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February 2021

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Keywords: COVID-19; Global value chains; Supplier diversification
JEL Classification: F15; F53

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Does the Import Diversity of Inputs Mitigate the Negative Impact of COVID-19 on Global Value Chains?§

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1. Introduction

The ongoing coronavirus pandemic (hereinafter, COVID-19) has severely disrupted international supply chains, also known as global value chains (GVCs). In general, supply chains involve many countries in a region or even beyond a region. Therefore, the negative impact of any shock can be transmitted to those involved countries, rather than being limited to the specific countries that are the origin of the shock. Of course, COVID-19 is not the first collapse of GVCs. The 2008–2009 Global Financial Crisis (GFC), for instance, represents a typical demand shock that seriously affected the world economy and GVCs, although it primarily started as drastic decline in demand in the United States (US) and

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European Union (EU) markets. In 2011, the Great East Japan Earthquake (EJE) and flooding in Thailand delivered big supply shocks that were broadly extended to other countries through supply chains.

Due to the physical and psychological effects of COVID-19, there is a growing debate on how to enhance the "resilience" or "robustness" of GVCs for future crises (Remko, 2020). Resilience can be defined as the ability to return to normal operations over an acceptable period of time, while robustness is the ability to maintain operations during a crisis (Miroudot, 2020). In this context, there is a trade-off between efficiency and resilience/robustness. According to Jain et al. (2020), supplier concentration (i.e., having fewer suppliers) may benefit from volume leverage, better supplier selection, and less coordination complexity. In contrast, supplier diversification (i.e., having more suppliers) may have advantages in terms of access to alternate sources and supplier competition. In short, while choosing the most cost-efficient supplier for each component will improve the efficiency of GVCs, sourcing from multiple suppliers for each component may enhance the robustness of GVCs. Similarly, an increase in inventory or slack resources raises resilience but lowers the efficiency of GVCs. These concepts in GVCs may be at odds with each other, at least in the short run (Golgeci et al., 2020).

Against this backdrop, we empirically examine the role of the import diversity of inputs in the effect of COVID-19 on GVCs. As mentioned above, supplier diversification has attracted considerable attention as a practical strategy to enhance the robustness of supply chains.[1] An increase in suppliers enables buyers to easily shift sourcing from disrupted suppliers to other suppliers in the event of idiosyncratic supply disruptions (Jain et al., 2020). It also lowers the variance in profits induced by disruptions and decreases the time required to resolve the disruptions (Mizgier et al., 2015). Diversifying suppliers are expected to mitigate the negative effects of the pandemic on GVCs. In this study, we explore this mitigation effect at a country level. Namely, we investigate the role of country-level import diversity in terms of input varieties and source countries. Although COVID-19 negatively affected international trade, such negative effects might be lower for countries importing various inputs from various countries.

Specifically, we explicitly investigate the supply-side impact of COVID-19 on GVCs during the period from January to August 2020 using monthly export data of final machinery products for 35 countries and their indicator on the import diversity of inputs with 252 trade partner countries. The indicator for the import diversity of inputs is constructed to measure how much import sources of machinery parts were diversified in 2019, i.e., a pre-pandemic year, for those exporting countries. Using the interaction term of COVID-19 damage with this indicator, we examine how the import diversity of inputs

[1] See, for example, Tomlin and Wang (2005), Babich et al. (2007), Wang et al. (2010), Tang and Kouvelis (2011), Mizgier et al. (2015), Ang et al. (2017), Chod et al. (2020), and Jain et al. (2020).

affects the negative supply-side effects, if any, under an environment in which the uncertainty in supply chain is high, due to COVID-19.

Our findings can be summarized as follows. The negative supply-side effects of COVID-19 on exports in final machinery products are the largest in the transport equipment industry among the three machinery industries analyzed. This negative supply-side impact on all machinery industries is larger in the trade fall period from February to May. Our main finding is that the import diversity of inputs played a significant role in partially mitigating the harmful supply-side effects of COVID-19, particularly during the initial period, i.e., February and March 2020. In this period, the uncertainty in supply chains rose due to sudden changes in the spread of COVID-19 and related policies as well as direct and indirect supply disruptions from China that made the procurement of necessary inputs more unstable. In short, we discovered that supplier diversification mitigated the negative supply-side effects of COVID-19.

Our study is related to many existing studies on the effects of negative shocks on GVCs. Ando and Kimura (2012) examined the effects of the 2008–2009 GFC and the 2011 EJE using Japan's machinery export data. They found that for production networks in East Asia, trade in machinery parts and components was robust and the trade relationships were maintained and could recover even if they were interrupted. Todo et al. (2015) investigated how supply chain networks affected the recovery of firms from the 2011 EJE, using firm-level data, and revealed that the positive effects of supply chains exceeded the negative effects. Hayakawa et al. (2015) explored how Japanese affiliates in Thailand adjusted their production networks before and after flooding in 2011. Barrot and Sauvagnat (2016) examined major natural disasters in the past 30 years in the US. They showed that when a natural disaster hits suppliers, their customers experience a substantial drop in their products' sales. Boehm et al. (2019) is a study on the 2011 EJE and showed that firms in the US that relied on Japanese inputs experienced large drops in production after this natural disaster.[2]

Furthermore, there are several studies on the effect of COVID-19 on GVCs employing trade data.[3] For example, Hayakawa and Mukunoki (2020) demonstrated that export of finished machinery products significantly decreased when the COVID-19 burden was more severe in exporting countries and in countries that supplied inputs to those exporting countries by using worldwide trade data like ours. Similar findings were obtained when focusing on China's trade (Friedt and Zhang, 2020) and the EU's trade (Kejzar and Velic, 2020). In addition, Meier and Pinto (2020) found that US industries with extensive exposure

[2] Regarding the theoretical analyses, see Acemoglu and Tahbaz-Salehi (2020) and the literature review available in that study.

[3] Inoue and Todo (2020), George et al. (2020), and Pichler et al. (2020) provided simulation analyses of COVID-19's effect on GVCs. Inoue and Todo (2020) simulated the economic effect of Tokyo's possible lockdown on production not only in Tokyo but also in other parts of Japan through supply chains.

to intermediate goods imports from China experienced a large drop in exports (as well as imports, employment, and production).

Although these studies suggested negative effects being propagated through supply chains, they did not explicitly examine the role of supplier diversification. In this sense, Jain et al. (2020) might be one of the studies closest to ours. They used firm-level data from the US during the 2008–2009 GFC and discovered that supplier diversification is associated with slower recovery from disruptions. Although both their study and ours explicitly examine the role of supplier diversification in GVCs, there are some crucial differences between the two, e.g., firm level versus country level, GFC versus COVID-19, country coverage, and empirical methodology. Their analysis is finer in terms of using a firm-level measure of diversification but is limited to the case of US, while ours has stronger external validity due to the use of worldwide trade data. Also, the GFC had negative effects stemmed primarily from the demand side, while COVID-19 seems to cause not only demand disruptions but also direct and indirect supply disruptions. In short, these two studies are complementary.

The remainder of this study is organized as follows. Section 2 presents an overview of the worldwide machinery trade in 2020. After explaining our indicator for the import diversity of inputs in Section 3, we report our empirical framework and results in Section 4. Lastly, Section 5 provides the conclusions of the study.

2. Worldwide Machinery Trade in 2020

This section provides an overview of global exports of machinery goods in 2020. The machinery industries [harmonized system (HS) 84–92] in this study are defined as the general and electric machinery industry (HS84–85), the transport equipment industry (HS86–89), and the precision machinery industry (HS90–92). Monthly trade data at the HS six-digit level are available from the *Global Trade Atlas* maintained by IHS Markit[4]; the database collects the monthly exports and imports by 35 reporting countries as of November 2020.[5] Using this database, global monthly trade in final machinery products is calculated since these reporting countries include most of the major countries that export machinery goods.[6] To avoid possible time lag issues on monthly import data particularly for long-distance trade via sea freight/sea cargo, we prefer to use monthly export data as much as possible instead of using import data as a proxy.

Figure 1 shows the change in the worldwide exports of machinery goods in January to August 2020 relative to those in 2019 by three machinery industries; (a) final machinery

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[4] See https://connect.ihsmarkit.com/gta/home.

[5] The reporting countries and their trade partners are listed in Appendix A.

[6] See the next section for the definition of final machinery products and parts and components in this paper.

products and (b) machinery parts and components. In this figure, "Month 2" includes both January and February. As Table 1 clearly presents, China is one of the most important exporters of final machinery products, particularly in the general and electric machinery industry. In a period from January to August 2019 (as a benchmark of the normal period), China has a share of over 30% of global exports in final products of this industry. However, China reports only aggregated trade in January and February in 2020. Moreover, exports from China and possibly some other countries with the Chinese New Year holidays in general tend to decline during the Chinese New Year holidays, which were in February 2019 (started on February 5) and January 2020 (started on January 25). Thus, the change in trade in February 2020 expressed as a ratio to that in 2019 may underestimate the effects of COVID-19 on trade in February 2020. To avoid this, we provide a picture of worldwide machinery trade by aggregating trade for two months in Figure 1.

=== Figure 1 & Table 1 ===

Clearly, the worldwide exports of final machinery products in 2020 started to fall in "Month 2" and sharply declined to record the lowest values in April and May (Figure 1a). In January and February, the worldwide exports in general and electric final machinery products declined by approximately 10%, which is the largest among the three final machinery products. At the bottom or in April and May, however, the transport equipment industry experienced a drastic drop of over 60%, while precision machinery and general and electric machinery industries dropped by approximately 20% and 10%, respectively. Interestingly, worldwide machinery trade started to recover in June, returning close to the pre-pandemic level as of August 2020. A similar pattern can also be observed for trade in machinery parts and components, although the drop at the bottom for the transport equipment industry is smaller for parts and components than for final products (Figure 1b). These trade patterns in 2020 suggest that COVID-19 has a negative impact on GVCs in the machinery industries and that the period until May can be regarded as a phase of trade decline.

Let us check the detailed patterns of trade and COVID-19 spread, focusing on this phase. Figure 2 presents the number of COVID-19 (a) cases and (b) deaths from January to August 2020 for East Asia, North America, and the EU. COVID-19 began in January and hit China severely in February with a large portion of cases/deaths for East Asia in February of this figure. This sudden and rapid spread of COVID-19 in China prevented production activities in some provinces, notably Hubei Province, in which many manufacturing factories are located. In addition, other East Asian countries also began to be subject to COVID-19 (see also Figure B1 in the Appendix). On the other hand, COVID-19 did not yet affect most of the countries in other regions such as Europe and North America at that time. Nevertheless, worldwide exports in general and electric final machinery products in particular declined by approximately 10% in "Month 2." Since China is a prominent exporter of final machinery products, notably, in this industry, a direct supply shock from China must be reflected in the worldwide decline that occurred in "Month 2."

=== Figure 2 ===

Moreover, there may be indirect supply shocks through supply chains. Upstream supply disruptions in the affected countries may induce downstream supply shocks even in less affected countries.[7] China's shares of exports in machinery parts and components in three machinery industries are large (Table 1), and value-added shares of direct and indirect inputs from China in each country's total manufacturing output are also large (Table C1 in the Appendix).[8] These large shares suggest that China plays a central role as an input supplier for many countries not only in East Asia but also in North America and Europe in machinery industries. To reveal the patterns in monthly exports from China, particularly in February 2020, Figure 3 presents China's monthly machinery exports to the world based on import data as well as those to Japan, the US, and Germany, which are the key players in production networks in East Asia, North America, and Europe.[9] Apparently, China's machinery parts exports to the world, in particular those to the key players in supply chains in three regions, significantly dropped in February (and March).[10] This fact indicates possible upstream supply disruption in other East Asian countries as well as in North America and Europe, which may also induce a decline in their production and exports in February and possibly the next month, March.

=== Figure 3 ===

Since March, the COVID-19 situation has started to worsen in Europe and North America as well (Figure 2). As Figure B1 clearly shows, many countries have suddenly started implementing restrictions on the movement of people and lockdown policies in

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[7] Baldwin and Freeman (2020) summarized the impact of COVID-19 as the following three shocks: "demand disruptions" (due to macroeconomic drops in aggregate demand, wait-and-see purchase delays by consumers, and investment delays by firms), "direct supply disruptions" in the affected countries, and "supply-chain contagion" in the less affected countries through supply chains. See also Hayakawa and Mukunoki (2020) for the negative supply chain effects of COVID-19.

[8] See Baldwin and Freeman (2020) for additional details on Table C1.

[9] For Figure 3, the data on imports from China by 35 reporting countries are used and expressed as an index to January 2019, instead of taking a ratio of the same month of the previous year, considering issues related to the timing of the Chinese New Year holiday. As mentioned above, a possible time lag issue for monthly import data may remain.

[10] The largest drop in US imports from China in March for machinery parts may partially reflect a time lag in import statistics as well as a delay in input imports from China.

March, although the timing and severity of policies differ across countries. Accordingly, global trade in final machinery products significantly declined with a bottom in April/May, particularly in the transport equipment industry. One of the reasons for relatively small negative effects on the general and electric machinery industry would be that East Asian countries, which are important exporters of these final products (6 out of the top 10 countries with a share of over 50% of worldwide exports in Table 1), are less affected by COVID-19. Another reason would be that positive demand shock products due to the nature of COVID-19, such as teleworking-related products, exist in this industry.[11,12] A typical example is HS847130 for laptop computers, including tablets; their worldwide monthly exports from April to August in 2020 were constantly 30% greater than during the normal period. On the other hand, major export countries for final products of the transport equipment industry were severely affected by COVID-19. As Table 1 indicates, Germany, Japan, the US, and France account for half of the global exports in these products. Their direct and indirect supply disruptions in addition to the demand shocks in this industry may be reflected in the severe decline in exports.[13]

3. Import Diversity of Machinery Parts and Components

This section constructs an indicator for import diversity of inputs in three machinery industries. With this indicator, we intend to measure how much import sources of machinery intermediate goods are diversified in each machinery industry. Since our aim is to measure "*Diversity*," we simply use the standard deviation. Specifically, our indicator of *Diversity* in country i for each machinery industry is defined as follows.

$$Diversity_i \equiv \left\{ SD_{pj} \left(\frac{M_{pij}}{\sum_q \sum_k M_{qik}} \right) \right\}^{-1},$$

where M_{pij} represents country i's imports of a machinery part p from country j at the HS six-digit level. Machinery parts here refer to all machinery parts at the HS six-digit level, including those with zero-valued imports in each machinery industry, to make this index comparable across countries. $SD_x(\cdot)$ is the mathematical operator of taking the standard

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11 Ando (2020) presented a detailed investigation of the impact of COVID-19 on Japan's exports and imports by shedding light on direct and indirect negative supply shocks in February, negative demand shocks, and product-specific positive demand shocks. Positive demand shock products are those related to teleworking, disinfection, and the "stay-at-home" environment due to the nature of COVID-19 in the machinery industries.

12 In this industry, the change for final products has been over one since June, while that for parts and components has not yet reached one. This indicates that these positive demand shock products contribute to such an increase in final products though the negative effects on this industry as a whole still remain.

13 Most of the final products in this industry are "postpone-able" goods. In addition, e-commerce is not very active, unlike some final products in the general and electric machinery industry. This nature of the products may also induce more severe demand shocks in this industry.

deviation over x.

Namely, our measure of diversity is computed as follows. First, the magnitude of each import (M_{pij}) is normalized by total imports in each machinery industry (i.e., imports of all machinery parts in the corresponding industry from all trade partner countries). Then, we take the standard deviation of the import share over all machinery parts in each industry and all countries. Last, we take the inverse of the standard deviation to show that the higher value of this index indicates more diversified import sources of machinery parts. This index captures country–product–level diversity. Firms may diversify their input sources by procuring inputs from multiple firms within *one* country. Our measure takes a low value for this type of supplier diversification. Since COVID-19 affects production and trade in many countries, the higher variation over source countries would be more crucial than that over supplier firms within a country. In addition, our diversity index tends to take a lower value, for instance, if a country is highly dependent on some specific countries at the product level from the perspective of the magnitude of import values. In other words, this index captures not only the diversity among trade partner countries, but also the diversity in the size of trade at the product level.

We compute the index above by employing data for 2019, which is the year before the onset of the COVID-19 pandemic. We use the same database in Section 2, the *Global Trade Atlas,* to obtain data on imports by 35 reporting countries (exporting countries of finished machinery goods) from their 252 partner countries. Kimura and Obashi (2010) carefully defined the HS six-digit codes of parts and components in machinery industries and regarded machinery goods other than those parts and components as final machinery products. Our classification of machinery inputs at the HS six-digit level follows this list.[14] Note that this list includes only parts and components categorized in HS84 to HS92. Thus, we do not consider intermediate products categorized in other chapters (e.g., tires of HS401120)[15]. Moreover, the value of the index above is sensitive to the total number of HS six-digit codes. Since the total number differs among industries, the value of the index is not comparable across industries.

Figures 4–6 depict the index for the import diversity of inputs in three machinery industries. East Asian countries, except for Thailand, have lower indices than the average in the general and electric machinery industry (Figure 4) and in the transport equipment

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[14] There may be some specific inputs that can be produced by a very limited number of suppliers. Since it is almost impossible to diversify suppliers of these specific inputs, the disruption of such suppliers causes their global shortage. Obviously, our index based on inputs at the HS six-digit level does not enable us to investigate this specific effect.

[15] Input–output (IO) tables are useful for covering these input values from other chapters. However, industry classifications in the IO table are too rough to examine the input diversity over products. Furthermore, the country coverage in the international IO table tends to be limited and is not sufficient for exploring the diversity over countries.

industry except Korea and Japan (Figure 5).[16] In East Asia, fragmentation of production and agglomeration have been formed in production networks, which makes it possible to procure necessary inputs relatively easily domestically and/or inside the region. The reason for lower diversity in most East Asian countries in these two industries would be that their procurement is mostly conducted within the region, including domestic procurement, together with their relatively high dependence on China as an input supplier.[17] As for the precision machinery industry, we cannot find such an extreme tendency; some countries are more diversified, while others are not (Figure 6).

=== Figures 4–6 ===

From the perspective of input suppliers, East Asian countries, including China, play an important role in production networks in Europe and North America, particularly, in the electric machinery industry.[18] Long-distance trade is relatively easy and active in this industry because parts and components tend to be standardized, small, and highly valued for the volume, while the transport equipment industry tends to prefer forming industry clustering with short-distance transactions because of the nature of the industry and relatively heavy and large intermediate goods that require high transport costs. During the last two decades or so, import of parts and components from East Asia by European countries, notably by those in Central and Eastern Europe as a bridge between East Asia and Western Europe, has rapidly expanded. Such imports by Mexico also rapidly grew as a bridge to strengthen the production links between East Asia and the US.

The above-mentioned features of production linkages between East Asia and other regions seem to be reflected in our indicators. European countries have higher indices in three machinery industries, indicating that the import diversity of inputs is relatively high for most European countries. Indeed, many European countries use direct and indirect inputs from other European countries as well as East Asian countries, while East Asian countries have almost no input source country in Europe except for Germany (Table C1). Such diversity over countries, even beyond the region, would possibly be reflected in the relatively high diversity of our index for European countries. Interestingly, Germany has very high diversity indices in all machinery industries. Regarding countries in North

[16] Korea and Japan are included in the top 10 export countries (Table 1).

[17] Relatively lower diversity does not necessarily indicate fewer trade relationships. In Figure D1 in the Appendix, for instance, half of the East Asian countries show a larger number of country–product pairs with positive trade than average. This implies that East Asian countries have production linkages with more countries, although the weight of regional transactions including domestic procurement must be heavy in this industry.

[18] See Ando and Kimura (2013, 2014) for the strengthening production linkages of East Asia as input suppliers with production networks in Europe and North America.

America, only US has high diversity, whereas Canada and Mexico have lower indices than the average in all machinery industries. This suggests a typical feature of production networks in North America: their significantly high dependence on the US and China (and some East Asian countries).[19]

4. Empirical Analysis

This section conducts an empirical analysis of the role of import diversity in the trade effects of COVID-19. We first explain our empirical framework and then report the estimation results.

4.1 Empirical Framework

To investigate the role of import diversity of inputs in the supply-side impact of COVID-19 on GVCs, we separately examine finished machinery exports at a monthly level in three machinery industries, i.e., the general and electric machinery, the transport equipment, and the precision machinery industries. Again, we obtained trade data from the *Global Trade Atlas*, which include monthly exports from the 35 reporting countries to their 252 partner countries. The entire period of our study extends from January to August in 2019 and 2020.

We specify our model as follows.

$$
\begin{aligned}
Finish_{ijym} = \exp\{&\beta_1 \ln(1 + COVID_{iym}) + \beta_2 \ln(1 + COVID_{iym}) \cdot Diversity_i + \delta_{ijy} \\
&+ \delta_{ijm} + \delta_{jym}\} \cdot \epsilon_{ijym},
\end{aligned} \qquad (1)
$$

where $Finish_{ijym}$ indicates exports of finished machinery goods from country i to country j in month m of year y. $COVID_{iym}$ shows the damage by COVID-19 or the uncertainty in supply chains due to COVID-19 for export country i in month m of year y. As a proxy variable, we use the number of newly-confirmed cases or deaths, which are obtained from the *European Centre for Disease Prevention and Control*.[20] The numbers are set to zero for observations in 2019. We produce the interaction term of this COVID variable with the diversity index computed in the previous section, which indicates the import diversity of machinery parts in 2019. The coefficient for this interaction term shows how the import diversity of machinery parts influences the supply-side effects of COVID-19 on exports of finished machinery products under the environment in which supply chains are subject to

[19] Canada's ranking increases considerably in terms of the trade relationships in the three industries (Figures D1 to D3) compared with Figures 4 to 6, while the ranking of Mexico remains low or even declines. This implies that Mexico's production links might be very limited to a few specific countries. On the other hand, Canada may have production links with many countries, although the weight of regional transactions is large.

[20] See https://data.europa.eu/euodp/en/data/dataset/covid-19-coronavirus-data.

disruptions due to the uncertainty attributed to COVID-19. To focus only on the supply-side impact, we control for three kinds of fixed effects (δ_{ijy}, δ_{ijm}, and δ_{jym}), which will be explained below. ϵ_{ijt} is a disturbance term. We estimate the equation for each machinery industry using the Poisson pseudo maximum likelihood (PPML) method.

Our fixed effects control for various elements. Country–pair–year fixed effects (δ_{ijy}) capture the effects of standard gravity variables such as geographical distance in addition to those of trade agreements, importer's demand sizes, and exporter's factor prices (e.g., wages). Since this type of fixed effect also controls for the total population, the estimation results do not change even if we measure the damage from COVID-19 using the ratio of cases or deaths to the total population. Country–pair–month fixed effects (δ_{ijm}) control for the seasonality of trade between the two countries. In addition, the exporter component in these two kinds of fixed effects controls for the general effect of diversity, i.e., its effect not related to COVID-19. δ_{jym} represents the importer–year–month fixed effects. This type of fixed effect controls for all importer-specific effects, including the effects of COVID-19 in importing countries such as negative demand shocks and product-specific positive demand shocks, if any. Namely, we explicitly extract the supply-side impact of COVID-19 by absorbing its demand-side impact. These sets of fixed effects contribute to controlling for various elements to avoid omitted variable bias. Furthermore, our use of the diversity index in the year before the pandemic will lower the possibility of reverse causality.

Although the entire period of our study is from January to August in 2019 and 2020, the restricted period from February to May is also investigated because exports significantly declined during this period (the trade fall period, hereafter).[21] In addition, we further split this trade fall period into two periods, i.e., the initial period (February and March) and the more widely spread period (April and May), and examine the differences in input diversity effects. As discussed in Section 2, during the initial period, there seem to be direct and indirect supply shocks from China. In addition, the supply chain uncertainty attributed to COVID-19 rose particularly in this initial period in the sense that the COVID-19 pandemic and related policies suddenly changed in many countries worldwide (Figure B1), which may have made the procurement of necessary intermediate goods more unstable and difficult. In other words, the import diversity of inputs might be more crucial in adjusting procurement during these two months.

4.2 Empirical Results

This subsection reports our estimation results. We cluster standard errors by country pair. Table 2 shows the estimation results of the equation without the interaction term with

[21] For China, the months January and February of both years are omitted due to a lack of data on monthly exports (reported by China) for January and February 2020, separately.

the diversity index for the whole period from January to August (Panel (a)], and for the trade fall period from February to May (Panel (b)).[22] In Table 2, the coefficients for COVID-19 are negative and statistically significant in all three machinery industries, regardless of whether the COVID-19 variable was the number of cases or deaths, except for (V) of Panel (b) with the number of COVID-19 cases for the precision machinery industry. As is expected, the negative effects tend to be larger when we focus on the trade fall period from February to May. As mentioned in the previous section, our econometric specification explicitly extracts only the supply-side impact by absorbing its demand-side impact. Therefore, our results indicate that COVID-19 had negative supply-side effects on exports in final products of all three machinery industries, and that such negative effects tend to be strongest during the trade fall period from February to May.

=== Table 2 ===

Furthermore, the absolute values of the coefficients are larger for the transport equipment industry than other machinery industries, implying that the negative supply-side effects are the largest in this industry among the three machinery industries. For the whole period, for instance, if the number of COVID-19 cases/deaths increases by 1%, exports decrease by 0.079%/0.073% in this industry. Such rates for the transport equipment industry are about four times the rates for other machinery industries over the whole period.

As discussed in Section 2, Germany, Japan, the US, and France account for half of the worldwide exports in this industry. According to European Automobile Manufacturers Association (ACEA) (2020), most vehicle manufacturers in Europe had had to shut down their development centers and production sites for several weeks or even months during the lockdown period, and, as a result, EU-wide production losses amounted to more than 2.4 million motor vehicles (13% of total production in 2019) during the peak crisis months of March, April, and May 2020. Three major US vehicle manufacturers also shut down approximately 100 factories in North America for about two months since mid-March.[23] The situation in Japan was less serious, but the Japan Automobile Manufacturers Association pointed out that exports in motor vehicles significantly declined in May due to a drop in overseas demand and a disturbance in input procurement[24]; the input disturbance was more serious for some firms, including occurrences such as unstable imports from affected countries (such as India and the Philippines) due to lockdown policies, delayed imports (from Southeast Asian countries) due to COVID-19, and unstable procurement from

[22] Some singleton observations were dropped due to our inclusion of fixed effects.
[23] See the Nikkei article: https://www.nikkei.com/article/DGXMZO59273230Z10C20A5000000.
[24] See the *Daily Automotive News* online article: https://www.netdenjd.com/articles/-/234519).

domestic suppliers due to workers being infected with COVID-19.[25] Aside from the negative demand shocks, these supply-side factors must have caused huge negative supply-side effects on this industry.

Table 3 reports the estimation results of Equation (1) for the whole period (Panel (a)) and the trade fall period (Panel (b)). The key variable here is the interaction term of the COVID-19 numbers with the indicator of the import diversity of countries that export final machinery products; this measure implies how diversified import sources of machinery parts were in 2019. While the coefficients for the COVID-19 numbers are negative, the coefficients for their interaction term with import diversity are positive, regardless of whether the results are for the whole period or the trade fall period, except for the case with the number of COVID-19 deaths for the general and electric machinery industry.[26] This suggests that the import diversity of intermediate goods with increasing supply chain uncertainty due to COVID-19 played a significant role in mitigating the negative supply-side effects of COVID-19 on exports of finished machinery products.

=== Table 3 ===

With a focus on the trade fall period from February to May, we further examined the differences in input diversity effects between the initial period (February and March) and the more widely spread period (April and May). In Table 4, the coefficients for the interaction term with the import diversity of inputs are negative and statistically significant in all three cases of the machinery industry, except for the case with the number of deaths for the general and electric machinery industry in the more widely spread period. Moreover, the corresponding coefficients are much larger for February and March than those for April and May in both general and electric machinery and precision machinery industries, while the differences between the two periods seem small in the transport equipment industry. In the initial period of February and March, increasing uncertainty due to sudden changes in the spread of COVID-19 and related policies (see Figure B1) must have been terrible for most firms in the world that had never previously experienced this type of crisis. Such uncertainty may make the procurement of necessary inputs considerably unstable. In addition, many countries tend to depend on China's inputs and may have faced severe upstream supply disruption and possible delay in imports from China. Under these conditions, the import diversity of inputs are more likely to mitigate the negative supply-side effects by allowing more flexible adjustments in the procurement of necessary inputs during this initial period.

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[25] See the Nikkei article: https://www.nikkei.com/article/DGXMZO58087210V10C20A4I00000 and the Daily Automotive News online article: https://www.netdenjd.com/articles/-/233746).

[26] The results for (II) in Table 3 with the number of COVID-19 deaths for the general and electric machinery industry show somewhat different patterns. Although the coefficients for two COVID-19 variables have opposite signs with statistical significance in Panel (a), they are insignificant in Panel (b).

=== Table 4 ===

The smaller coefficients for April and May in two industries suggest that the role of import diversity of inputs is weakened. This may be because the upstream supply disruption is no longer a major reason behind the negative supply-side effects on exports in the more widely spread period. For instance, production activities may stop or decline simply because of policies such as lockdowns or workplace closures in a country that produces finished machinery goods. The increasing number of seriously affected countries (places) during the more widely spread period could be another reason for the weakened role of import diversity of inputs. This reduces the number of potential source countries and may make flexible adjustment of procurement more difficult. On the other hand, in the transport equipment industry, the import diversity of inputs mitigates the negative supply-side effects throughout the trade fall period with the uncertainty of maintaining supply chains due to COVID-19.

Last, we take an alternative measure of the potential diversity index. Specifically, we use the number of import country–product pairs with positive parts imports in 2019 without considering the magnitude of imports. Table 5 reports the results using this potential diversity index for the whole period. The coefficients for the interaction term with this type of diversity index are positive and statistically significant only for the transport equipment industry. This suggests that import diversity with a larger number of trade relationships without considering import size matters in this industry while it does not in other machinery industries. In other words, considering the magnitude of trade is important when it comes to the import diversity of inputs at the country–product level.

=== Table 5 ===

5. Concluding Remarks

Amid the pandemic, there is a growing debate on how to enhance the resilience/robustness of GVCs for future crises. As a practical strategy for that purpose, supplier diversification has attracted much attention. Therefore, this study empirically examined the role of the import diversity of inputs in the effects of COVID-19 on GVCs. We explicitly investigated the supply-side impacts of COVID-19 on GVCs from January to August 2020, using monthly export data of final machinery products for 35 countries and their indicator on the import diversity of inputs with 252 trade partner countries. Our main finding is that the import diversity of inputs played a significant role in partially mitigating the harmful supply-side effects of COVID-19, particularly during the initial period, i.e., February and March. Namely, it is shown that supplier diversification contributes to enhancing the robustness of GVCs.

Last, it is worth discussing why we obtained opposite results from Jain et al. (2020). One reason may be differences in the shocks, i.e., the 2008–2009 GFC versus COVID-19. The GFC had negative effects primarily from the demand side while COVID-19 caused not only "demand disruptions" but also "direct supply disruptions" in the affected countries, including those in the center of world manufacturing, and "indirect supply disruptions" in less affected countries through supply chains, which results in involving most of the firms in the world. Thus, under the GFC without severe supply disruptions, lower diversification of suppliers worked as follows: "*fewer suppliers make it easier for the buyer firm to identify those that are better managed and that can recover most quickly from a disruptive event*," as Jain et al. (2020) claimed.

On the other hand, amid COVID, many countries have implemented some form of restriction on people and businesses, including lockdown policies and workplace/factory-closing orders, as well as infection control measures (e.g., social distancing). Moreover, whether a country is more or less affected changes over time, and the spread of the COVID-19 pandemic and related policies also suddenly change. Such variations in the timing and degree of suffering from COVID-19 across countries create additional complexity and raise uncertainty regarding GVCs. In that sense, supplier diversification may be beneficial for GVCs because it can enable firms more flexible adjustments in their procurement by more easily shifting from affected suppliers to less affected suppliers.

References

Acemoglu, Daron and Alireza Tahbaz-Salehi, 2020. Firms, Failures, and Fluctuations: The Macroeconomics of Supply Chain Disruptions, NBER Working Paper No. 27565.

Ando, Mitsuyo, 2020. Demand and Supply Shocks of COVID-19 and International Production Networks: Evidences from Japan's Machinery Trade, Paper Prepared for ERIA Research on COVID-19 and Regional Economic Integration. Mimeo.

Ando, Mitsuyo and Fukunari Kimura, 2012. How Did the Japanese Exports Respond to Two Crises in the International Production Networks? The Global Financial Crisis and the Great East Japan Earthquake, *Asian Economic Journal*, 26(3), pp.261–87.

Ando, Mitsuyo and Fukunari Kimura, 2013. Production Linkage of Asia and Europe via Central and Eastern Europe, *Journal of Economic Integration*, Vol. 28, No. 2: 204-240.

Ando, Mitsuyo and Fukunari Kimura, 2014. Evolution of Machinery Production Networks: Linkage of North America with East Asia, *Asian Economic Papers*, Vol.14, No.3: 121-163.

Ang, Erjie, Dan A. Iancu, and Robert Swinney, 2017, Disruption Risk and Optimal Sourcing in Multitier Supply Networks, *Management Science*, 63(8): 2397-2419.

Babich, Volodymyr, Apostolos N. Burnetas, and Peter H. Ritchken, 2007, Competition and Diversification Effects in Supply Chains with Supplier Default Risk, *Manufacturing & Service Operations Management*, 9(2): 123–146.

Baldwin, Richard and Rebecca Freeman (2020) Supply Chain Contagion Waves: Thinking Ahead on Manufacturing 'Contagion and Reinfection' from the COVID Concussion, *VoxEU.org*, https://voxeu.org/article/covid-concussion-and-supply-chain-contagion-waves.

Barrot, Jean-Noël and Julien Sauvagnatm 2016. Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks, *Quarterly Journal of Economics*, 131(3): 1543-1592.

Boehm, Christoph E., Aaron Flaaen, and Nitya Pandalai-Nayar, 2019, Input Linkages and the Transmission of Shocks: Firm-level Evidence from the 2011 Tōhoku Earthquake, *Review of Economics and Statistics*, 101(1): 60-75.

Carvalho, Vasco, Juan Ramón García, Stephen Hansen, Alvaro Ortiz, Tomasa Rodrigo, José V. Rodríguez Mora, and Pep Ruiz, 2020. Tracking the Covid-19 Crisis with High-Resolution Transaction Data, CEPR DP14642.

Chod, Jiri, Nikolaos Trichakis, and Gerry Tsoukalas, 2019, Supplier Diversification Under Buyer Risk, *Management Science*, 65(7): 3150-3173.

European Automobile Manufacturers' Association (ACEA), 2020, *Automobile Industry Pocket Guide 2020-2021*. https://www.acea.be/publications/article/acea-pocket-guide.

Friedt, Felix L. and Kaichong Zhang, 2020, The Triple Effect of Covid-19 on Chinese Exports: First Evidence of the Export Supply, Import Demand and GVC Contagion Effects, *Covid Economics*, 53: 72-109.

George, Ammu, Changtai Li, Jing Zhi Lim, and Taojun Xie, 2020, Propagation of Epidemics' Economic Impacts via Production Networks: The Cases of China and ASEAN during SARS and COVID-19, *Covid Economics*, 37: 27-56.

Hayakawa, Kazunobu, Toshiyuki Matsuura, and Fumihiro Okubo, 2015, Firm-level Impacts of Natural Disasters on Production Networks: Evidence from a Flood in Thailand, *Journal of the Japanese and International Economies*, 38: 244-259.

Hayakawa, Kazunobu and Hiroshi Mukunoki, 2020, Impacts of COVID-19 on Global Value Chains, IDE Discussion Papers No.797.

Inoue, Hiroyasu and Yasuyuki Todo, 2020, The Propagation of the Economic Impact through Supply Chains: The Case of a Mega-city Lockdown to Contain the Spread of Covid-19, *Covid Economics*, 2: 43-59.

Jain, Nitish, Karan Girotra, and Serguei Netessine, 2020, Recovering Global Supply Chains from Supply Interruptions: the Role of Sourcing Strategy. Forthcoming in the *Manufacturing and Service Operations Management*.

Kejzar, Katja Zajc and Alan Velic, 2020, Covid-19, Trade Collapse and GVC Linkages: European Experience, *Covid Economics*, 61: 222-244.

Kimura, Fukunari and Ayako Obashi, 2010, International Production Networks in Machinery Industries: Structure and Its Evolution, Working Papers DP-2010-09, Economic Research Institute for ASEAN and East Asia (ERIA).

Meier, Matthias and Eugenio Pinto, 2020, COVID-19 Supply Chain Disruptions, *Covid Economics*, 48: 139-170.

Miroudot, Sebastien, 2020 Resilience versus Robustness in Global Value Chains: Some Policy Implications, in Richard E. Baldwin and Simon J Evenett (eds), *COVID-19 and Trade Policy: Why Turning Inward Won't Work, a VoxEU.org eBook*, CEPR Press.

Mizgier, Kamil J., Stephan M. Wagner, and Matthias P. Jüttner, 2015, Disentangling Diversification in Supply Chain Networks, *International Journal of Production Economics*, 162: 115-124.

Pichler, Anton, Marco Pangallo, R. Maria del Rio-Chanona, François Lafond, and J. Doyne Farmer, 2020, Production Networks and Epidemic Spreading: How to Restart the UK Economy?, *Covid Economics*, 23: 79-151.

Remko, Hoek, 2020, Research Opportunities for a More Resilient Post-COVID-19 Supply Chain – Closing the Gap between Research Findings and Industry Practice, *International Journal of Operations & Production Management*, 40(4): 341-355.

Tang, Sammi Yu and Panos Kouvelis, 2011, Supplier Diversification Strategies in the Presence of Yield Uncertainty and Buyer Competition, *Manufacturing & Service Operations Management*, 13(4): 439–451.

Todo, Yasuyuki, Kentaro Nakajima, and Petr Matous, 2015, How Do Supply Chain Networks Affect the Resilience of Firms to Natural Disasters? Evidence from the Great East Japan Earthquake, *Journal of Regional Science*, 55(2): 209-229

Tomlin, Brian and Yimin Wang, 2005, On the Value of Mix Flexibility and Dual Sourcing in Unreliable Newsvendor Networks, *Manufacturing & Service Operations Management*, 7(1): 37–57.

Wang, Yimin, Wendell Gilland, and Brian Tomlin, 2010, Mitigating Supply Risk: Dual Sourcing or Process Improvement, *Manufacturing & Service Operations Management*, 12(3): 489–510.

Table 1. Top 10 Export Countries and Their Shares in Global Machinery Exports in the Pre-Pandemic Period (%)

	Final products						Parts and components					
	Gnrl & Elec		Transport		Precision		Gnrl & Elec		Transport		Precision	
1	CN	34.4	DE	20.4	US	18.1	CN	19.1	DE	18.4	CN	23.0
2	DE	9.1	JP	12.3	DE	15.1	HK	10.4	US	12.7	JP	10.7
3	US	8.4	US	9.2	CN	9.2	DE	9.9	CN	10.3	US	9.7
4	NL	6.2	FR	8.0	CH	8.4	US	9.8	JP	9.1	DE	9.5
5	HK	5.8	KR	6.2	NL	7.6	KR	7.1	MX	6.6	KR	7.8
6	MX	4.5	CN	6.1	JP	5.0	JP	7.0	FR	5.7	HK	6.8
7	JP	4.0	ES	4.7	FR	3.9	SG	5.8	GB	5.5	TW	6.5
8	KR	2.7	CA	5.2	SG	3.9	TW	5.3	KR	4.9	GB	3.5
9	TH	2.3	MX	4.7	GB	3.6	NL	3.2	CA	3.8	SG	3.2
10	TW	2.1	GB	4.5	HK	3.4	FR	3.1	ES	3.4	NL	2.6

Source: Authors' compilation, based on data available from the Global Trade Atlas.

Notes: The ranking and shares are based on exports from January through August 2019. East Asian countries are highlighted.

Table 2. Basic Results

Industry	Gnrl & Elec		Transport		Precision	
	(I)	(II)	(III)	(IV)	(V)	(VI)
(a) From January to August						
ln COVID	-0.020***	-0.017***	-0.079***	-0.073***	-0.017***	-0.021***
	[0.003]	[0.002]	[0.020]	[0.021]	[0.004]	[0.004]
COVID	Cases	Deaths	Cases	Deaths	Cases	Deaths
Log pseudolikelihood	-1.3.E+10	-1.3.E+10	-3.4.E+10	-3.4.E+10	-3.7.E+09	-3.6.E+09
Pseudo R-squared	0.9978	0.9978	0.9891	0.9891	0.9974	0.9974
No. of observations	84,508	84,508	58,448	58,448	74,528	74,528
(b) From Feburary to May						
ln COVID	-0.034***	-0.028***	-0.105***	-0.111***	-0.008	-0.018**
	[0.009]	[0.006]	[0.018]	[0.017]	[0.008]	[0.008]
COVID	Cases	Deaths	Cases	Deaths	Cases	Deaths
Log pseudolikelihood	-5.4.E+09	-5.4.E+09	-1.2.E+10	-1.2.E+10	-1.6.E+09	-1.6.E+09
Pseudo R-squared	0.998	0.9981	0.9918	0.9919	0.9976	0.9976
No. of observations	40,818	40,818	27,376	27,376	35,774	35,774

Notes: This table reports the estimation results obtained using the PPML method. ***, **, and * indicate the 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are those clustered by country pairs. In all specifications, we control for country–pair–year fixed effects, country–pair–month fixed effects, and importer–year–month fixed effects. "COVID" indicates the measure of the COVID-19 variables. "Cases" and "Deaths" represent the number of confirmed cases and deaths, respectively.

Table 3. Estimation Results for Supplier Diversity

Industry	Gnrl & Elec		Transport		Precision	
	(I)	(II)	(III)	(IV)	(V)	(VI)
(a) From January to August						
ln COVID	-0.054*	0.055**	-0.280**	-0.303**	-0.140**	-0.126**
	[0.031]	[0.024]	[0.113]	[0.129]	[0.063]	[0.059]
ln COVID * ln Diversity	0.004	-0.009***	0.031**	0.036**	0.018**	0.016*
	[0.004]	[0.003]	[0.015]	[0.018]	[0.009]	[0.008]
COVID	Cases	Deaths	Cases	Deaths	Cases	Deaths
Log pseudolikelihood	-1.3.E+10	-1.3.E+10	-3.4.E+10	-3.4.E+10	-3.6.E+09	-3.6.E+09
Pseudo R-squared	0.9978	0.9978	0.9891	0.9891	0.9974	0.9974
No. of observations	84,508	84,508	58,448	58,448	74,528	74,528
(b) From Feburary to May						
ln COVID	-0.259***	-0.013	-0.468***	-0.386***	-0.251**	-0.255***
	[0.069]	[0.043]	[0.107]	[0.096]	[0.102]	[0.078]
ln COVID * ln Diversity	0.028***	-0.002	0.056***	0.042***	0.035**	0.035***
	[0.008]	[0.005]	[0.016]	[0.014]	[0.015]	[0.011]
COVID	Cases	Deaths	Cases	Deaths	Cases	Deaths
Log pseudolikelihood	-5.4.E+09	-5.4.E+09	-1.2.E+10	-1.2.E+10	-1.6.E+09	-1.6.E+09
Pseudo R-squared	0.9981	0.9981	0.9919	0.992	0.9976	0.9977
No. of observations	40,818	40,818	27,376	27,376	35,774	35,774

Notes: This table reports the estimation results obtained using the PPML method. ***, **, and * indicate the 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are those clustered by country pairs. In all specifications, we control for country–pair–year fixed effects, country–pair–month fixed effects, and importer–year–month fixed effects. “COVID” indicates the measure of the COVID-19 variables. “Cases” and “Deaths” represent the number of confirmed cases and deaths, respectively.

Table 4. Estimation Results from February to May: Comparison of Two Periods

Industry	Gnrl & Elec		Transport		Precision	
	(I)	(II)	(III)	(IV)	(V)	(VI)
ln COVID * Feb/Mar	-0.352***	-0.390***	-0.439***	-0.467***	-0.389***	-0.549***
	[0.076]	[0.076]	[0.136]	[0.125]	[0.136]	[0.126]
ln COVID * Apr/May	-0.142*	0.06	-0.516***	-0.336***	-0.255***	-0.226***
	[0.073]	[0.049]	[0.118]	[0.118]	[0.084]	[0.057]
ln COVID * ln Diversity * Feb/Mar	0.044***	0.048***	0.058***	0.058***	0.056***	0.077***
	[0.009]	[0.009]	[0.022]	[0.020]	[0.020]	[0.018]
ln COVID * ln Diversity * Apr/May	0.014*	-0.01	0.054***	0.033**	0.036***	0.032***
	[0.008]	[0.006]	[0.017]	[0.017]	[0.012]	[0.008]
COVID	Cases	Deaths	Cases	Deaths	Cases	Deaths
Log pseudolikelihood	-5.0.E+09	-5.0.E+09	-1.2.E+10	-1.2.E+10	-1.6.E+09	-1.5.E+09
Pseudo R-squared	0.9982	0.9982	0.9921	0.992	0.9977	0.9977
No. of observations	40,818	40,818	27,376	27,376	35,774	35,774

Notes: This table reports the estimation results obtained using the PPML method. ***, **, and * indicate the 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are those clustered by country pairs. In all specifications, we control for country–pair–year fixed effects, country–pair–month fixed effects, and importer–year–month fixed effects. "COVID" indicates the measure of the COVID-19 variables. "Cases" and "Deaths" represent the number of confirmed cases and deaths, respectively. "Feb/Mar" is a dummy variable taking the value of one for observations in February or March. Similarly, "Apr/May" is a dummy variable taking the value of one for observations in April or May.

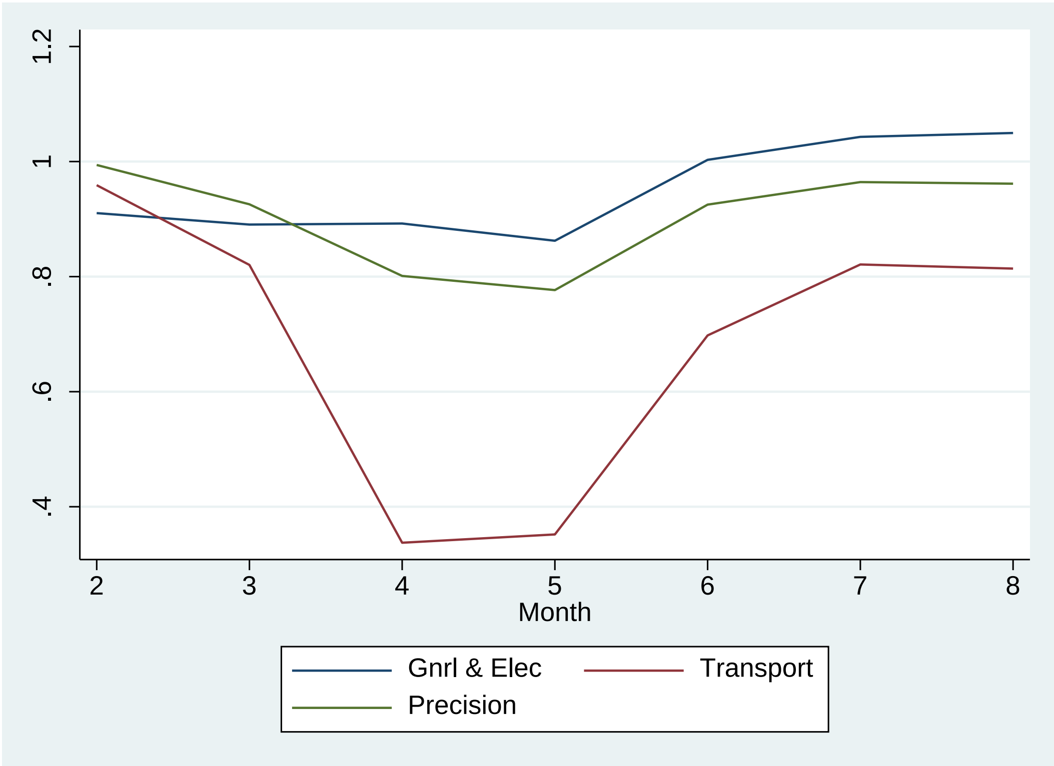
Table 5. Estimation Results with an Alternative Measure of Diversity

Industry	Gnrl & Elec		Transport		Precision	
	(I)	(II)	(III)	(IV)	(V)	(VI)
ln COVID	-0.068*	-0.08	-0.561***	-0.609***	-0.058**	-0.036
	[0.041]	[0.051]	[0.190]	[0.207]	[0.028]	[0.035]
ln COVID * ln Diversity	0.005	0.007	0.065***	0.073***	0.005	0.002
	[0.004]	[0.005]	[0.025]	[0.027]	[0.004]	[0.004]
COVID	Cases	Deaths	Cases	Deaths	Cases	Deaths
Log pseudolikelihood	-1.3.E+10	-1.3.E+10	-3.4.E+10	-3.4.E+10	-3.7.E+09	-3.6.E+09
Pseudo R-squared	0.9978	0.9978	0.9893	0.9893	0.9974	0.9974
No. of observations	84,508	84,508	58,448	58,448	74,528	74,528

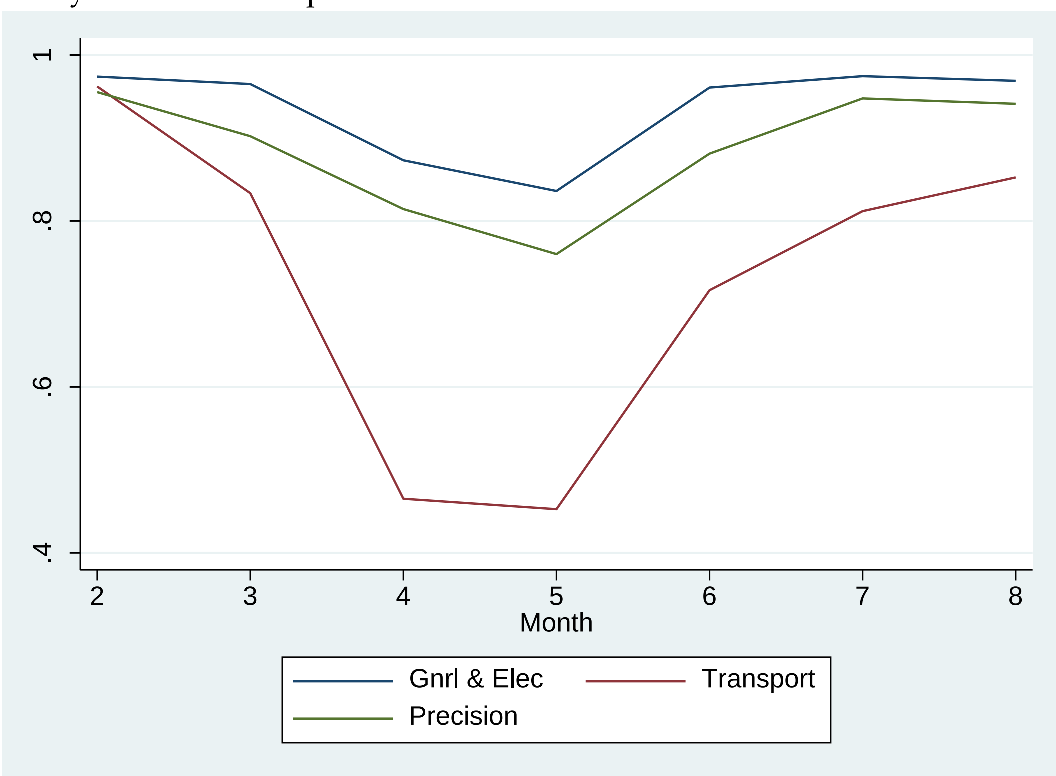
Notes: This table reports the estimation results obtained using the PPML method. ***, **, and * indicate the 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are those clustered by country pairs. In all specifications, we control for country–pair–year fixed effects, country–pair–month fixed effects, and importer–year–month fixed effects. "COVID" indicates the measure of the COVID-19 variables. "Cases" and "Deaths" represent the number of confirmed cases and deaths, respectively. In this table, we use the number of import country–product pairs with positive imports of machinery parts in 2019 as a measure of diversity.

Figure 1. Global Trade of Machinery Goods in 2020 Relative to Trade in 2019

(a) Final Machinery Products



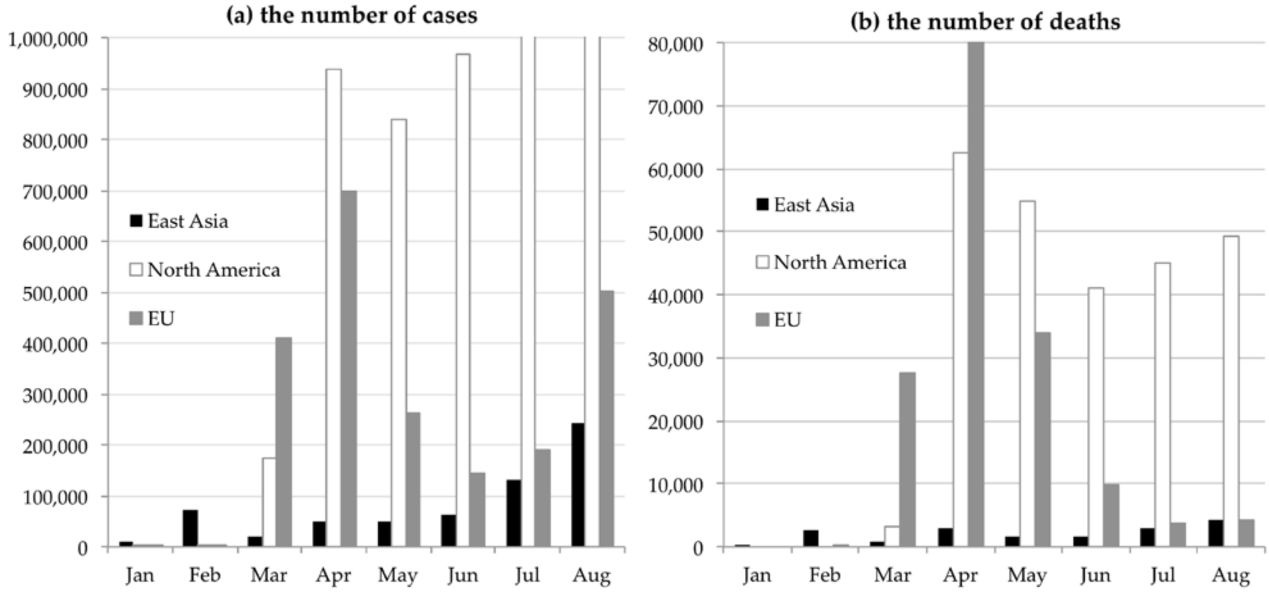
(b) Machinery Parts and Components



Source: Global Trade Atlas.

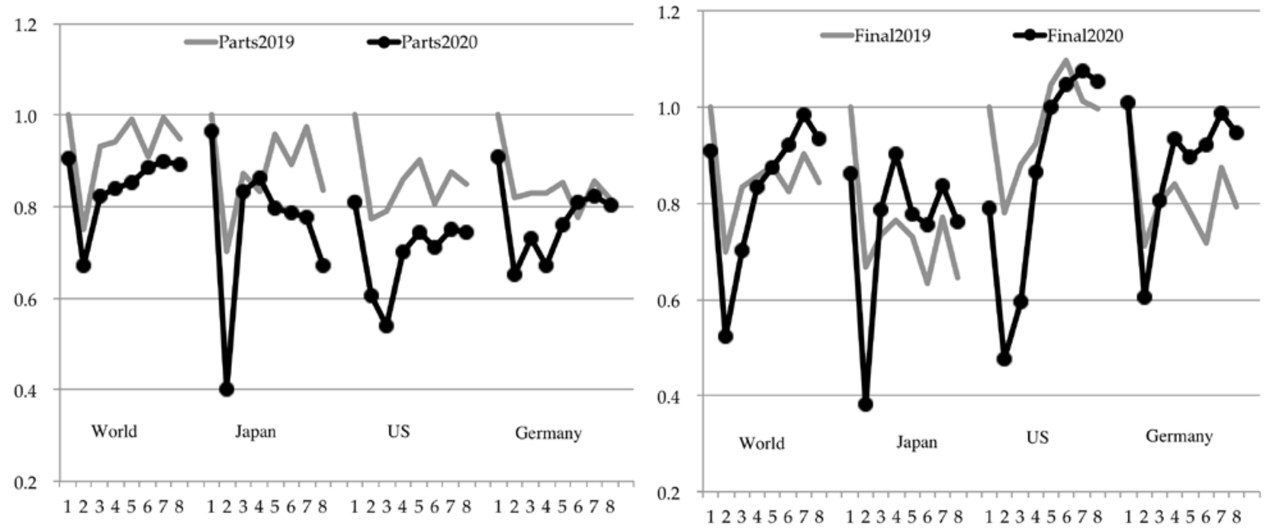
Note: Month 2 includes both January and February.

Figure 2. Spread of COVID-19 in East Asia, North America, and the EU



Source: Authors' compilation, using data from the European Centre for Disease Prevention and Control.
Notes: East Asia includes China, Hong Kong, Japan, Korea, Taiwan, and 10 ASEAN countries; North America includes US, Canada, and Mexico; and the EU includes 27 EU member states and the United Kingdom. The number of cases in July and August for North America and the number of deaths in April for the EU are not fully expressed here since the number is over 1,000,000 for cases and 80,000 for deaths.

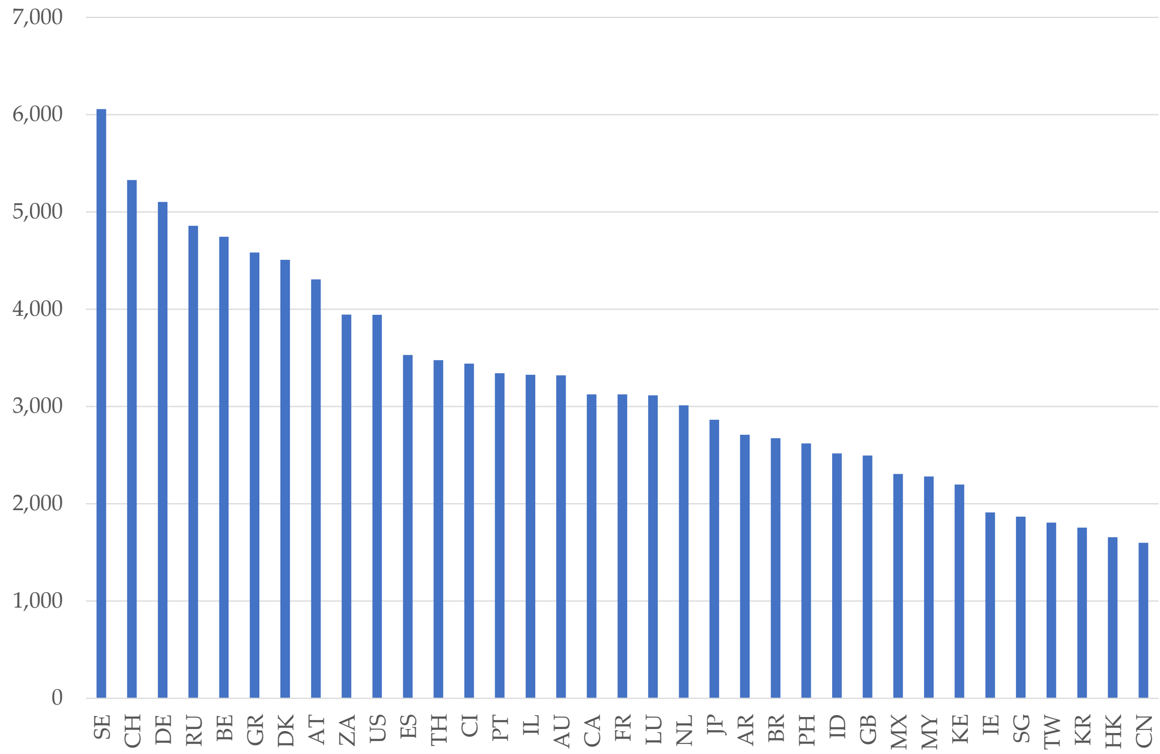
Figure 3. Export of Machinery from China to the World, Japan, US, and Germany in 2020 (indexed to January 2019 = 1)



Source: Authors' compilation, based on data available from Global Trade Atlas.

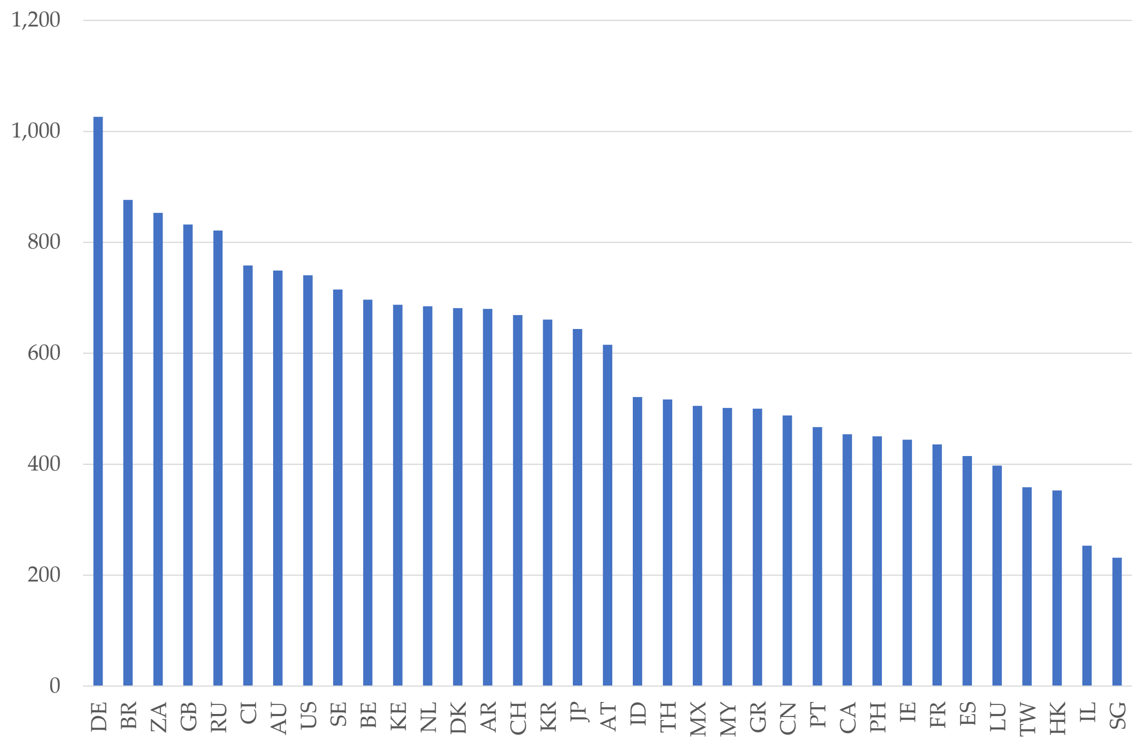
Notes: Data on the monthly imports from China by 35 reporting countries for January through August are used to calculate the export indices of China. Parts2020(2019) and Final2020(2019) refer to exports for parts and components in 2020(2019) and those for final products in 2020(2019), respectively.

Figure 4. Diversity Index for General and Electric Machinery Goods



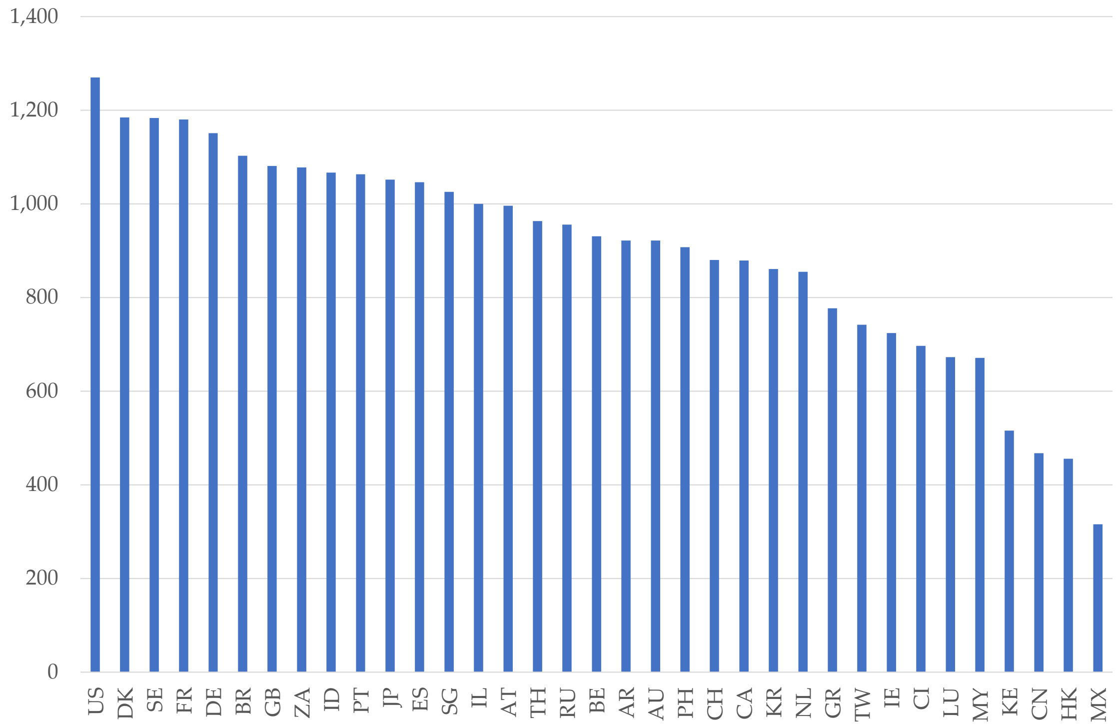
Source: Authors' compilation.

Figure 5. Diversity Index for Transport Equipment



Source: Authors' compilation.

Figure 6. Diversity Index for Precision Machinery Goods



Source: Authors' compilation.

Appendix A. Study Countries

35 Reporting Countries (ISO 2-letter codes):

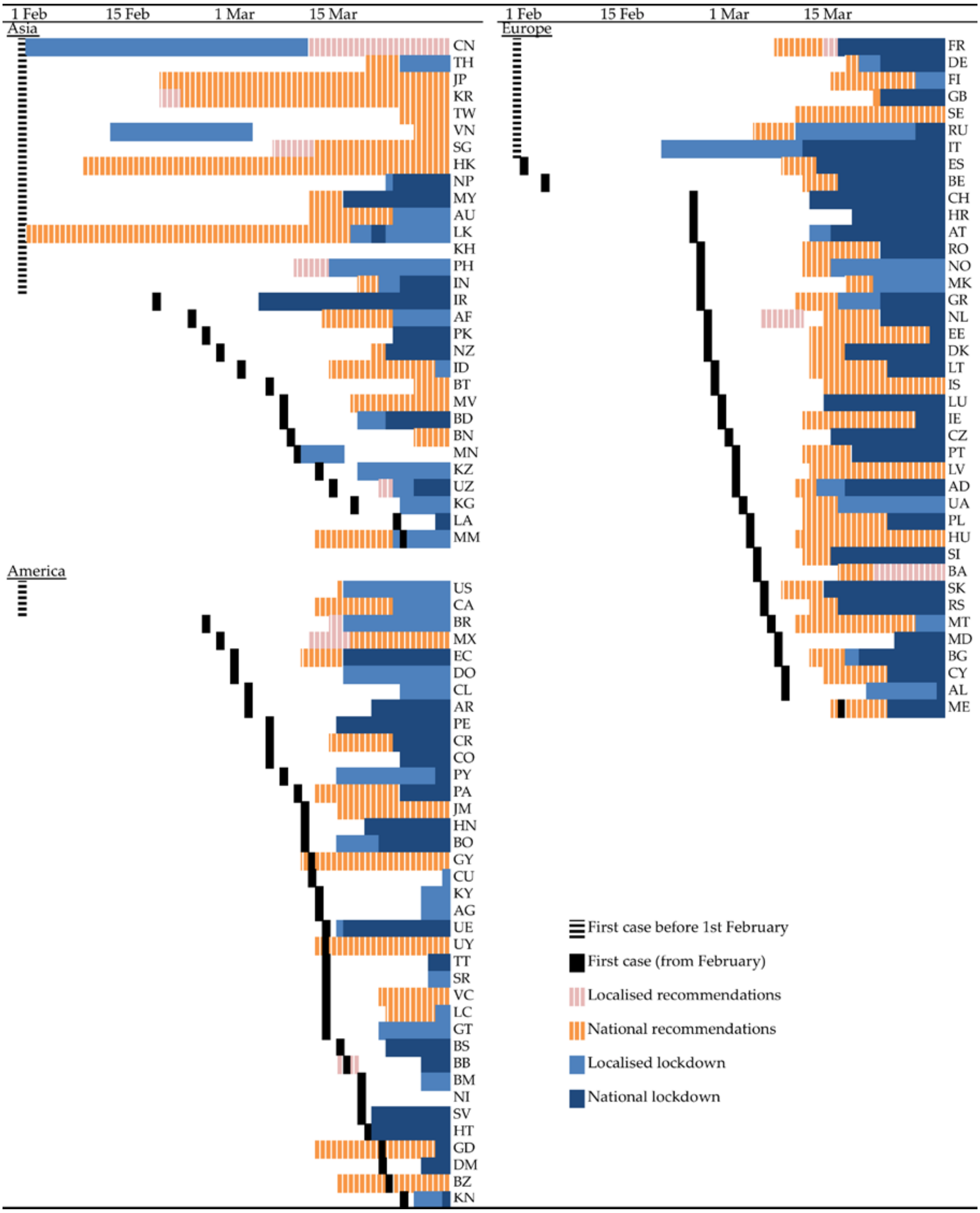
AR, AT, AU, BE, BR, CA, CH, CI, CN, DE, DK, ES, FR, GB, GR, HK, ID, IE, IL, JP, KE, KR, LU, MX, MY, NL, PH, PT, RU, SE, SG, TH, TW, US, ZA

252 Partner Countries (ISO 2-letter codes):

AD, AE, AF, AG, AI, AL, AM, AO, AQ, AR, AS, AT, AU, AW, AX, AZ, BA, BB, BD, BE, BF, BG, BH, BI, BJ, BL, BM, BN, BO, BQ, BR, BS, BT, BV, BW, BY, BZ, CA, CC, CD, CF, CG, CH, CI, CK, CL, CM, CN, CO, CR, CS, CU, CV, CW, CX, CY, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, EH, ER, ES, ET, EU, FI, FJ, FK, FM, FO, FR, GA, GB, GD, GE, GF, GG, GH, GI, GL, GM, GN, GP, GQ, GR, GS, GT, GU, GW, GY, HK, HM, HN, HR, HT, HU, ID, IE, IL, IM, IN, IO, IQ, IR, IS, IT, JE, JM, JO, JP, KE, KG, KH, KI, KM, KN, KP, KR, KW, KY, KZ, LA, LB, LC, LI, LK, LR, LS, LT, LU, LV, LY, MA, MC, MD, ME, MF, MG, MH, MK, ML, MM, MN, MO, MP, MQ, MR, MS, MT, MU, MV, MW, MX, MY, MZ, NA, NC, NE, NF, NG, NI, NL, NO, NP, NR, NU, NZ, OM, PA, PC, PE, PG, PH, PK, PL, PM, PN, PR, PS, PT, PW, PY, QA, RE, RO, RS, RU, RW, SA, SB, SC, SD, SE, SG, SH, SI, SJ, SK, SL, SM, SN, SO, SR, SS, ST, SV, SX, SY, SZ, TC, TD, TF, TG, TH, TJ, TK, TL, TM, TN, TO, TR, TT, TV, TW, TZ, UA, UG, US, UY, UZ, VA, VC, VE, VG, VI, VN, VU, WF, WS, XK, YE, YT, ZA, ZM, ZW, ZZ

Appendix B. Sudden Changes in COVID Policies across the World

Figure B1. Restricted Movement of People and Lockdown Policies in Asia, America, and Europe in February and March 2020



Source: Authors' compilation, using data obtained from https://www.bbc.com/news/world-52103747.

Note: While China and Thailand confirmed their first cases before January 15, 2020, other countries with "the first cases before February 1, 2020" did so in late January.

Appendix C. Direct and Indirect Inputs for Manufacturing Output

Table C1. Total Exposure of Row Countries to Manufacturing Sectors of Column Countries: Asia, North America, and Europe

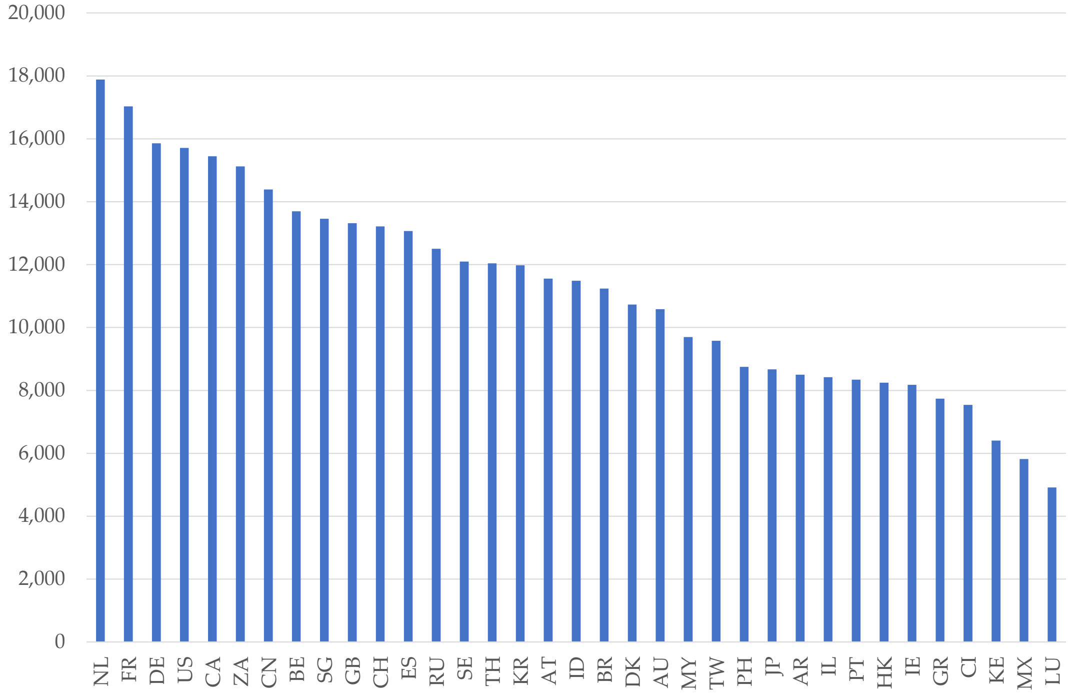
		Asia							North America			Europe							
		CN	JP	KR	IN	TW	AU	ID	US	CA	MX	DE	GB	FR	IT	ES	TR	NL	CH
Asia	CN		1.9	3.0		1.9			1.5			0.9							
	JP	6.3		1.2		0.6			1.4			0.7							
	KR	16.4	4.4		0.6	1.8			2.9			1.8			0.5				
	IN	7.2	0.9	1.5		0.5			2.1			0.9	0.5						
	TW	13.8	6.4	3.4	0.6			0.8	2.7			1.3							
	AU	7.1	2.2	1.5		0.5			1.8			1.0							
	ID	7.4	2.1	1.9	0.6	0.7			0.9			0.5							
North America	US	6.5	1.2	1.0						1.6	1.6	1.0							
	CA	7.2	1.2	1.1		0.5			14.1		1.4	1.2	0.5						
	MX	14.3	2.3	2.6	0.7	1.1			15.5	1.0		1.7			0.6	0.6			
Europe	DE	4.6	0.9	0.6					1.6				1.0	2.0	1.9	1.1	0.6	1.3	1.0
	GB	4.8	0.6	0.6	0.6				2.6	0.5		3.9		1.6	1.2	1.0	0.6	1.0	
	FR	4.1	0.6						2.4			5.7	1.2		2.3	1.9		0.8	0.6
	IT	4.6		0.7	0.6				1.1			4.9	0.8	2.3		1.6	0.8	0.8	0.6
	ES	4.6	0.6	0.6	0.6				1.2			4.5	1.2	3.3	2.3		0.6	0.8	
	TR	5.0		1.3	1.0				1.1			2.1	0.6	0.8	0.8	0.8		0.8	
	NL	3.7	0.7						1.8			5.0	1.2	1.2	0.7	0.7			
	CH	5.2	0.9		0.5				2.4			8.2	1.6	1.9	1.1	1.1	0.6	0.7	

Source: Baldwin and Freeman (2020).

Notes: The figures indicate the value-added shares of direct and indirect inputs from the column country to the total manufacturing output of the row country, based on Organization of Economic Cooperation and Development Inter-Country Input–Output Tables. Shares below 0.5% are omitted for the sake of clarity. ISO-2 codes are used for the country names. Countries in other regions, which are included in Baldwin and Freeman (2020), are omitted.

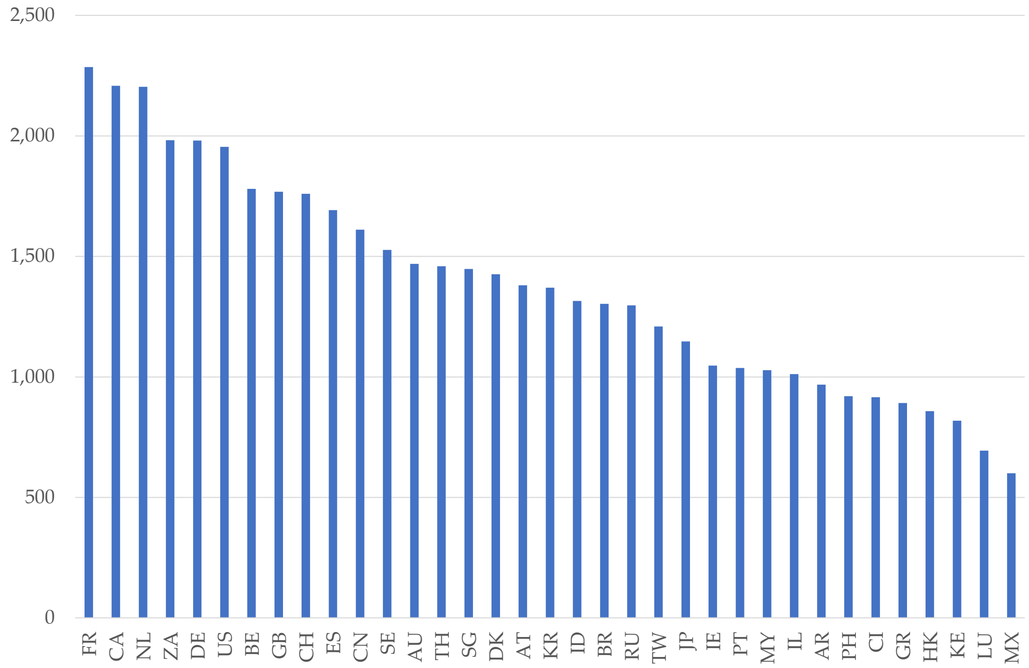
Appendix D. Other Figures

Figure D1. Number of Country–Product Pairs with Positive Trade for General and Electric Machinery



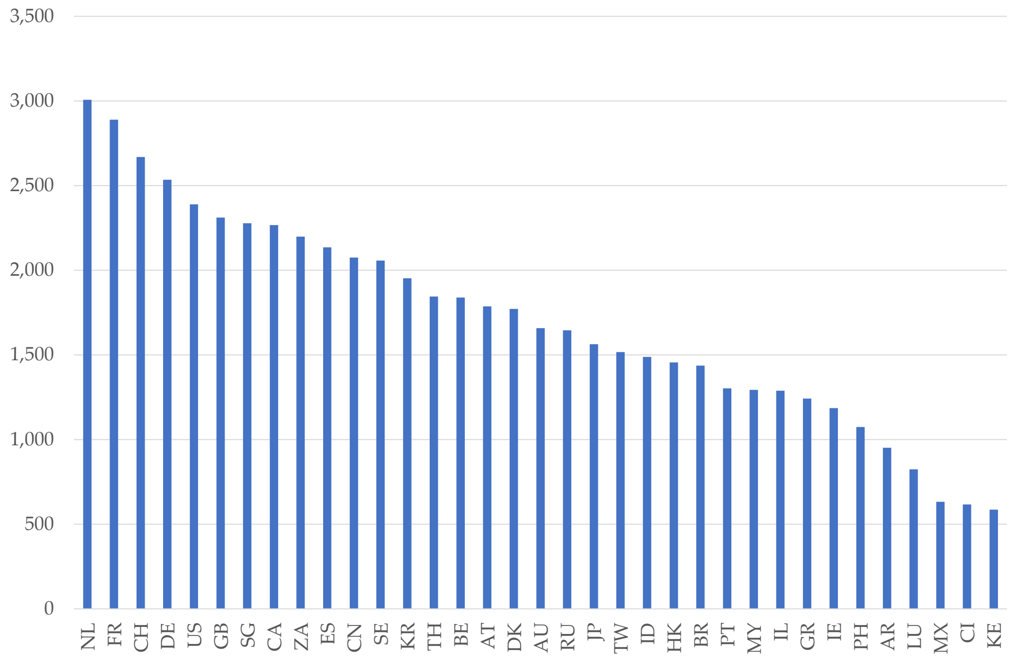
Source: Authors’ compilation.

Figure D2. Number of Country–Product Pairs with Positive Trade for Transport Equipment



Source: Authors' compilation.

Figure D3. Number of Country–Product Pairs with Positive Trade for Precision Machinery



Source: Authors' compilation.