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The COVID-19 Pandemic and the World Machinery Trade Network

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Abstract

In light of the importance of machinery trade in the world trade, this paper examines whether or not the patterns of machinery exports changed significantly after the COVID-19 pandemic outbreak. We apply a framework of the network analysis and that of the structural break analysis to the monthly-level bilateral export data from January 2016 to March 2022. Our main findings are threefold. First, we find positive structural change in exports in the major machinery exporting countries. Second, we find negative structural change in the centrality in Japan and some ASEAN countries, which implies the decline in the relative importance of these countries in the world machinery network. Third, the decline in the Japanese centrality is not caused by the decline in export values or number of destination countries. Rather, it is attributable to the decline in the centrality of Japan's export destination countries such as ASEAN countries. Noting that Japan has a relatively strong trade relationship with ASEAN countries, these results together suggest that the negative shock of the pandemic spread through the supply chain, which lead to the decline in the relative importance of some countries such as Japan in the world machinery trade network.

JEL classification: F14, F40

Keywords: Machinery trade; COVID-19 pandemic; Network; Centrality

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1. Introduction

Whether and how the global supply chain is resilient to the various shocks such as the coronavirus disease (COVID-19) pandemic is one of the concerns for policy makers. For example, building resilient supply chains is featured in the US White House (2022). Freeman and Baldwin (2022) in their VoxEU article also argued that "Supply disruptions caused by systemic shocks such as Brexit, Covid, and Russia-Ukraine tensions have catapulted the issue of risk in global supply chains to the top of policy agendas".

Despite the fact that the year 2020 was marked by some of the largest reductions in trade since World War II, the world economy is rapidly recovering from the coronavirus disease (COVID-19) pandemic. According to the International Monetary Fund (IMF) (2022), the global output growth was -3.1 percent in 2020 and it recovered to 5.9 percent in 2021. Similarly, world trade volume declined -8.2 percent in 2020 but increased 9.3 percent in 2021. These estimates suggest that the negative impacts are temporal rather than perpetual. In other words, trade was resilient against the shock of the pandemic.[1]

When discussing supply chains, however, people will assume manufacturing products rather than trade as a whole, especially machinery products such as iPad, car, and airplane because they have many parts and components whose production process spreads across different countries. While the negative effect of the pandemic on overall goods trade was disappeared because of a V-shaped recovery, the effect on machinery trade is inconclusive.[2]

For example, Ando, Kimura, and Obashi (2021) examined the impacts of the COVID-19 pandemic on Japanese machinery trade. Using the data between January 2017 and October 2020, their results indicate that trade relationships for parts and components were robust even amid the pandemic. Moreover, international production networks in machinery sectors were almost intact. Ando, Kimura, and Yamanouchi (2022) found that the negative impacts of COVID-19 pandemic on exports were much smaller for East Asia than for North America and Europe.

In contrast, Arriola, Kowalski, and van Tongeren (2021) argued that the variation in trade impacts across the different product categories in 2020 was not only larger than during the global financial crisis, but also larger than in any other year in the past two decades. Based on the detailed descriptive analysis of the trade data between January 2000 and January 2021, they pointed out that

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[1] In this paper, we limit our focus to goods trade due to the limited availability of the monthly data. Ando and Hayakawa (2022) utilized the quarterly data and examined the impact of the pandemic on trade in services. They found that the pandemic had a more significantly negative impact on the services trade than the goods trade.

[2] Kiyota (2022) examined how the pandemic affected global trade, using the monthly-level bilateral trade data from January 2000 and March 2021. The study found no evidence for major trading countries and ASEAN countries that changed trade significantly after the pandemic began.

the changes in the trade structure caused by the pandemic in a single year was a similar magnitude to changes otherwise typically seen over five years. Hayakawa and Mukunoki (2021) examined the effects of the COVID-19 pandemic on the trade of finished machinery products from January—June 2019 and January—June 2020. Their study found that, on the one hand, the pandemic did not have a significant effect on demand for finished machinery products in importing countries. On the other hand, the finished machinery trade is significantly hurt by higher rates of COVID-19 infection in countries exporting finished machinery products as well as countries exporting machinery parts to those countries.

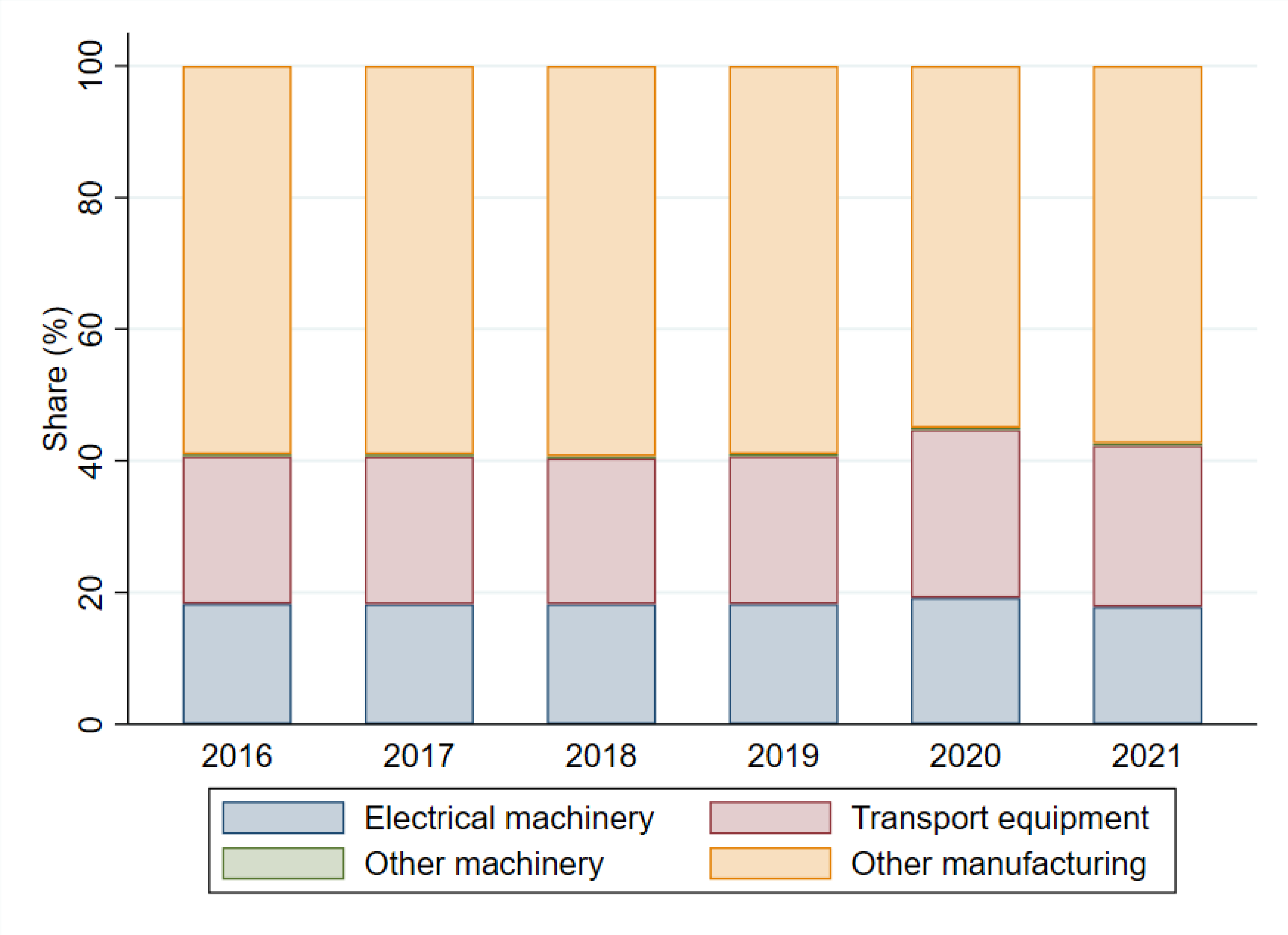
In a nutshell, whilst the previous studies made significant contributions to the literature, it is still not necessarily clear whether or not the patterns of machinery trade changed significantly after the COVID-19 pandemic outbreak. Did the pandemic cause the structural change in the pattern of machinery trade?[3] How the relative importance of countries in machinery trade changed after the pandemic outbreak?

Figure 1 presents the share of machinery exports in the world manufacturing exports in the world between 2016 and 2021. Figure 1 indicates that the share of machinery exports in total manufacturing exports was 41.0 percent in 2016, and slightly increased to 42.7 percent in 2021. Moreover, the machinery exports were dominated by two categories: electrical machinery and transport equipment. Indeed, the share of these two categories exceeded 40 percent in manufacturing trade in 2021. Because machinery exports indicate the large share of manufacturing exports, it is essential to answer these questions for a deeper understanding of the impact of the pandemic on international trade.

Figure 1

Share of Machinery in Manufacturing Exports in the World

[3] As we will explain below, the structural breaks are defined as the break points in the time series of variables, where break points are defined as a significant shift in mean or trend in the variables concerned.



Notes: Manufacturing is defined as the Harmonized System (HS) categories from 16 to 96. Machinery exports are from 84 to 92, where 84 is electrical machinery and 85 is transport equipment.
Source: UN Comtrade Database.

Based on this background, this study investigates whether or not the patterns of machinery trade changed significantly after the COVID-19 pandemic outbreak. Our study builds upon Kiyota (2022) that examined how total trade and the centrality of each country in the world trade changed after the pandemic outbreak.[4] Following Kiyota (2022), this study focuses on trade and centrality. Unlike Kiyota (2022), however, this study focuses particularly on the machinery trade.[5] This paper thus contributes to the literature, by providing a more detailed analysis on the machinery trade and by employing formal statistical analysis to evaluate the significance of the changes in the world machinery

[4] After the COVID-19 pandemic outbreak, several studies employed the framework of the network analysis to analyze the trade patterns between countries. See, for example, Vidya and Prabheesh (2020), Antonietti, Falbo, Fontini, Grassi, and Rizzini (2022), and Kiyota (2022).

[5] In this connection, Hayakawa and Mukunoki (2020) estimated a gravity model using data for 186 countries. One of their important findings was that the negative impacts of the pandemic are particularly evident in exports from developing countries. Although they presented interesting findings, the network structure of trade is beyond the scope of their study.

trade network after the pandemic outbreak. We believe that such disaggregated-level analysis would clarify whether there are shifts in the global value chains landscape as a result of the COVID-19 pandemic.

The analysis of this paper could also have important policy implications. Understanding the vulnerability of supply chains helps policy makers to identify the sources of uncertainty in policy making. Our analysis attempts to clarify whether and which machinery products were vulnerable or resilient against the pandemic outbreak. Based on the importance of machinery trade in Asian countries, our study will provide policy makers with useful information.

2. Methodology and Data

2.1. Network analysis

This study employs the framework of the network analysis in order to identify the relative importance of each country in the world machinery trade and the framework of the structural break to statistically detect the structural change in machinery trade and the centrality. In the framework of network analysis, each country is represented as a node while trade relationship between countries is represented as a link. The world machinery trade network thus is represented by the nodes and links, which is called graph.

There are three advantages to employing the framework of network analysis. First, the data requirement for the analysis is relatively low. Basically, only the information on the bilateral trade is necessary for the analysis. It thus is easy to implement the analysis. Second, trade data is helpful to examine the current economic situation because they are available on a monthly basis. Finally, the network analysis is outstanding in terms of visualization. The network analysis visualizes the network of countries, based on graph theory. It thus is helpful to capture the relative importance of each country in a relatively easy manner.

The relative importance of each node is represented by centrality measures. There are several centrality measures such as the closeness centrality that are based on the distance between nodes and the degree centrality that is based on the number of links. However, because countries generally trade with many countries simultaneously, these centrality measures are not necessarily useful for the analysis of the world machinery trade network.

Several recent economic studies such as Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi (2012) and Carvalho (2014) utilized eigenvector centrality, which is also called Bonacich centrality. However, it is not applicable to directed graphs. Therefore, it is not applicable to analyzing the world machinery trade network because trade has a direction (from exporting countries to importing countries).

To overcome this problem, this study utilizes PageRank centrality, which was originally developed to evaluate the ranking of webpages (Page, Brin, Motwani, and Winograd, 1999). PageRank centrality is a variant of eigenvector centrality but has the following two advantages. First, like eigenvector centrality, PageRank centrality considers not only the number of edges (i.e., trade relationship) that a node (i.e., country) has, but also the number of edges that other directly connected nodes have. Indeed, as Kiyota (2023) showed, PageRank centrality is consistent with the index of upstreamness. Second, unlike eigenvector centrality, this centrality is applicable to a directed graph. Because trade has directions (from origin to destination), this is another desirable property for the analysis of trade.

Let the number of nodes be n. We denote the adjacency matrix as A:

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{pmatrix}, \tag{1}$$

where:

$$a_{ij} = \begin{cases} 1, & \text{if there is a link from node } i \text{ to node } j; \\ 0, & \text{othewise.} \end{cases} \tag{2}$$

Now, let us introduce time dimension t. Let PageRank centrality be PR_{it} for country i at time t. Then, it is defined as:

$$PR_{it} = \psi \sum_{j=1}^{n} a_{ijt} \frac{PR_{jt}}{k_{jt}} + \chi, \tag{3}$$

where ψ and χ are positive constants and k_{jt} is the outdegree. In computing PageRank centrality, we use exports as a link weight. Equation (1) thus means that PageRank centrality for country i becomes high if 1) the number of country i's partners increases; 2) country i's trade increases; and 3) PageRank for country i's partner increases. Conventionally, we set $\psi = 0.85$ and $\chi = 1$. To make comparisons between years, we also adjust PageRank centrality such that its total equals to one.

2.2. Structural break analysis

2.2.1. Regression equations

Once we obtain the centrality measures, we conduct structural break analysis to identify whether there are break points in machinery trade and centrality measures in their time series, where break points are defined as a significant shift in mean or trend in the variables concerned. To detect the structural break, we employ the test developed by Clemente, Montañés, and Reyes (1998) that allows for estimation of two events within the observed history of a time series.[6] This allows us to investigate whether countries experienced significant changes in trade and their centrality during the sample period.

We denote an outcome variable of country i as y_t (suppressing the country subscript i), where outcome variable is either the log value of machinery exports or PageRank centrality. Consider that the time series of outcome y_t experiences one structural break during the sample. There are two types of models that can capture the structural break: an additive outlier (AO) model that captures a sudden change, and an innovational outliers (IO) model that captures a gradual shift in the mean of the series.[7]

The AO model consists of the following two steps. In the first step, we estimate the following regression equation:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \tilde{y}_t, \tag{4}$$

where:

$$DU_{mt} = \begin{cases} 1, & \text{if } t > T_{bm}; \\ 0, & \text{otherwise,} \end{cases} \tag{5}$$

where $m = 1, 2$; T_{b1} and T_{b2} are the break points to be located by grid search. and $\tilde{y}_t$ denotes the residuals. In the second step, the residuals from this regression are used as the dependent variable for the following equation:

$$\tilde{y}_t = \sum_{\tau=1}^{d} \omega_{1\tau} DT_{b1,t-\tau} + \sum_{\tau=1}^{d} \omega_{2\tau} DT_{b2,t-\tau} + \alpha \tilde{y}_t + \sum_{\tau=1}^{d} \theta_\tau \Delta \tilde{y}_{t-\tau} + \varepsilon_t, \tag{6}$$

where:

$$DT_{bm,t} = \begin{cases} 1, & \text{if } t = T_{bm} + 1; \\ 0, & \text{otherwise,} \end{cases} \tag{7}$$

for $m = 1, 2$. The lag order d is also unknown. The second regression is estimated over feasible values of T_{bm} to search for the minimal t-statistic to test whether the autoregressive parameter $\alpha = 1$ (i.e., the strongest rejection of the unit root null hypothesis) for all the break time combinations, while d is determined by a set of sequential F-tests.[8] The significance level of this minimal t-statistic is investigated based on the critical values provided by Perron and Vogelsang (1992).

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[6] There are several structural break tests. To compare the results with those of Kiyota (2022), we employ the test developed by Clemente, Montañés, and Reyes (1998). In addition, for the test developed by Clemente, Montañés, and Reyes (1998), stata code is available (and thus easy to implement and replicate).

[7] One may concern that trade involves future contracts and thus could not change suddenly. Because the IO model captures a graduate shift in the mean series, it would capture the gradual change in futures contracts if that were the case.

[8] We set the maximum lag number as 12 to reduce the computational burden and to account for seasonality (i.e., $d = 12$). Note that there is no intercept because the mean of $\tilde{y}_t$ is zero.

In contrast, the IO model is based on the one-step procedure. The following regression equation is estimated:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \phi_1 DT_{b1,t} + \phi_2 DT_{b2,t} + \alpha y_{t-1} + \sum_{\tau=1}^{d} \theta_\tau \Delta y_{t-\tau} + \varepsilon_t. \tag{8}$$

As in the AO model, the regression equation is estimated over feasible values of T_{bm} to search for the minimal *t*-statistic to test whether the autoregressive parameter $\alpha = 1$ (i.e., the strongest rejection of the unit root null hypothesis) for all the break time combinations, while d is determined by a set of sequential F-tests.

Note that it is necessary to choose some trimming values because the test is not defined at the limits of the sample (Clemente, Montañés, and Reyes, 1998). Banerjee, Lumsdaine, and Stock (1992) suggested using a window $(0.15, 0.85)$. However, Perron and Vogelsang (1992) pointed out that "this choice is arbitrary" (p.305). To adapt the largest window possible in both the theoretical derivations and the empirical applications, following Zivot and Andrews (1992), we set the values $((d+2)/T, (T-1)/T)$ interval.[9]

2.2.2. Hypothesis

The COVID-19 pandemic is an ongoing global pandemic of coronavirus disease 2019. The virus was first identified from an outbreak in Wufan, China, in December 2019 and then spread to other areas of the world. The World Health Organization (WHO) declared the outbreak a public health emergency of international concern on January 30th, 2020, and a pandemic on March 11th, 2020. Although the pandemic is still ongoing, most of the strict measures including lockdown were introduced in early 2020 and therefore we expect a significant change in the patterns of machinery trade, if any, appeared in 2020. We thus focus on year 2020 and examine whether we can find a break point in the patterns of machinery trade in 2020. Our hypothesis is as follows.

Hypothesis: If the COVID-19 pandemic has a significantly negative impact on the patterns of machinery exports, we will find significantly negative coefficients in 2020.

Note that the focus of our analysis is to identify the timing of the structural change. Although

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[9] This interval was also adopted by Perron and Vogelsang (1992) and Lumsdaine and Papell (1997). It is technically difficult to set the interval and lag order simultaneously. As a short cut, we use maximum lag order (i.e., $d = 12$) for the interval while determining the lag order by a set of sequential F-test.

investigating the sources of the structural change is beyond the scope of our study, we will discuss the possible factors for further research. It is also important to note that there were several shocks during the sample period (January 2016—March 2022). If those shocks are more significant than the pandemic outbreak, those shocks will be the break points. In other words, our question is whether the pandemic outbreak had more significant effects on exports than other shocks.

2.2.3. Data

We mainly use the monthly export data from January 2016 to March 2022 (75 months), obtained from the UN Comtrade Database. In the UN Comtrade Database, monthly imports are valued at the c.i.f. price (i.e., cost, insurance, and freight price) while monthly exports are valued at the f.o.b. (i.e., free on-board price). To exclude the effects of the freight charges and the shipping insurance, we utilize exports rather than imports.[10]

Note that the availability of the monthly-level trade data varies between countries. Table 1 summarizes the data availability for major machinery exporting countries and ASEAN countries. Because monthly export data are not available for China between October 2012 and December 2015, we focus on the period after 2015.

Table 1

Sample Period in the UN Comtrade Database

		Start	End	*T*	Not available
Major countries	CHN	2016m1	2022m3	75	2012m10-2015m12
	DEU	2010m1	2022m3	147	
	HKG	2010m1	2022m3	147	
	JPN	2010m1	2022m3	147	
	USA	2010m1	2022m3	147	
ASEAN	BRN	2015m1	2020m12	72	2014m1-2014m12
	IDN	2015m1	2022m3	87	2013m9 & 2014m11-2014m12
	KHM	2015m1	2020m12	72	2010m1-2014m12 & 2021m1-
	LAO	2015m1	2020m12	72	2010m1-2014m12 & 2021m1-
	MMR	2011m1	2021m12	132	2010m1-2010m12 & 2022m1-
	MYS	2014m8	2021m12	89	2014m7 & 2022m1
	SGP	2013m5	2021m6	98	2013m4 & 2021m7-
	VNM	2015m1	2021m12	84	2010m1-2014m12 & 2022m1-
	PHL				2019m6
	THA				2019m10

[10] As a robustness check, we also utilized import data, as we will discuss later.

Following Ando, Kimura, and Obashi (2022), we focus on 2-digit classifications of the Harmonized System (HS) codes between 84 and 92: general machinery (HS84), electrical machinery (HS85), transport equipment (HS86-89), and precision machinery (HS90-92). We first aggregate these classifications and focus on machinery trade as a whole as a benchmark. A more disaggregated-level analysis will be provided in the discussion section (Section 4).

Throughout the paper, we mainly focus on five major machinery exporting countries: China, Germany, Hong Kong, Japan, and the United States because these countries have been ranked in the top five machinery exporters for most of the years between 2016 and 2021. In 2021, these five countries account for over 50 percent of the world machinery exports. South Korea also ranked in the top five for some years during this period. However, South Korean export data are not available from 2020 at the monthly level in the UN Comtrade Database. We thus mainly focus on the above five countries. In Section 5.1, however, we also look at ASEAN countries where machinery is actively traded through the international production networks (e.g., Ando, Kimura, and Yamanouchi, 2022), accounting for more than 11 percent of the world machinery exports in 2021 (UN Comtrade Database).

Note that the HS classification codes were revised several times during the sample period. While we acknowledge the importance of tracing the same product throughout the period, it is difficult to do so at the 2-digit level because classification changes occurred at the detailed product level. In addition, for machinery products, most of the products are classified within the same 2-digit levels, although some of the electrical machinery products are classified into different categories. We thus decided not to pursue this issue here and continue to use the HS84-92 codes.

Note also that we have to trim the data for the structural break analysis. As mentioned above, we use $((k+2)/T, (T-1)/T)$ interval, where $k=12$ and $T=75$. This means that the interval is (14, 74), which dropped 10 percent of the sample (i.e., the first 13 months at the beginning of the sample period and the last month of the sample). Because the pandemic started from March 2020 $(t = 51)$, we have basically $23(= 74 - 51)$ months after the pandemic outbreak. Our analysis thus has the enough observations after the pandemic outbreak.

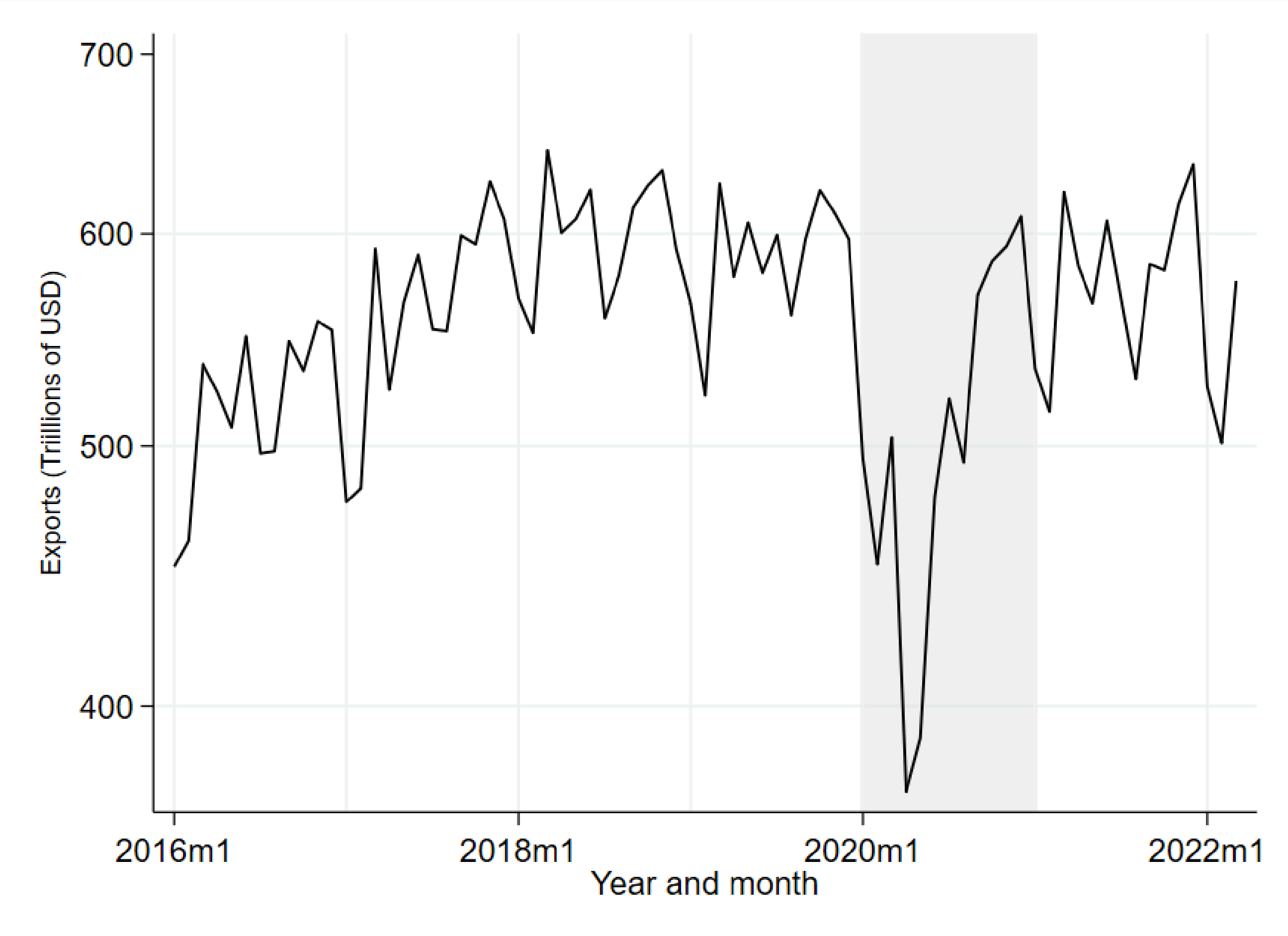
2.2.4. Continuing export countries

Figures 2 and 3 present the changes in the total value of machinery exports and the total number of destination countries in the world. The total value indicates the sum of all the countries' exports while the total number of destination countries indicates the number of origin countries times the number of destination countries. We highlight two findings. First, the value of the machinery exports declined when the COVID-19 pandemic started around March 2020, it showed a quick recovery from mid-2020.

Second, in contrast, the number of destination countries declined around March 2020, and then continued to decline with some fluctuation afterword.

Figure 2

Value of the Machinery Exports in the World

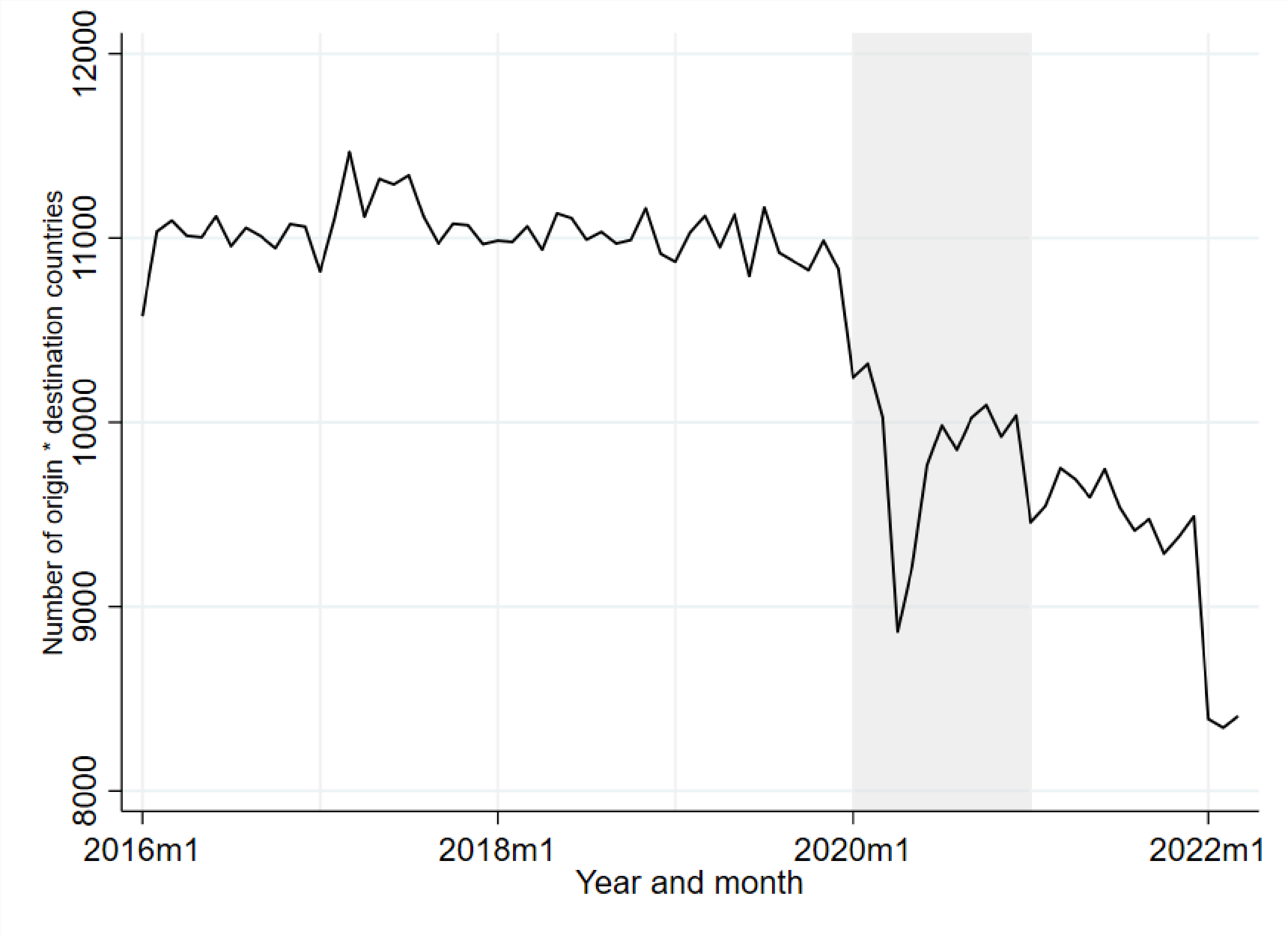


Notes: Total value of machinery exports indicates the aggregation of export values for each country. The gray shaded area indicates the year 2020.

Source: UN Comtrade Database.

Figure 3

Number of Destination Countries of the Machinery Exports in the World



Notes: Total number of destination countries indicates the aggregation of export destination countries for each country. The gray shaded area indicates the year 2020.
Source: UN Comtrade Database.

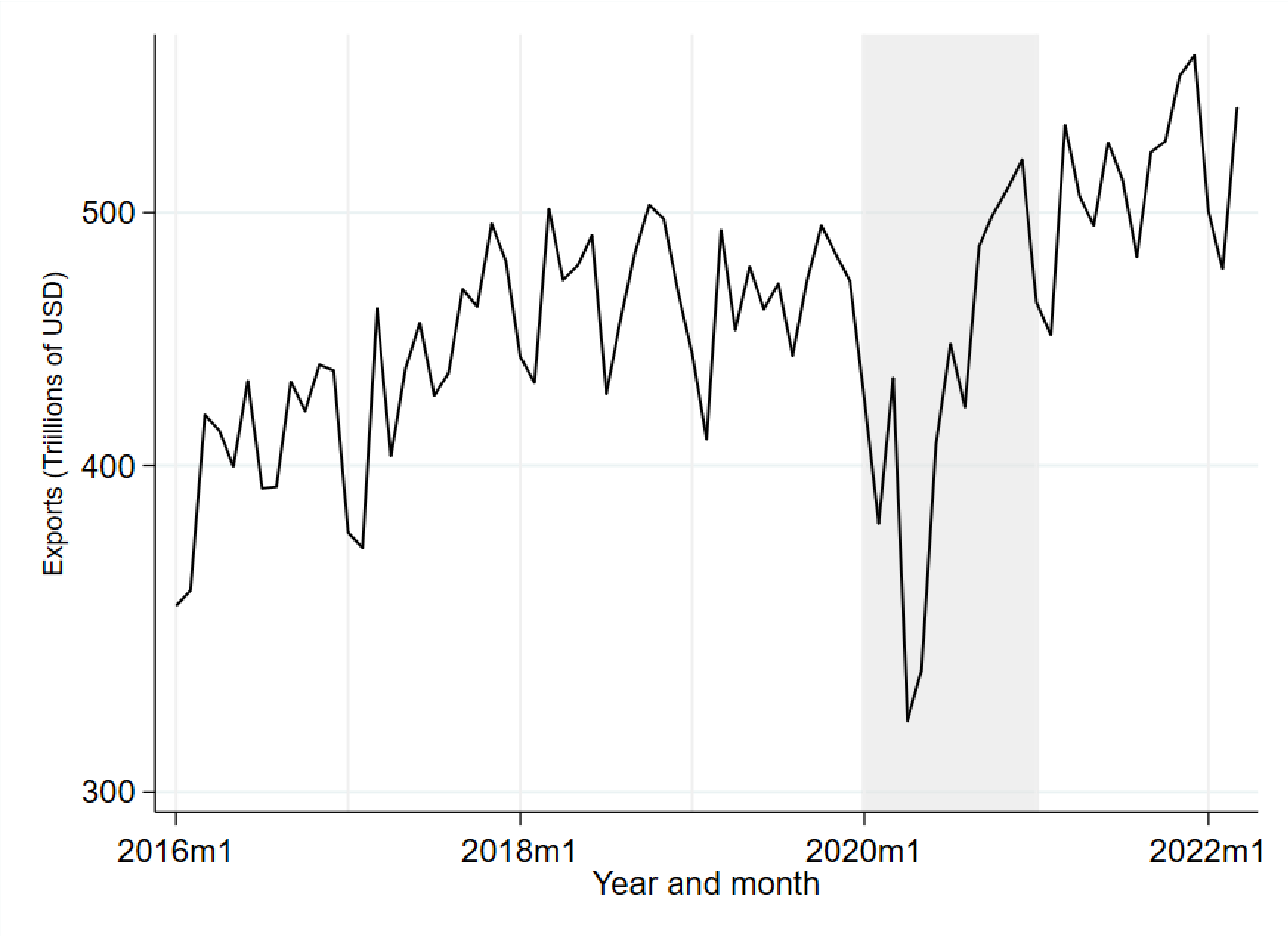
Note that, in the UN Comtrade Database, monthly export data are not available for some countries for a certain period, especially after the pandemic outbreak. As mentioned above, South Korean monthly export data are not available from 2020. Similarly, monthly export data are not available from 2021 for some ASEAN countries such as Cambodia, Lao PDR, and Viet Nam (Table 1). Chinese monthly export data are not available from October 2012 to December 2015 (Table 1). Because PageRank centrality is affected by the presence or absence of trade between countries, the data availability could affect the results.

To address this issue, we restrict our sample to countries that continue to be available from January 2016 to March 2022. These are countries that continued to export machinery products to at least one country throughout the period. In 2019 (before the pandemic), there are about 117 exporting countries (monthly average). The number of continuing export countries is 48. In 2019, the share of these continuing export countries is 58.9 percent of total machinery exports in the world.

Figures 4 and 5 present the changes in the total value of machinery exports and the total number of destination countries in the world for continuing export countries. There are two notable findings. First, like the results of all exporting countries (Figure 2), although the value of the machinery exports declined when the COVID-19 pandemic started around March 2020, it showed a quick recovery from mid-2020. Second, unlike the results of all exporting countries (Figure 3), the number of export destination countries did not decline significantly except for the period between March 2020 and April 2020. These results imply that the decline in the number of destination countries in Figure 3 is attributable to the data availability.

Figure 4

Value of the Machinery Exports in the World: Continuing Export Countries

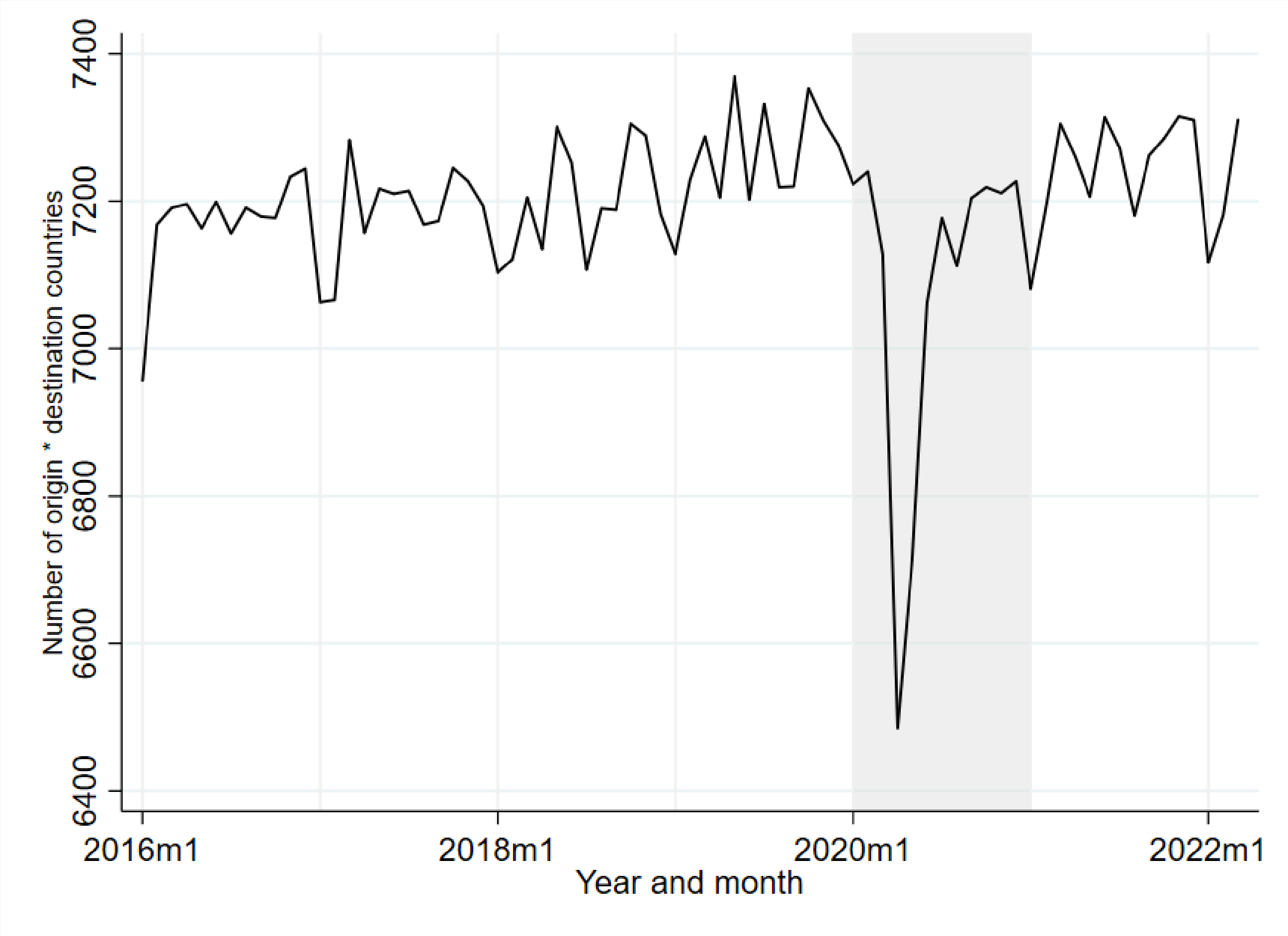


Notes: Total value of machinery exports indicates the aggregation of export values for each country. The gray shaded area indicates the year 2020.

Source: UN Comtrade Database.

Figure 5

Number of Destination Countries of the Machinery Exports in the World: Continuing Export Countries

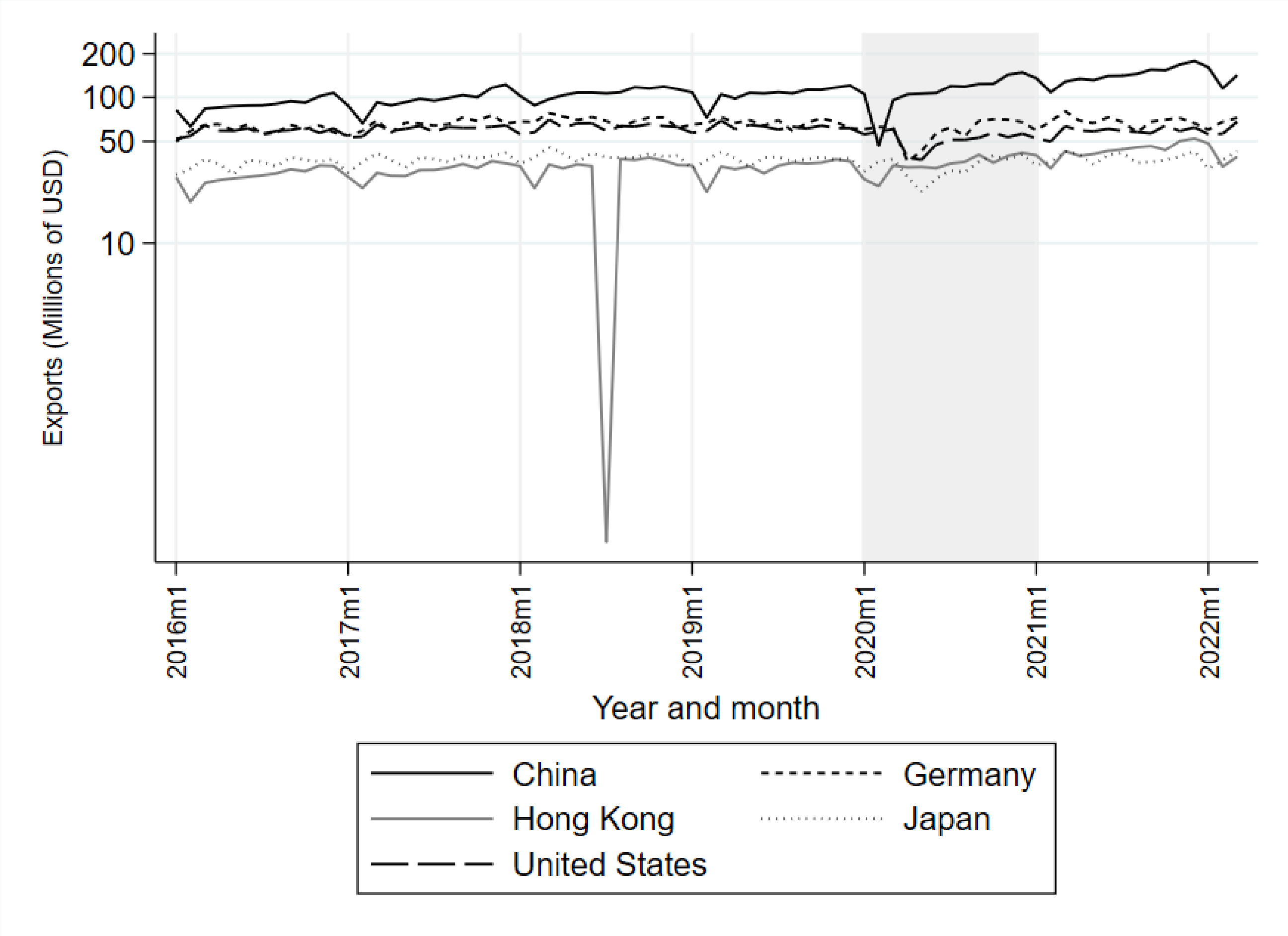


Notes: Total number of destination countries indicates the aggregation of export destination countries for each country. The gray shaded area indicates the year 2020.
Source: UN Comtrade Database.

Figure 6 presents the machinery exports for the five countries from January 2016 to March 2022. There are three notable findings. First, machinery exports declined significantly in the early 2020 for these countries. Second, the exports of Hong Kong dropped significantly in the mid-2018. This is because the exports of many machinery products including electrical machinery and transport equipment are missing in July 2018 in the UN Comtrade Database. Although this may be regarded as an outlier, a caution is needed in interpreting the results of Hong Kong. Third, it is difficult tell which month-year indicates the break points. In the next section, we employ an econometric analysis to identify the break points in a precise manner.

Figure 6

Machinery Exports: Major Machinery Exporting Countries



Notes: Machinery exports are from HS84 to 92, where 84 is electrical machinery and 85 is transport equipment. The gray shaded area indicates the year 2020.
Source: UN Comtrade Database.

3. Estimation Results

3.1. Structural breaks in machinery exports

We first investigate whether or not we observe a structural break in exports in 2020. We estimate equations (4) and (6) for the AO model and equation (8) for the IO model, using machinery export data as an outcome variable. Because we take the log for the dependent variable, the coefficients are interpreted as the percentage change of the dependent variable.

Table 2 presents the estimation results for major machinery export countries: China (CHN), Germany (DEU), Hong Kong (HKG), Japan (JPN), and the United States (USA). The upper part indicates the results of the AO model while the lower panel indicates the lower part indicates the results of the IO model. Figures A1-A5 indicate the break points to visually check them.

Table 2

Break Points of Machinery Exports: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2018m12	**2020m1**	2018m5	**2020m2**	**2020m1**
	0.016	**-0.123*** **	-0.033	**-0.111*** **	**-0.110*** **
	(0.527)	**(-5.874)**	(-0.321)	**(-6.479)**	**(-6.603)**
Break point 2	2019m12	2020m6	2021m4	2020m8	2020m7
	0.076**	0.121***	0.178	0.113***	0.079***
	(2.558)	(5.549)	(1.524)	(6.188)	(4.484)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m1	**2020m2**	2018m6	**2020m2**	**2020m2**
	-0.007	**-0.239*** **	-0.002	**-0.134*** **	**-0.171*** **
	(-0.548)	**(-7.291)**	(-0.113)	**(-5.910)**	**(-9.187)**
Break point 2	2020m1	2020m7	2020m7	2020m8	2020m7
	0.043***	0.225***	0.109***	0.126***	0.147***
	(3.653)	(6.963)	(5.519)	(5.415)	(7.323)

Notes: Countries are represented by their ISO codes. The symbols ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t-statistics. The break points indicate the estimated year and month when the structural breaks are identified. Bold letters indicate significantly negative coefficient in 2020 while gray-highlights indicate significantly positive coefficients.
Source: UN Comtrade Database.

Let us highlight three findings in the AO model results. First, for China and Hong Kong, the results indicate no significantly negative coefficient in 2020. This implies that our hypothesis is rejected. Machinery exports in these countries were resilient to the shocks from the COVID-19 pandemic. This result is consistent with the findings of Ando, Kimura, and Obashi (2021) and Ando, Kimura, and Yamanouchi (2022) that found the resilience of machinery trade in East Asia during the pandemic period.

Second, in contrast, the results indicate significantly negative coefficient in January 2020 for Germany and the United States and February 2020 for Japan. This result suggests that, for Germany, Japan, and the United States, the hypothesis is not rejected. The COVID-19 pandemic had a significant impact on the machinery exports of these three countries. However, we also confirmed significantly positive coefficients in mid-2020 for all these three countries. Note that the absolute value of the coefficients indicates similar magnitude: -0.123 and 0.121 for Germany; -0.111 and 0.113 for Japan; and -0.110 and 0.079 for the United States. Noting that the coefficients indicate the percentage change of dependent variable, this implies the significant drop in exports was mostly offset by their increases in mid-2020. These findings are also basically in line with the finding of Ando, Kimura, and Obashi (2021) and Ando, Kimura, and Yamanouchi (2022).

The results of the IO model are very similar to those of the AO model. One notable difference is that we now confirm significantly positive coefficients in 2020 for China. This implies that that the COVID-19 pandemic positively affected the machinery exports of China. This may be due to the positive demand shocks.

One may be concerned about a lag between the business contract and the actual transaction of the products (i.e., trade). This means that the effects of the pandemic outbreak do not appear instantaneously. Rather, the effects appear with some lags, which in turn implies that the effects appear in 2021 rather than in 2020. However, Table 2 does not indicate any significant break points in 2021. The effects of the future contract, if any, do not have any significant effects on our results.

In sum, the impacts of the COVID-19 pandemic on machinery exports were basically not negative but positive in China and Hong Kong. The impacts on Germany, Japan, and the United States were significantly negative, but they were temporal as we observed both negative and positive break points in 2020. These results together suggest that the machinery exports were basically resilient for these five countries.

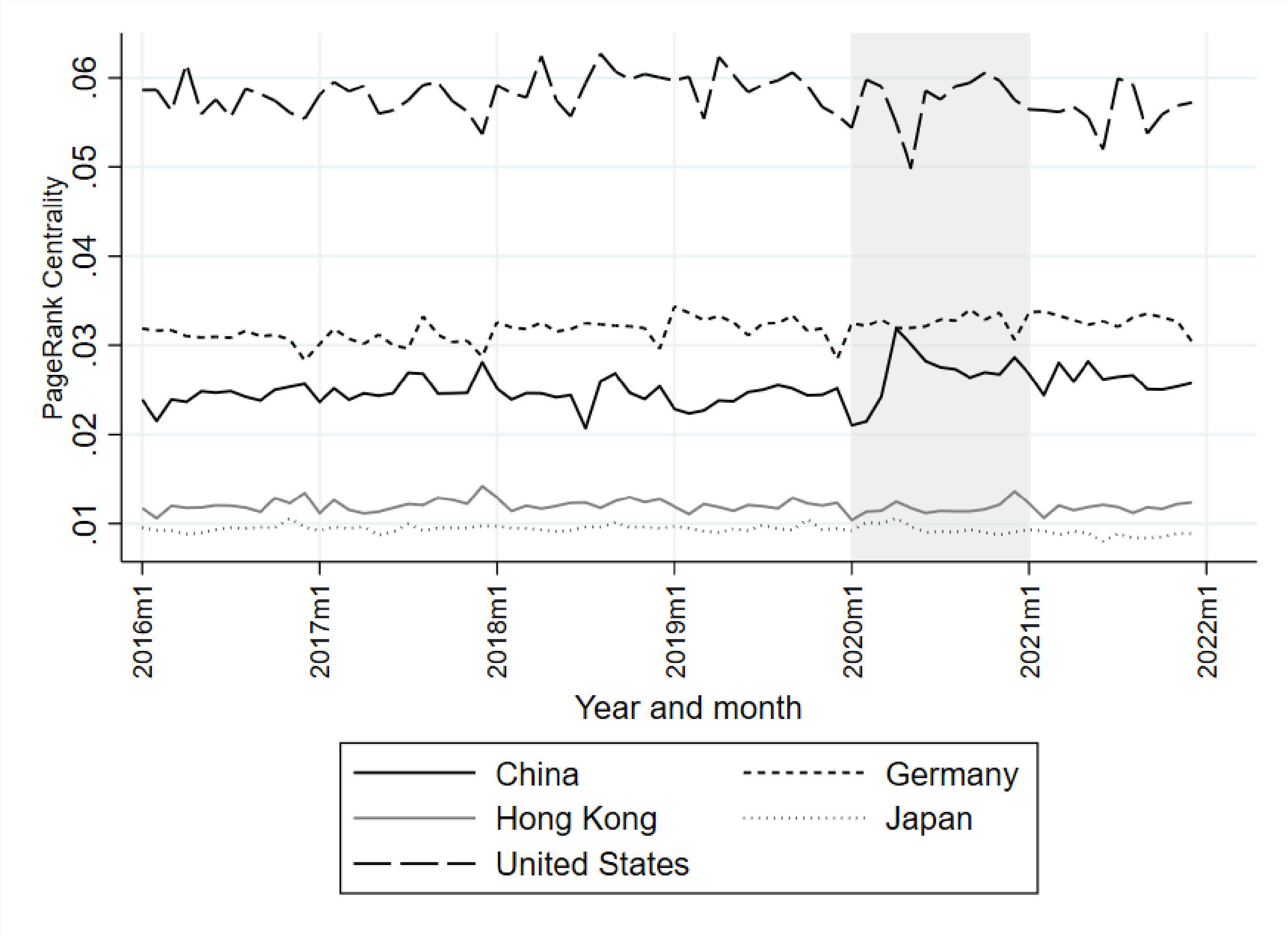
3.2. Structural breaks in centrality

Section 3.1 confirmed that the machinery exports were basically resilient for major exporting countries. Now, let us estimate equations (4) and (6) for the AO model and equation (8) for the IO model, using PageRank centrality as an outcome variable.

Figure 7 presents the changes in PageRank centrality between January 2016 and March 2022. Table 3 presents the estimation results for PageRank centrality. The upper part indicates the results of the AO model while the lower part indicates the results of the IO model. Figures A6-A10 indicate the break points to visually check them.

Figure 7

Centrality of Machinery in Manufacturing Exports in the World



Notes: Machinery exports are from HS84 to 92, where 84 is electrical machinery and 85 is transport equipment. The gray shaded area indicates the year 2020.
Source: UN Comtrade Database.

Table 3

Break Points of the Centrality of Machinery Exports: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2018m5	2017m10	2017m10	2020m2	2018m2
	-0.031	0.036**	0.014	-0.022	0.029*
	(-1.268)	(2.437)	(0.655)	(-1.644)	(2.104)
Break point 2	2019m12	2019m10	2019m11	2021m3	2019m11
	0.082***	0.012	-0.037**	-0.069***	-0.044***
	(3.717)	(1.149)	(-2.475)	(-3.863)	(-3.795)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2018m6	2019m11	2017m11	**2020m3**	2017m11
	-0.022	0.005	0.009	**-0.040*****	0.029*
	(-1.100)	(0.561)	(0.362)	**(-3.255)**	(1.836)
Break point 2	2020m1	Not detected	2018m11	2021m4	2019m9
	0.082***		-0.045**	-0.057***	-0.043***
	(3.826)		(-2.517)	(-2.993)	(-3.436)

For notes and source, see Table 2.

While the AO model indicates no significant coefficients in 2020 for these countries, the IO model indicates a significantly negative coefficient in 2020 for Japan. This result supports the hypothesis, implying that the COVID-19 pandemic had significantly negative impacts on the relative importance of Japan in the world machinery trade network. This result is different from the result of overall exports. Indeed, Kiyota (2022) employed the same framework and found no significant coefficient after the COVID-19 pandemic outbreak, using overall trade data. This in turn suggests that the patterns of machinery trade are slightly different from those of overall trade.

A concern may be that there is a lag between the business contract and the actual transaction of the products (i.e., trade), which suggests that the effects appear with some lags. However, Table 3 indicates significantly negative coefficient only for Japan in both AO and IO models. This result strengthens our main message. Even if we take into account the lagged effect, our main message does not change.

We found that the relative importance of top five countries except for Japan did not change when the COVID-19 pandemic started. This result implies that Japanese relative importance in the world machinery export network declined after the pandemic started. In the next section, we will examine whether this pattern is confirmed at the more disaggregated levels and for ASEAN countries. [11] We also discuss possible reasons why Japanese relative importance in the world

[11] We also estimated the break points of machinery imports and centrality for these five countries. We similarly

machinery export network declined after the pandemic outbreak.

4. Discussion

4.1. Electrical machinery and transport equipment

Section 3 presents the results of all machinery exports, covering the HS categories between 84 and 92. However, the results may be different between sectors. For example, Ando, Kimura, and Obashi (2021) found that the negative impacts of the COVID-19 pandemic on exports were larger in the transport equipment industry than in other machinery industries. This section thus presents the disaggregated-level analysis, focusing on two major machinery categories: electrical machinery and transport equipment.

Tables 4 and 5 present the estimation results for the exports of electrical machinery and transport equipment, respectively. We cannot estimate the break points for Hong Kong because the exports of electrical machinery and transport equipment are missing in July 2018, as mentioned above. We highlight two findings. First, for the exports of electrical machinery, the results in Table 3 are very similar to the results in Table 1. One notable difference is that the significantly negative coefficient is confirmed before 2020 for Japan in the IO model. Although the month is sometimes different, the same patterns are confirmed in Tables 2 and 4. This in turn means that the export patterns of machinery goods as a whole are basically the same as those of electrical machinery.

Table 4

Break Points of Electrical Machinery Exports: Major Machinery Export Countries

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found positive coefficients for imports and negative coefficients for centrality in 2020. The results are presented in Tables A1 and A2.

AO model	CHN	DEU	HKG	JPN	USA
Break point 1	2018m12	**2020m1**	Not	**2020m2**	**2020m1**
	0.024	**-0.062*** **	available	**-0.046*** **	**-0.050*** **
	(0.737)	**(-4.234)**		**(-2.976)**	**(-4.853)**
Break point 2	2019m12	2020m7		2020m8	2020m9
	0.076**	0.105***		0.093***	0.074***
	(2.441)	(6.750)		(5.697)	(6.638)

IO model	CHN	DEU	HKG	JPN	USA
Break point 1	2019m1	**2020m2**	Not	2019m11	**2020m2**
	-0.006	**-0.123*** **	available	-0.030**	**-0.091*** **
	(-0.444)	**(-6.115)**		(-2.116)	**(-5.495)**
Break point 2	2020m1	2020m7		2020m7	2020m8
	0.039***	0.172***		0.057***	0.124***
	(2.902)	(6.669)		(3.237)	(5.593)

For notes and source, see Table 1.

Second, for the transport equipment, the results in Table 5 are also very similar to the results in Table 2. A notable difference is that the significantly positive coefficient is confirmed after 2019 for China in the AO model. The month is sometimes different, but basically the same patterns are confirmed in Tables 2 and 5. This in turn means that the export patterns of machinery goods as a whole are also basically the same as those of transport equipment.

Table 5

Break Points of Transport Equipment Exports: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m11	**2020m1**	Not	**2020m3**	**2020m1**
	-0.052	**-0.222*** **	available	**-0.257*** **	**-0.225*** **
	(-1.612)	**(-5.820)**		**(-9.260)**	**(-7.835)**
Break point 2	2020m8	2020m6		2020m7	2020m7
	0.231***	0.186***		0.207***	0.118***
	(6.677)	(4.683)		(7.173)	(3.902)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m12	**2020m2**	Not	**2020m2**	**2020m2**
	-0.160***	**-0.453*** **	available	**-0.309*** **	**-0.414*** **
	(-3.549)	**(-7.692)**		**(-9.420)**	**(-12.102)**
Break point 2	2020m7	2020m6		2020m7	2020m7
	0.325***	0.398***		0.159***	0.282***
	(4.551)	(7.222)		(5.551)	(6.529)

For notes and source, see Table 1.

Tables 6 and 7 present the estimation results for PageRank centrality of exports of electrical machinery and transport equipment, respectively. Table 6 indicates the significantly negative coefficients in 2020 for Japan: February 2020 in the AO model and March 2020 in the IO model. This result implies that the relative importance of Japan in the network of electrical machinery exports declined during the pandemic period. Table 7 presents that, for the transport equipment, we confirm significantly negative coefficients in 2020 for Japan and the United States in both AO and IO models. The decline in the centrality of machinery exports for Japan may be due to the decline in the centrality of transport equipment export. This finding is in line with the finding of Ando, Kimura, and Obashi (2021) that found that the negative impacts of the COVID-19 pandemic on exports were larger in the transport equipment industry than in other machinery industries.

4.2. Results for ASEAN countries

Thus far, we found that the decline in the relative importance of major machinery exporting countries in the world machinery trade network. This may be due to the increases in the relative importance of other countries, particularly in ASEAN countries where the machinery trade is active, as mentioned above. This subsection runs the same regressions as those in Section 3, focusing on ASEAN countries. Due to the limited availability of the data (Table 1), we focus on the period between January 2015 and June 2021 for Indonesia (IDN), Myanmar (MMR), Malaysia (MYS), Singapore (SGP), and Viet Nam

(VNM).[12] To save space, we present the results of PageRank centrality. The results for exports are presented in the Appendix.

Table 6

Break Points of the Centrality of Electrical Machinery Exports: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m12	2017m4	Not	2018m9	2018m2
	0.136***	0.050**	available	0.007	0.044
	(7.346)	(2.227)		(0.496)	(1.671)
Break point 2	2021m7	2020m10		**2020m2**	2018m10
	-0.098***	0.044***		**-0.040*****	-0.004
	(-3.562)	(4.056)		**(-3.075)**	(-0.193)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2020m1	2019m11	Not	2018m10	2017m11
	0.113***	0.015	available	0.009	0.069
	(4.895)	(1.554)		(0.890)	(1.120)
Break point 2	2021m7	Not		**2020m3**	2018m11
	-0.093***	detected		**-0.041*****	0.039
	(-3.447)			**(-3.686)**	(1.592)

For notes and source, see Table 2.

Table 7

Break Points of the Centrality of Transport Equipment Exports: Major Machinery Export Countries

[12] In the monthly-level Comtrade Database, the data for June 2019 is not available for the Philippines and October 2019 is not available for Thailand (See Table 1).

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2018m12	2018m10	Not	2019m9	**2020m1**
	-0.128***	0.018	available	0.059*	**-0.066***
	(-3.333)	(0.992)		(1.861)	**(-1.778)**
Break point 2	2019m12	2019m10		**2020m6**	2020m6
	0.081**	0.016		**-0.143*** **	0.106**
	(2.165)	(0.924)		**(-4.231)**	(2.739)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2018m11	2018m11	Not	2019m10	2020m6
	-0.121***	0.044**	available	0.089**	0.144**
	(-3.232)	(2.333)		(2.491)	(2.516)
Break point 2	2020m1	2019m11		**2020m5**	**2020m10**
	0.101***	0.029*		**-0.167*** **	**-0.122***
	(2.934)	(1.922)		**(-3.733)**	**(-1.986)**

For notes and source, see Table 2.

Tables 8 and 9 present the estimation results for machinery exports and PageRank centrality, respectively, for ASEAN countries. In Table 8, Indonesia presents both negative and positive coefficients in 2020. This result is similar to the results of Germany, Japan, and the United States in Table 2. Malaysia, Singapore, and Viet Nam indicate positive coefficients in 2020, which is similar to the results of China and Hong Kong in Table 2. Myanmar does not indicate any significant break points. Overall, these results indicate that the results of ASEAN countries are similar to those of major exporting countries.

Table 8

Break Points of the Machinery Exports: ASEAN Countries

AO model					
	IDN	MMR	MYS	SGP	VNM
Break point 1	**2020m1**	2016m6	2017m5	2016m12	2017m5
	-0.084* **	-0.449**	0.104***	0.051***	0.162***
	(-3.371)	(-2.143)	(7.125)	(4.606)	(7.722)
Break point 2	2020m7	2017m2	2020m3	2020m7	2020m3
	0.148***	0.401***	0.041***	0.067***	0.106***
	(5.089)	(2.878)	(2.751)	(6.021)	(4.937)
IO model					
	IDN	MMR	MYS	SGP	VNM
Break point 1	**2020m2**	2017m3	2017m6	2020m4	2020m4
	-0.204* **	0.350***	0.060**	0.038***	0.079***
	(-5.862)	(3.285)	(2.341)	(3.747)	(3.376)
Break point 2	2020m7	2020m3	2020m4		
	0.309***	-0.126	0.063***		
	(6.362)	(-1.249)	(4.493)		

For notes and source, see Table 2.

Table 9

Break Points of the Centrality of Machinery Exports: ASEAN Countries

AO model					
	IDN	MMR	MYS	SGP	VNM
Break point 1	2019m1	2017m12	2017m11	2016m7	2017m4
	-0.006	-0.018**	-0.096***	-0.033	-0.064**
	(-0.391)	(-2.628)	(-6.098)	(-0.703)	(-2.465)
Break point 2	**2020m4**	2019m6	**2020m7**	**2020m2**	2018m3
	-0.050 **	0.010	**-0.048** **	**-0.080** **	0.060***
	(-2.787)	(1.434)	**(-2.390)**	**(-2.531)**	(2.691)
IO model					
	IDN	MMR	MYS	SGP	VNM
Break point 1	2019m2	2018m1	2017m12	2016m8	2017m5
	-0.018	-0.033***	-0.140***	-0.027	-0.092***
	(-1.374)	(-3.714)	(-3.004)	(-0.838)	(-3.575)
Break point 2	**2020m5**	2019m7	**2020m6**	**2020m3**	2018m4
	-0.042 **	0.021***	**-0.060** **	**-0.093*** **	0.097***
	(-2.501)	(3.285)	**(-2.424)**	**(-3.898)**	(4.231)

For notes and source, see Table 2.

In Table 9, we find significantly negative coefficients for Indonesia (April 2020 in the AO model and May 2020 in the IO model), Malaysia (July 2020 in the AO and June 2020 in the IO model) and Singapore (February 2020 in the AO model and March 2020 in the IO model). This result implies that the decline in the relative importance of these three ASEAN countries. These results are similar to the results of Japan in Table 3. These results have two important implications. First, the decline in the relative importance of Japan in the world machinery trade network is not attributed to the increases in the relative importance of these ASEAN countries. Second, the decline in the relative importance of Japan might be due to the close relationship with these ASEAN countries, because PageRank centrality reflects not only the importance of Japan but also that of her export partner countries. To investigate this issue, we conducted the same structural break analysis, replacing the log of the value of exports to the log of the number of destination countries.

Tables 10 and 11 present the estimated break points for the number of destination countries for major machinery export countries and ASEAN countries, respectively. We highlight two findings. First, Table 10 indicates significantly negative coefficients in 2020 for Hong Kong (November 2020 in the IO model) and the United States (January 2020 in the AO model). This implies that the number of destination countries declined for Hong Kong and the United States after the pandemic outbreak. Second, Japan did not indicate significantly negative coefficients in both AO and IO models. Finally, Table 11 presents significantly negative coefficients for four out of five countries (Indonesia, Myanmar, Malaysia, and Singapore). This suggests that the number of destination countries also decreased for these ASEAN countries after the pandemic outbreak.

Table 10

Break Points of the Number of Machinery Export Destination Countries: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m11	2017m9	2017m7	2018m2	2017m11
	-0.008**	-0.013**	-0.011	0.000	0.004
	(-2.386)	(-2.517)	(-0.239)	(0.068)	(0.919)
Break point 2	2020m4	2018m6	2018m5	2019m11	**2020m1**
	0.003	0.024***	-0.009	-0.008**	**-0.011*** **
	(0.965)	(6.225)	(-0.281)	(-2.477)	**(-3.594)**
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m12	2017m10	2018m6	2019m12	2018m7
	-0.015***	-0.016***	0.005	-0.011***	0.015***
	(-3.581)	(-2.821)	(1.263)	(-3.184)	(3.165)
Break point 2	2020m5	2018m6	**2020m11**	2021m5	2019m2
	0.004	0.027***	**-0.008** **	-0.003	-0.020***
	(1.036)	(4.911)	**(-2.184)**	(-0.747)	(-4.071)

For notes and source, see Table 2.

Table 11

Break Points of the Number of Machinery Export Destination Countries: ASEAN Countries

AO model					
	IDN	MMR	MYS	SGP	VNM
Break point 1	2018m4	2017m2	**2020m2**	2017m12	2016m10
	0.035***	0.406***	**-0.083*** **	0.029***	0.013***
	(4.217)	(6.238)	**(-5.653)**	(5.392)	(3.066)
Break point 2	**2020m3**	2019m10	2020m7	**2020m2**	2021m1
	-0.049* **	-0.172***	0.078***	**-0.013** **	0.009*
	(-5.091)	(-3.048)	(4.608)	**(-2.186)**	(1.693)
IO model					
	IDN	MMR	MYS	SGP	VNM
Break point 1	2018m2	2016m8	2019m12	2016m6	2016m11
	0.058***	0.225**	-0.099***	0.039***	0.015***
	(4.741)	(2.617)	(-5.434)	(3.630)	(2.916)
Break point 2	**2020m2**	**2020m12**	2020m6	2017m11	2021m2
	-0.078* **	**-0.167* **	0.092***	0.018***	0.014**
	(-5.701)	**(-1.963)**	(4.727)	(3.124)	(2.288)

For notes and source, see Table 2.

As we discussed earlier, PageRank centrality (equation (3)) increases when 1) the number of country i's partners increases; 2) country i's trade increases; and 3) PageRank for country i's partner.

Table 1 indicates that the negative shock of the pandemic on the machinery export of Japan is temporal. Table 10 presents no significant negative effects of the pandemic on the number of machinery export destination countries in 2020. These results together suggest that the decline in the Japan's centrality is not caused by the decline export values or the number of her destination countries. Rather, it is attributable to the decline in the centrality of Japan's export destination countries such as ASEAN countries. Indeed, Table 11 confirms the decline in the PageRank of the ASEAN countries in 2020. Noting that Japan has a relatively strong trade relationship with ASEAN countries, these results together suggest that the negative shock of the pandemic spread through the supply chain, which lead to the decline in the relative importance of some countries such as Japan in the world machinery trade network.

In sum, the world machinery trade network was basically resilient against the pandemic outbreak. However, this is not applicable to all countries. Some countries were negatively affected by the pandemic and their relative importance declined. While only indicative, our results suggest the transmission of negative shocks through the supply chain during the pandemic period. This finding is important because, when we focus on the overall trade, Kiyota (2022) did not find negative structural change in 2020. Our results thus suggest the importance of detailed disaggregated level analysis.

5. Concluding Remarks

In light of the importance of machinery trade in the world trade, this paper examines whether or not the patterns of machinery trade changed significantly after the COVID-19 pandemic outbreak. To do so, we employ the framework of the network analysis in order to identify the relative importance of each country in the world machinery trade and the framework of the structural break to statistically detect the structural change in machinery trade and the centrality.

We utilized the monthly-level bilateral export data from January 2016 to March 2022. Our main findings are threefold. First, we find positive structural change in exports in the major machinery exporting countries. Second, we find negative structural change in the centrality in Japan and some ASEAN countries, which implies the decline in the relative importance of these countries in the world machinery network. Third, the decline in the Japanese centrality is not caused by the decline in export values or number of destination countries. Rather, it is attributable to the decline in the centrality of Japan's export destination countries such as ASEAN countries. Noting that Japan has a relatively strong trade relationship with ASEAN countries, these results together suggest that the negative shock of the pandemic spread through the supply chain, which lead to the decline in the relative importance of some countries such as Japan in the world machinery trade network.

In sum the world machinery trade network was basically resilient against the pandemic outbreak. However, this is not applicable to all countries. Some countries were negatively affected by the pandemic and their relative importance declined. While only indicative, our results suggest the transmission of negative shocks through the supply chain during the pandemic period. This finding is important because, when we focus on the overall trade, Kiyota (2022) did not find negative structural change in 2020. Our results thus suggest the importance of detailed disaggregated level analysis. In this context, it is also interesting to examine the difference between the exports of intermediate goods and those of consumption goods. This issue will be explored in the next stage of our research.

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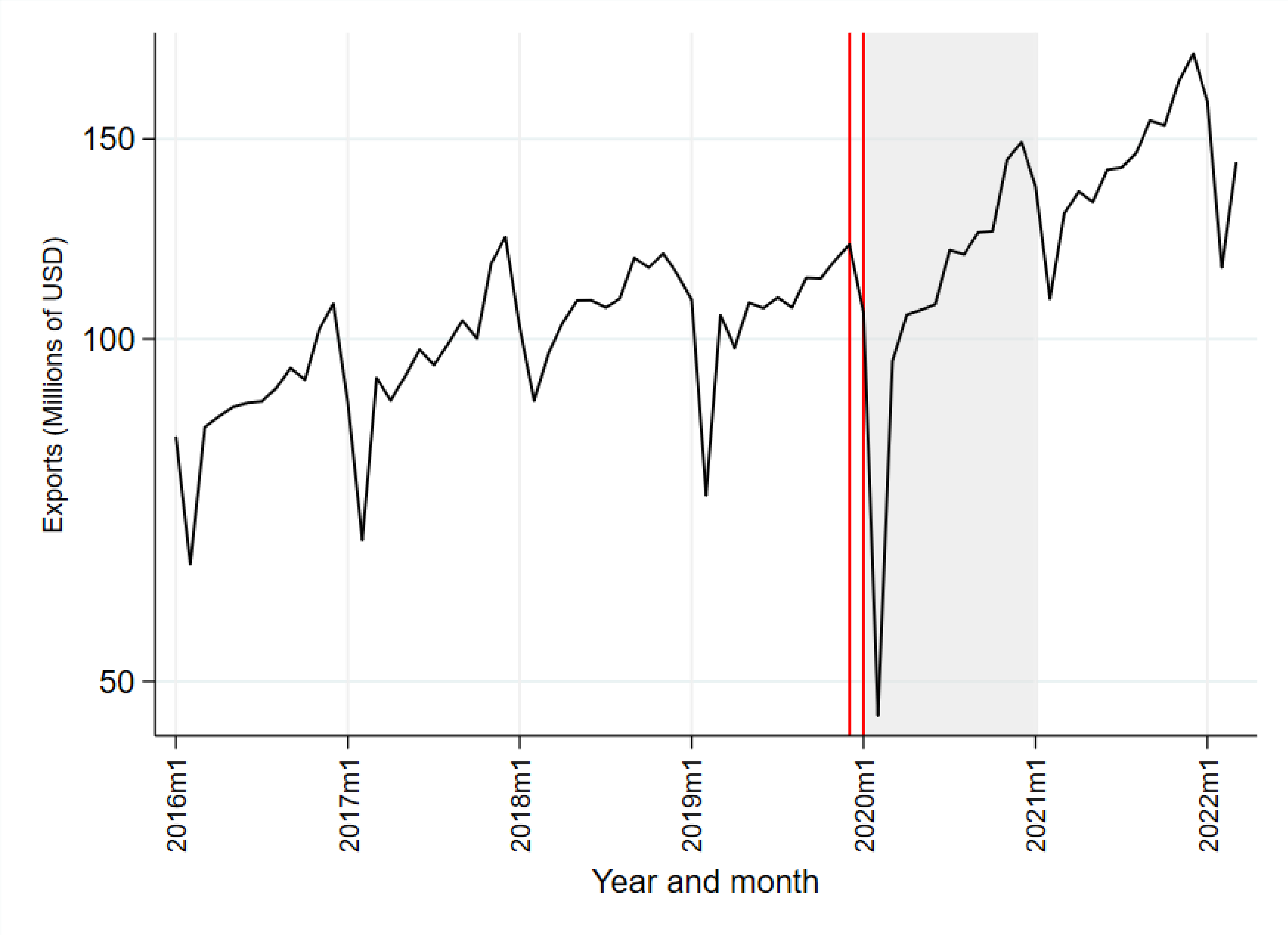
Appendix

Figure A1

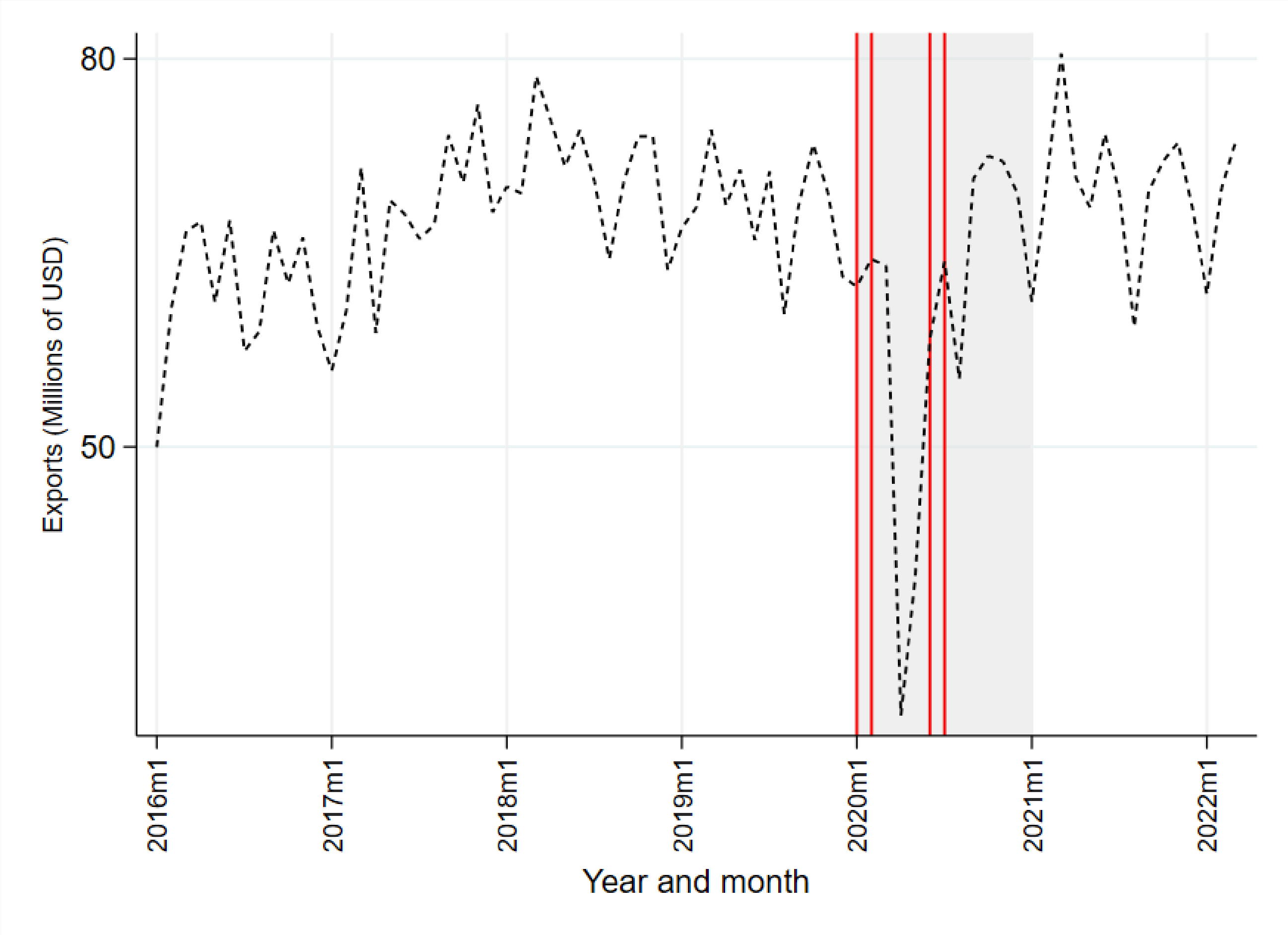
Machinery Exports and Estimated Break Points: China



Note: Chinese export data are not available from October 2012 to December 2015 in the UN Comtrade Database. The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points.
Source: UN Comtrade Database.

Figure A2

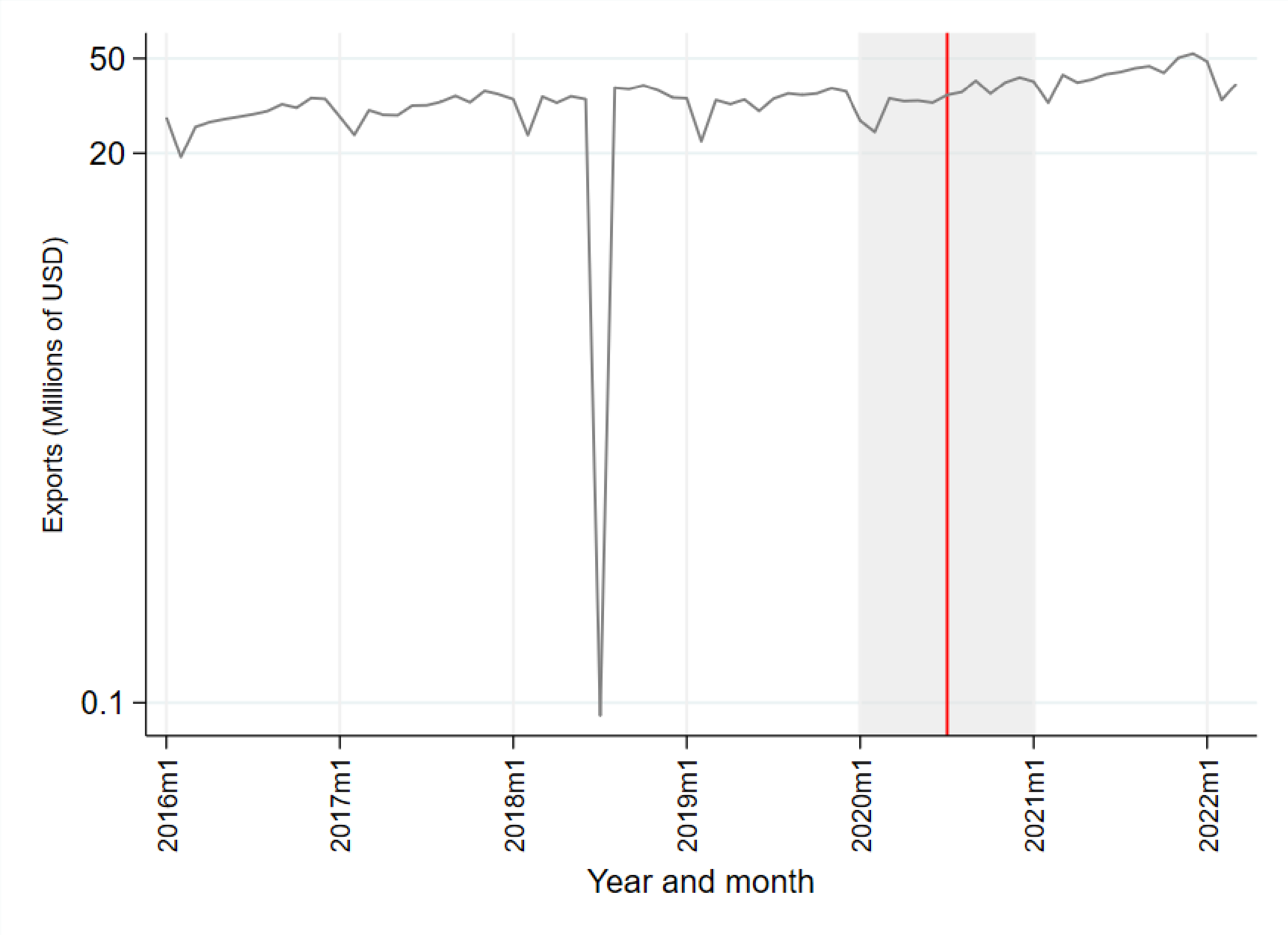
Machinery Exports and Estimated Break Points: Germany



Note: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points. Source: UN Comtrade Database.

Figure A3

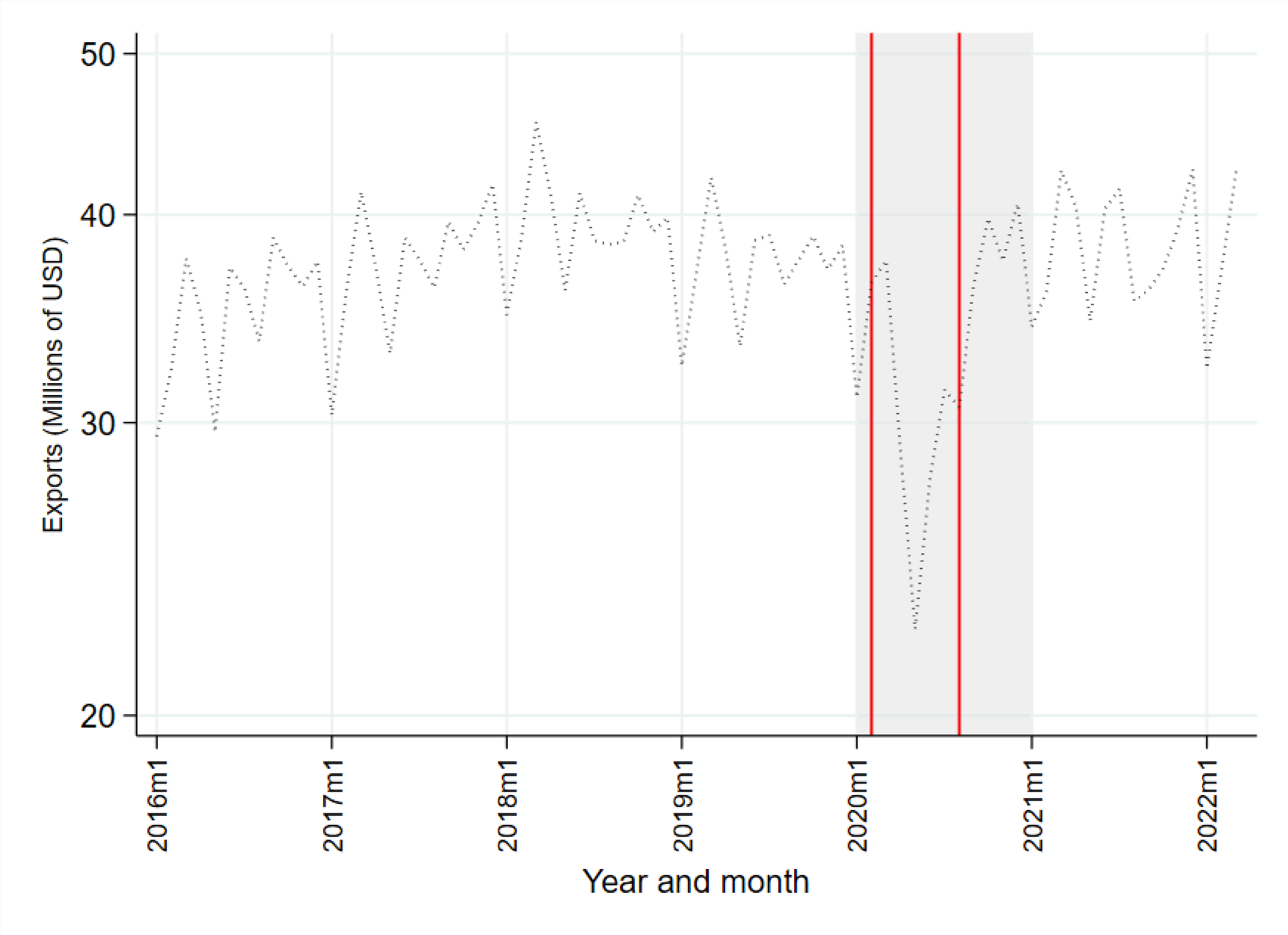
Machinery Exports and Estimated Break Points: Hong Kong



Note: The exports of many machinery products including electrical machinery and transport equipment are missing in July 2018 in the UN Comtrade Database. The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points.
Source: UN Comtrade Database.

Figure A4

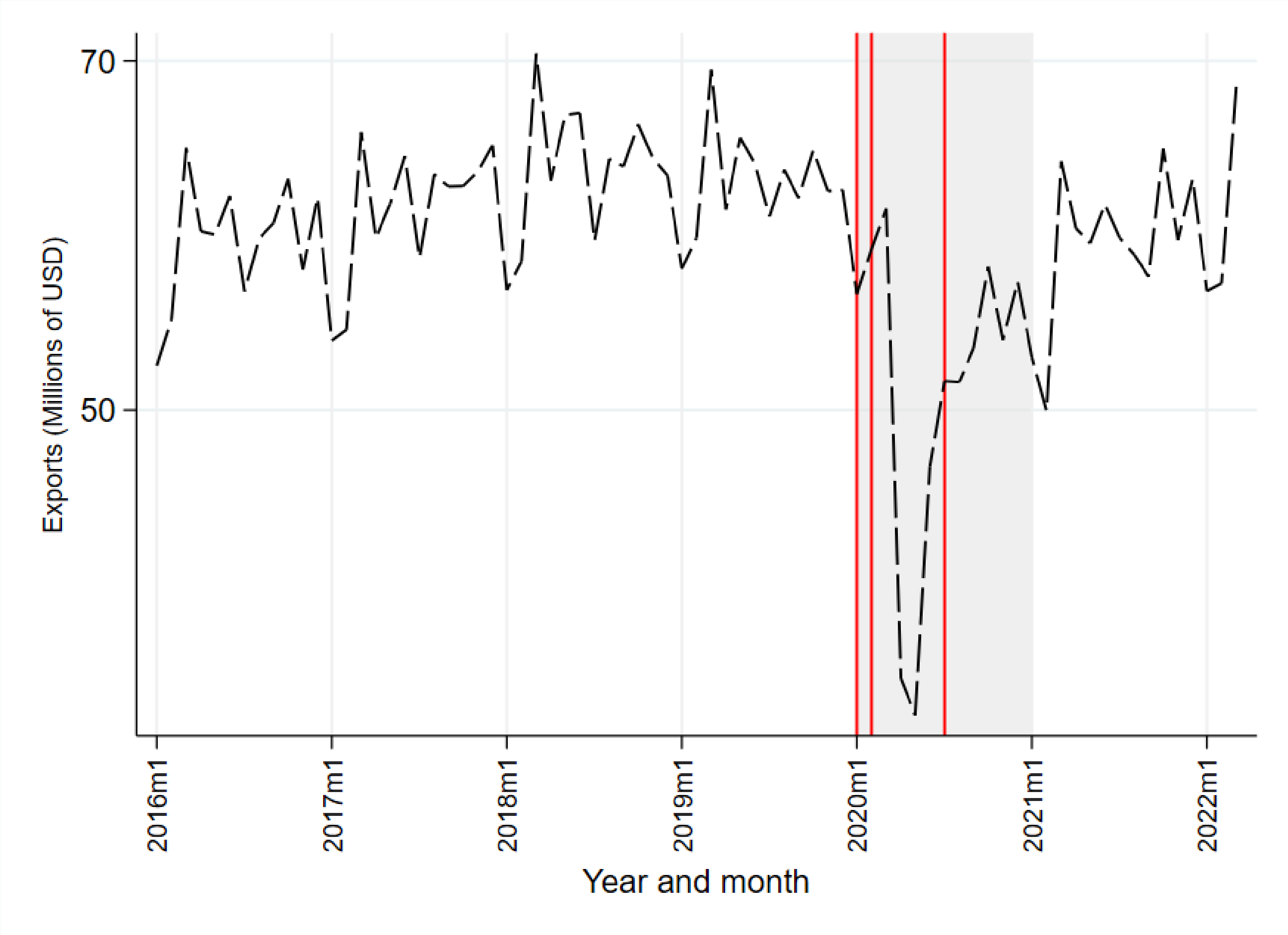
Machinery Exports and Estimated Break Points: Japan



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points. Source: UN Comtrade Database.

Figure A5

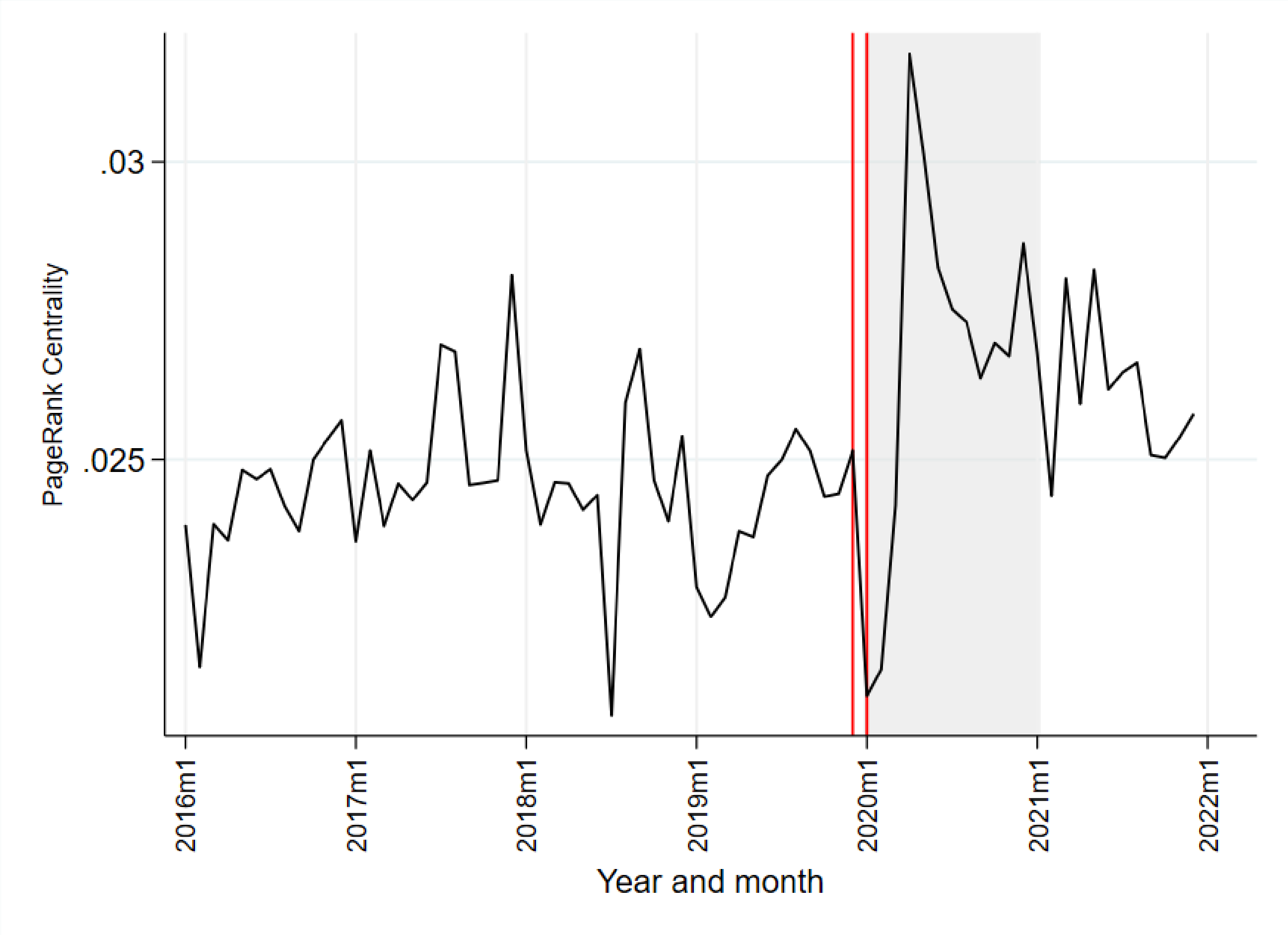
Machinery Exports and Estimated Break Points: United States



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points. Source: UN Comtrade Database.

Figure A6

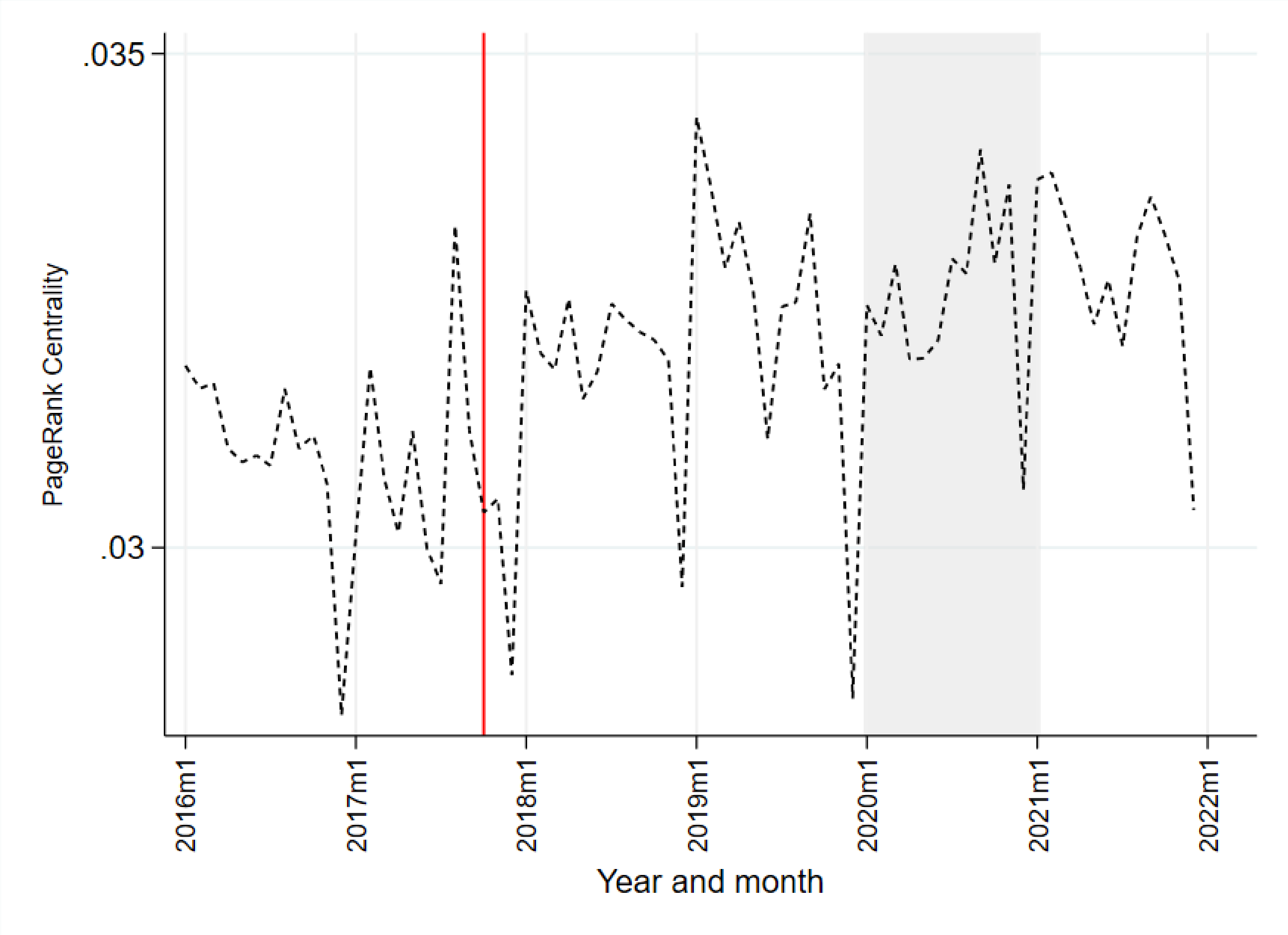
PageRank Centrality and Estimated Break Points: China



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points. Source: UN Comtrade Database.

Figure A7

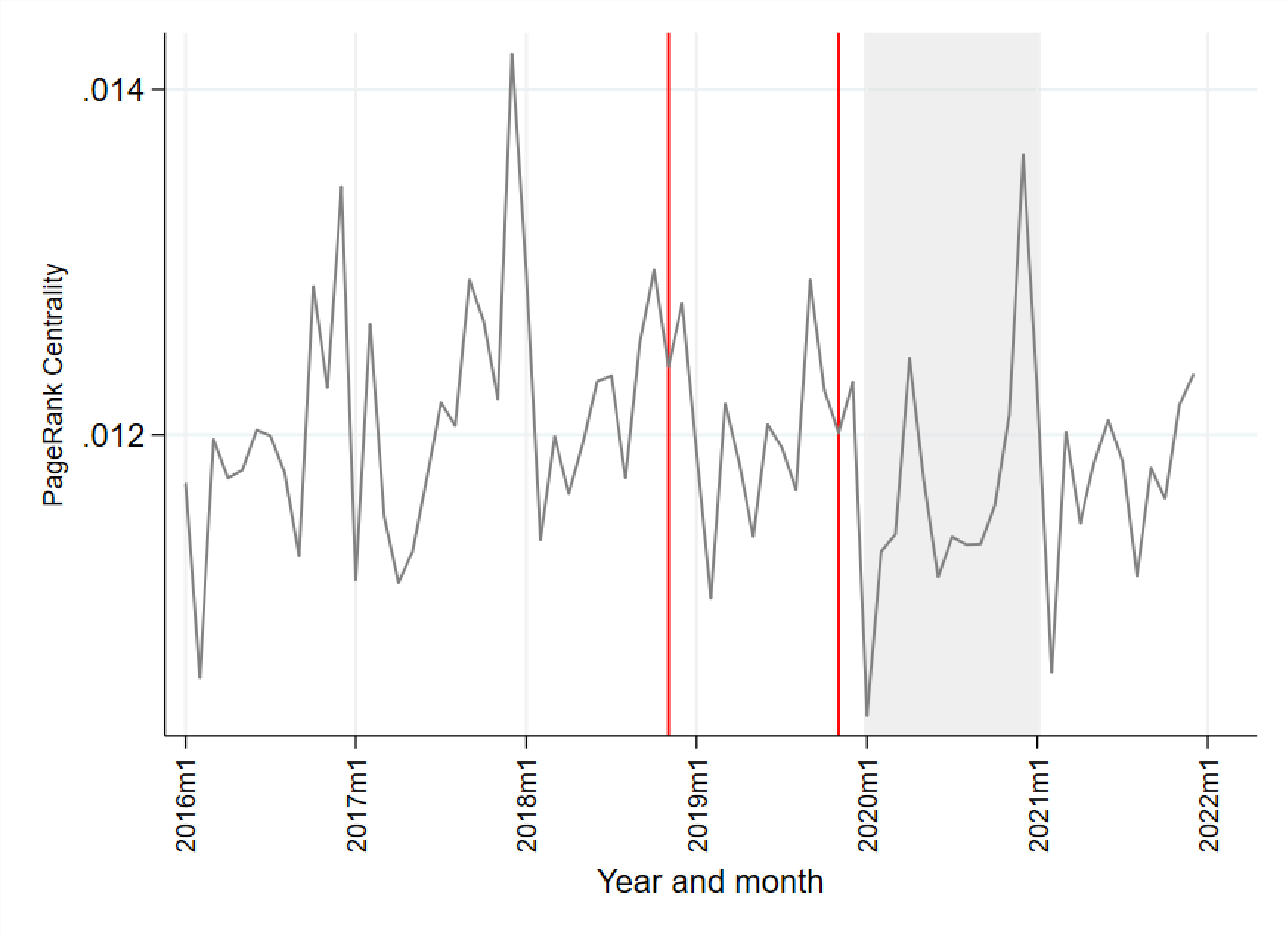
PageRank Centrality and Estimated Break Points: Germany



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points. Source: UN Comtrade Database.

Figure A8

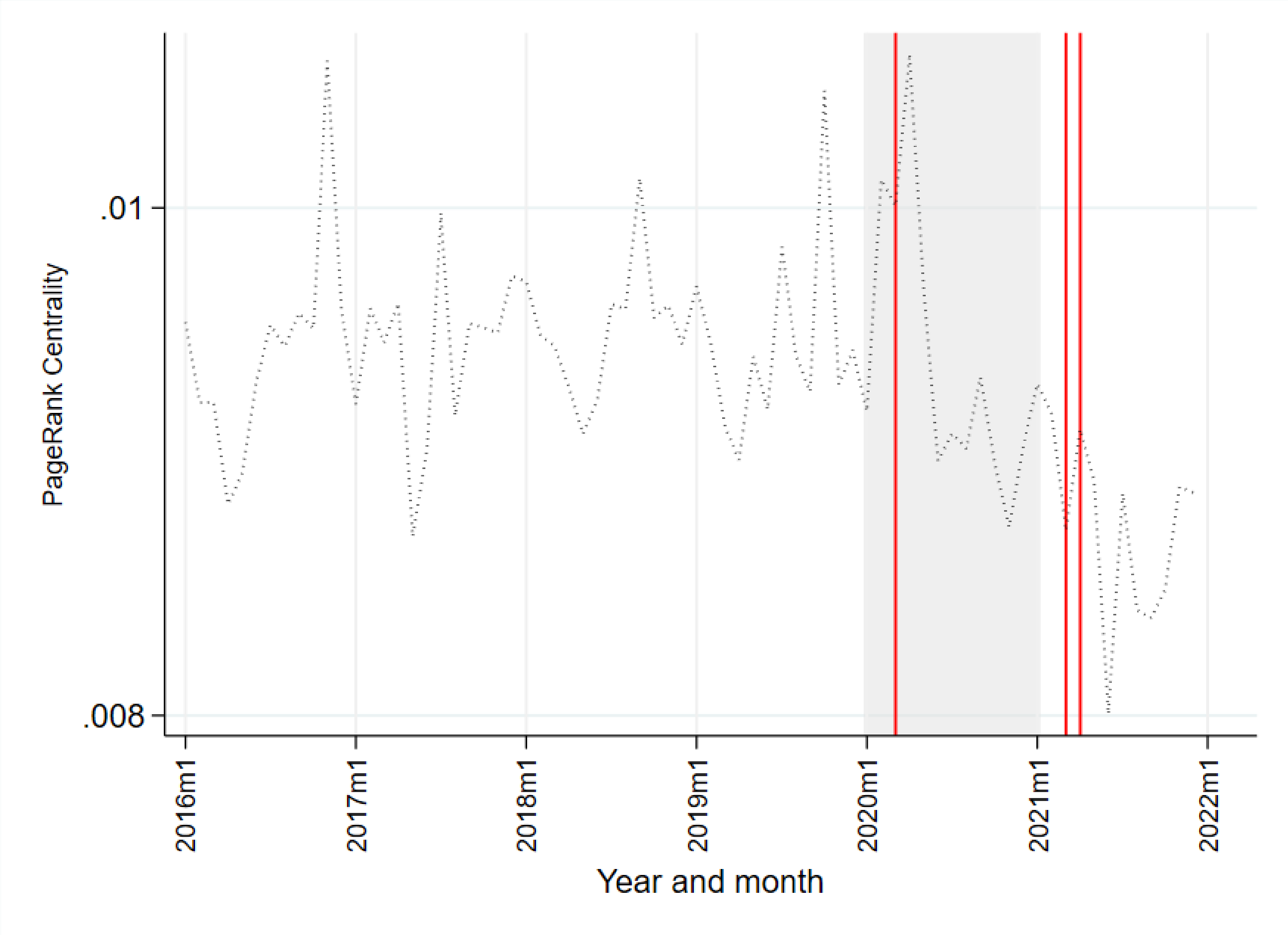
PageRank Centrality and Estimated Break Points: Hong Kong



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points.
Source: UN Comtrade Database.

Figure A9

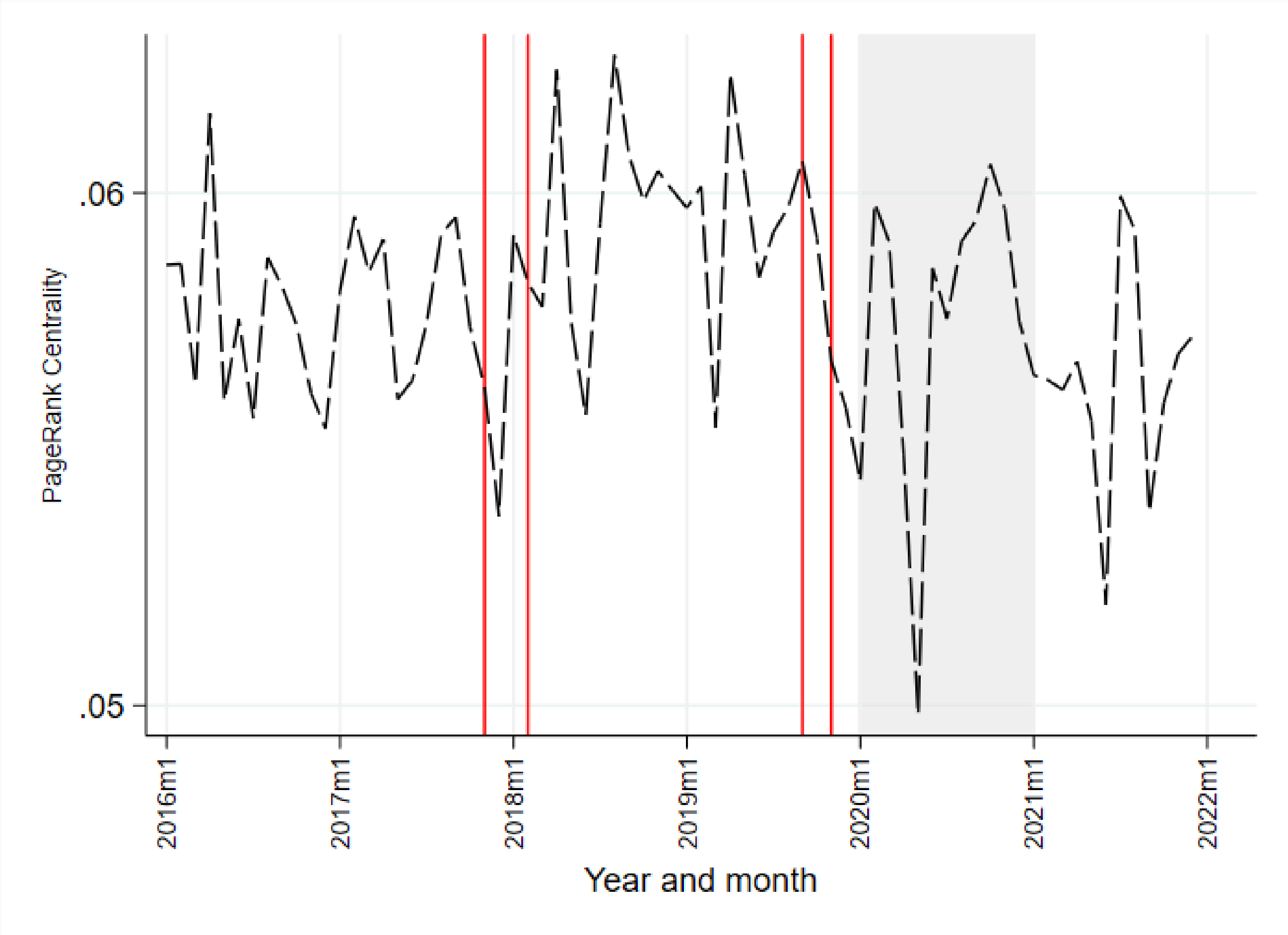
PageRank Centrality and Estimated Break Points: Japan



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points.
Source: UN Comtrade Database.

Figure A10

PageRank Centrality and Estimated Break Points: United States



Notes: The gray shaded area indicates the year 2020. The red lines indicate the estimated breakpoints by AO or IO model. We did not distinguish them because sometimes both AO and IO models estimated the same break points. Source: UN Comtrade Database.

Table A1

Break Points of Machinery Imports: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2018m12	**2020m1**	2020m8	2019m11	**2020m1**
	-0.014	**-0.077*** **	0.065***	-0.039***	**-0.085*** **
	(-0.860)	**(-4.882)**	(3.209)	(-3.082)	**(-5.462)**
Break point 2	2020m8	2020m7	2021m4	2020m9	2020m7
	0.104***	0.113***	0.050**	0.070***	0.122***
	(6.163)	(6.766)	(2.031)	(5.005)	(7.427)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m1	2020m2	2020m7	2019m12	2019m12
	-0.054***	-0.157***	0.084***	-0.074***	-0.065***
	(-3.010)	(-6.938)	(3.456)	(-4.982)	(-4.212)
Break point 2	2020m7	2020m7	2021m4	2020m8	2020m4
	0.117***	0.199***	0.073	0.103***	0.085***
	(4.730)	(7.417)	(1.416)	(5.919)	(5.235)

For notes and source, see Table 2.

Table A2

Break Points of the Centrality of Machinery Imports: Major Machinery Export Countries

AO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2019m12	2019m7	2018m3	2019m2	**2020m2**
	0.084***	-0.051***	0.098***	-0.049***	**-0.107*** **
	(4.900)	(-6.368)	(3.826)	(-3.389)	**(-9.364)**
Break point 2	2021m8	2021m8	2018m11	2020m2	2021m10
	0.077***	-0.060***	0.004	-0.017	-0.051**
	(2.863)	(-4.768)	(0.197)	(-1.175)	(-2.468)
IO model					
	CHN	DEU	HKG	JPN	USA
Break point 1	2020m1	2019m4	2018m2	2018m7	**2020m3**
	0.080***	-0.041***	0.110**	-0.044***	**-0.094*** **
	(4.830)	(-4.239)	(2.660)	(-2.915)	**(-5.968)**
Break point 2	2021m5	2021m6	2018m12	**2020m3**	2021m7
	0.072***	-0.053***	-0.005	**-0.050*** **	-0.026*
	(3.222)	(-3.951)	(-0.148)	**(-3.327)**	(-1.762)

For notes and source, see Table 2.