Volpe Martincus C. (2016). Did export promotion help firms weather the crisis? *Economic Policy, 31*, 653-702.

Wassenaar Arrangement (2021), Control Lists. https://www.wassenaar.org/control-lists/ (accessed February 11, 2022)

White House (2021), Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth: 100-Day Reviews under Executive Order 14071. https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf (accessed February 11, 2022)

White House (2022a), Executive Order on America's Supply Chains: A Year of Action and Progress. https://www.whitehouse.gov/wp-content/uploads/2022/02/Capstone-Report-Biden.pdf (accessed

July 28 2022b).

White House (2022b), FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China, Statements and Releases, August 9, 2022. https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/ (accessed August 11, 2022)

Wignaraja, G. (2016). Production Networks and Enterprises in East Asia. Springer.

Yomiuri Newspaper (2021), Risuku Shakai ni Idomu. Saigai he no Sonae (in Japanese). May 28, 2021. Reprinted in https://www.bosai-nippon.com/biz/article/3415. (accessed February 14, 2022)