

The COVID-19 Pandemic and the World Trade Network

Kozo Kiyota^{abc}

^a Keio Economic Observatory, Keio University, 2-15-45, Mita, Minato-ku, Tokyo 108-8345, Japan; E-mail: kiyota@sanken.keio.ac.jp

^b Research Institute of Economy, Trade and Industry (RIETI), Japan

^c Tokyo Center for Economic Research (TCER), Japan

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Kozo Kiyota[†]

Keio University, RIETI, and TCER

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Abstract

Global trade suffered a significant contraction in 2020 as a result of the COVID-19 pandemic, and its growth is expected to remain below the pre-pandemic trend. Did the relative importance of countries in the world trade network change as a result of the pandemic? The answer to this question is particularly important for the Association of Southeast Asian Nations (ASEAN) countries because of their relative importance in world trade as well as their strong trade linkages with China, where the COVID-19 virus originated. This paper examines how the world trade network has changed since the COVID-19 pandemic, with a particular focus on ASEAN countries. Tracking the changes in centrality from January 2000 to March 2021, we find no evidence for most ASEAN and major trading countries that centrality changed significantly after the pandemic began. Our results suggest the resilience of the trade pattern for these countries.

Key words: International trade, COVID-19 pandemic, network, centrality, resilience

JEL classification codes: F14, F40

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[†]Keio Economic Observatory, Keio University, 2-15-45, Mita, Minato-ku, Tokyo 108-8345, Japan; Research Institute of Economy, Trade and Industry, 1-3-1, Kasumigaseki, Chiyoda-ku, Tokyo 100-8901, Japan; Tokyo Center for Economic Research, 1-7-10-703, Iidabashi, Chiyoda-ku, Tokyo 102-0072, Japan; E-mail: kiyota@sanken.keio.ac.jp

1 Introduction

The COVID-19 pandemic has had significant negative impacts on the global economy. According to the International Monetary Fund (IMF) (2021b), global output growth was -3.2% in 2020, whereas global trade in goods and services suffered a much larger contraction of -8.3% due to weaker demand. Although merchandise trade volumes have returned to pre-pandemic levels, the World Trade Organization (WTO) (2021) projected that the growth of trade would likely slow, remaining below the pre-pandemic trend.

Such negative impacts on trade could vary between countries. Therefore, the question arises: did the relative importance of countries in the world trade network change as a consequence of the pandemic? The answer to this question is particularly important for Association of Southeast Asian Nations (ASEAN) countries for two reasons. First, they have strong trade linkages with China, where the COVID-19 virus originated. Second, ASEAN countries are well embedded in global value chains and possess one of the largest shares in global trade. In 2018, ASEAN had a 7.2% share in global trade in goods, ranked fourth after the European Union, China, and the United States (The ASEAN Secretariat, 2019). However, answering this question is not straightforward because of the complexity of the world trade network, as well as the heterogeneous impacts of the pandemic across countries.

Given this context, this study asks how the world trade network has changed since the COVID-19 pandemic, with a particular focus on the ASEAN countries. This paper contributes to two strands of literature. The first strand is the literature on the impacts of COVID-19 on international trade. Hayakawa and Mukunoki (2021b) investigated the effects of COVID-19 on international trade by comparing January–August 2019 with the same period for 2020 and confirmed the significant negative effects. Hayakawa and Mukunoki (2021a) extended Hayakawa and Mukunoki (2021b), focusing on finished machinery trade in the first six months of 2019 and 2020. They found that export of finished machinery products significantly decreased when the COVID-19 burden was more severe in countries exporting finished machinery products or supplying machinery inputs. Hayakawa and Mukunoki (2021c) examined the effects of lockdown policies on international trade in the first six months of 2019 and 2020 and found that workplace closures had significant negative effects on trade. Zhang (2021) focused on the exports of Japanese foreign affiliates and found that their exports to Japan and other countries significantly declined during the first three quarters of 2020.¹

¹In this connection, based on a series of survival analyses, Obashi (2021) found that trade

The second strand of literature to which this paper contributes involves the studies on the network structure of international trade. A number of studies have analyzed the international trade network using network analysis.² For example, De Benedictis and Tajoli (2011) examined the changes in the network of international trade between 113 countries from 1960 to 2000. They found that the centrality of the network changed from European countries to the United States over the period.

Both strands of literature have made significant contributions to economic understanding. However, the network structure of trade is beyond the scope of the first strand of research, and, within the second strand, to the best of our knowledge, only Vidya and Prabheesh (2020) have examined changes in the trade network after the COVID-19 pandemic. Furthermore, although they found changes in centrality measures after the pandemic, their study involved a simple descriptive analysis, and no statistical tests were provided. In addition, as they focused on the top 15 global trading countries,³ most of the ASEAN countries were excluded from their study. Thus, changes in the relative importance of the ASEAN countries in the world trade network remain unclear.

This paper attempts to fill this gap in the two strands of literature. That is, we extend the network analysis to ASEAN countries and employ formal statistical analysis to evaluate the significance of the changes in the international trade network after the COVID-19 pandemic. There are three advantages to employing a network analysis. First, the data requirement for the analysis is relatively low. Information on bilateral trade only is required for the analysis, which means that it is easy to implement and replicate. Second, trade data are suitable for examining the current economic situation because they are available on a monthly basis. Our sample period is between January 2000 and March 2021. Noting that the abovementioned related studies did not cover the year 2021, our study presents the latest update of the analysis on international trade in the literature. Finally, network analysis enables us to provide a superior visual representation of the results. It involves visualizing the network of countries based on graph theory, which is helpful in capturing the relative importance of each country in a reasonably simple manner.

To measure the relative importance of the ASEAN countries in the world trade network, we compute each country's centrality using the bilateral trade

relationships in the East Asian region were resilient even in the midst of the COVID-19 shocks.

²Several studies, such as Smith and White (1992) and Garlaschelli and Loffredo (2004), have applied network analysis to international trade data, but they did not provide an economic basis for their analyses.

³The top 15 global trading countries are Canada, China, France, Hong Kong, India, Indonesia, Italy, Japan, Germany, the Netherlands, Russia, Singapore, South Korea, the United Kingdom, and the United States.

data between January 2000 and March 2021. Then, we investigate whether the centrality changed significantly after the pandemic, employing the econometric framework of structural breaks. We find statistically significant breakpoints in the changes in centrality before 2020 for most ASEAN countries. The result suggests that the trade shock after the pandemic is temporary rather than perpetual.

The paper is organized as follows. The next section explains the methodology and data used in this study. Section 3 presents the estimation results. Section 4 checks the robustness of the results, and Section 5 presents extensions of our analysis. Section 6 provides our conclusions.

2 Methodology and Data

2.1 Methodology

2.1.1 Centrality

As noted above, this study employs network analysis. In this framework, each country is represented as a node, while the trade relationship between countries is represented as a link. Thus, the world trade network is represented by nodes and links, which make up a graph. The relative importance of each node is represented by centrality measures. Measures of centrality include closeness centrality, which is based on the distance between nodes, and degree centrality, which is based on the number of links. However, because countries generally trade with many countries simultaneously, these centrality measures are not necessarily useful for analysis of the world trade network.

Several studies, including Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi (2012) and Carvalho (2014), proposed theoretical models in which the influence of individual firms or sectors on aggregate outcomes is determined by their eigenvector centrality, which is also called Bonacich centrality.⁴ However, eigenvector centrality is not applicable to directed graphs; therefore, it is not applicable to analyzing the world 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,

⁴Behrens, Lamorgese, Ottaviano, and Tabuchi (2007) theoretically investigated the relationship between eigenvector centrality and international trade.

PageRank centrality considers not only the number of edges that a node has but also the number of edges that other directly connected nodes have. Indeed, as Kiyota (2021a) showed, PageRank centrality includes an index of forward linkages in input–output analysis as a special case. Second, unlike eigenvector centrality, this centrality is applicable to a directed graph. This is another desirable property for the analysis of trade.

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

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

where

$$a_{ij} = \begin{cases} 1 & \text{if there is a link from node } i \text{ to node } j; \\ 0 & \text{otherwise,} \end{cases} \quad (2)$$

where a link is measured by trade (e.g., country j imports from country i).

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

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

where ψ and χ are positive constants and k_{jt} is the outdegree, which is measured by the number of export destination countries of country j . In computing PageRank centrality, we use the share of imports of country i from country j to total imports of country i as a weight.⁵ Thus, equation (3) 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) the PageRank for country i 's partners 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 one. We examine how this centrality measure changes after the COVID-19 pandemic to check the relative importance of ASEAN countries within the world trade network.

⁵Note that it is difficult to use the share of exports as a weight because PageRank is computed by summing over all the import partner countries (j). If, for example, the import of country i from country j is zero, $a_{ij} = 0$. Therefore, export share from country j to country i will not be reflected for the PageRank calculation. In turn, this means that the sum of the weights will not be equal to one.

2.1.2 Structural break

Our main research question is whether the relative importance of the countries in the world trade network changed as a result of the pandemic. Note that such changes occur over the analysis period due to, for example, each country's economic growth. Thus, we investigate whether countries experienced statistically significant changes in their centrality paths by employing a structural change framework.⁶ Examples of the structural breaks in trade are trade liberalization (Ben-David and Papell, 1997) and the 1970s oil shocks (Abu-Bader and Abu-Qarn, 2010). We employ the approach developed by Zivot and Andrews (1992) and extended by Perron and Vogelsang (1992), which is summarized in our context as follows.

We denote an outcome variable of country i as y_t (suppressing the country subscript i). Although our main outcome variable is PageRank centrality, we also utilize trade as an outcome variable in the preliminary analysis to check the impacts on trade. Consider that the time series of outcome y_t experiences one structural break during the sample period. There are two types of models that can capture the structural break: an additive outlier (AO) model that captures a sudden change, and an innovative outlier (IO) model that captures a gradual shift in the mean of the series.

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

$$y_t = \mu + \delta DU_t + \tilde{y}_t, \quad (4)$$

where

$$DU_t = \begin{cases} 1 & \text{if } t > T_b; \\ 0 & \text{otherwise,} \end{cases} \quad (5)$$

where T_b is the time of the unknown breakpoint 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:

$$\tilde{y}_t = \sum_{\tau=1}^d \omega_{\tau} DT_{b,t-\tau} + \alpha \tilde{y}_{t-1} + \sum_{\tau=1}^d \theta_{\tau} \Delta \tilde{y}_{t-\tau} + \varepsilon_t, \quad (6)$$

where

$$DT_{bt} = \begin{cases} 1 & \text{if } t = T_b + 1; \\ 0 & \text{otherwise.} \end{cases} \quad (7)$$

⁶A recent study by Constantinescu, Mattoo, and Ruta (2020) employed a similar structural change framework to examine global trade patterns over the past four decades.

The lag order d is unknown. The second regression is estimated over feasible values of T_b 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, whereas d is determined by a set of sequential F -tests.⁷ Note that there is no intercept because the mean of $\tilde{y}_t$ is zero. The significance level of this minimal t -statistic is investigated based on the critical values provided by Perron and Vogelsang (1992).

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

$$y_t = \mu + \delta DU_t + \phi DT_{bt} + \alpha y_t + \sum_{\tau=1}^d \theta_{\tau} \Delta y_{t-\tau} + \varepsilon_t. \quad (8)$$

As in the AO model, the regression equation is estimated over feasible values of T_b 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, whereas d is determined by a set of sequential F -tests. Note that it is necessary to choose some trimming value because the test is not defined at the limits of the sample period (Clemente, Montañés, and Reyes, 1998). To adopt the largest window possible, we drop the first and the last observations, which is equivalent to setting the trimming value at 0.5% for the beginning and the end of the sample period.

2.1.3 Hypothesis

Equation (3) indicates that the centrality is affected by 1) changes in the number of countries, 2) changes in trade, and 3) changes in linkages (through the changes in other centrality). The pandemic could potentially affect all of these factors. For example, the demand and/or supply shocks from the pandemic could change the number of partner countries and/or volume of trade.⁸ Even though the ASEAN countries successfully weathered the shocks, their centrality would change if the relative importance of other countries changed.

As mentioned above, it is not easy to predict how the trade network has changed since the pandemic began because of the complexity of the world trade network, as well as the heterogeneous impacts of the pandemic across countries. Nevertheless, several studies such as Obashi (2010) and Ando and

⁷We set the maximum lag number as 12 to reduce the computational burden and to account for seasonality

⁸Bacchetta, Bekkers, Piermartini, Rubinova, Stolzenburg, and Xu (2021) argued that the COVID-19 pandemic could contribute to the diversification of sources of supply, which in turn would affect both the number of partner countries and the volume of trade.

Kimura (2012) have argued that the production networks in East Asia are stable and resilient against demand/supply shocks, such as the global financial crisis and the Great East Japan Earthquake. Thus, we hypothesize that the relative importance (measured by PageRank centrality) of the ASEAN countries in the world trade network did not change following the COVID-19 pandemic. In turn, this would mean that δ is significant before the pandemic started (i.e., before 2020).

2.2 Data and descriptive analysis

In measuring the trade network, we use the monthly bilateral trade data from the IMF's *Direction of Trade Statistics* for the period from January 2000 to March 2021 for 204 countries.⁹ That is, a_{ij} in the adjacency matrix is measured by the imports of country i from country j . Imports are measured by their cost, insurance, and freight prices. The imports do not cover services trade. For each country, the total number of observations is 255 (= 12 months $\times$ 21 years + 3 months). While our main focus is the 10 ASEAN countries (i.e., Brunei Darussalam, Cambodia, Indonesia, the Lao People's Democratic Republic (PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam), we also compute PageRank centrality for four major trading countries (i.e., China, Germany, Japan, and the United States) for reference.

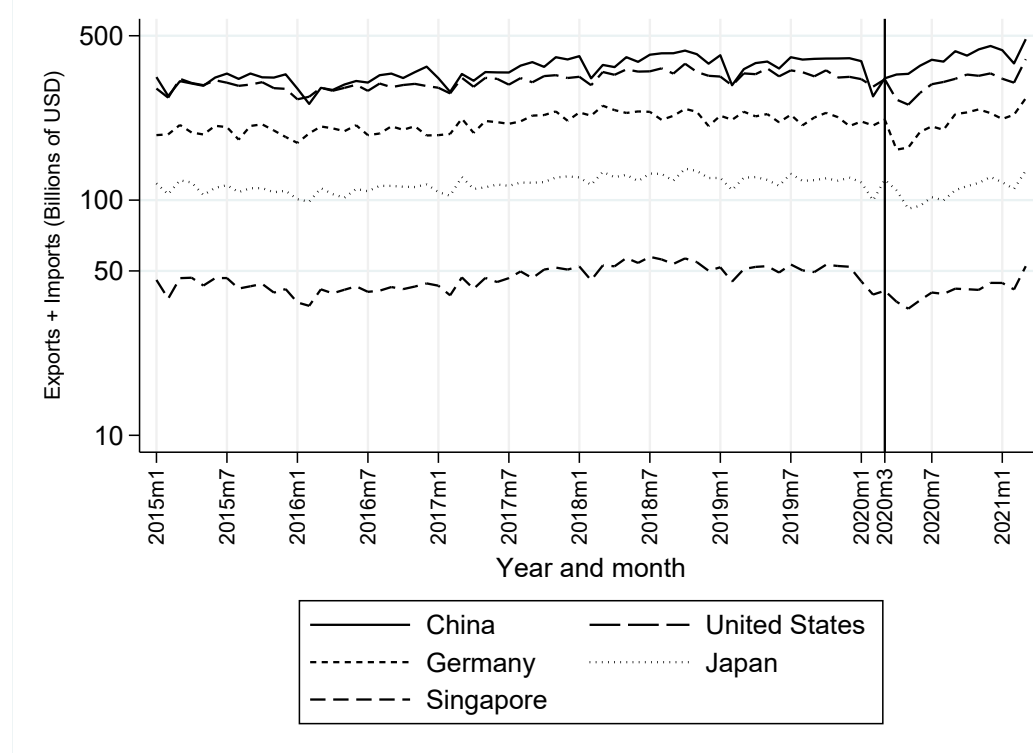
Figure 1 presents the changes in the overall trade for four major trading countries (i.e., China, Germany, Japan, and the United States) and one of the major trading ASEAN countries, Singapore, from January 2015 to March 2021.¹⁰ The overall trade is defined as the sum of exports to and imports from the world. We highlight two findings in this figure. First, overall trade dropped when the COVID-19 pandemic commenced (around March 2020), but it increased again around June 2020. Second, compared with the four major trading countries, the overall trade of Singapore, as our representative ASEAN country, is rather small even though ASEAN as a whole possesses one of the largest shares in the global economy. This implies that it would be difficult to determine the pattern of trade by comparing the ASEAN countries in this manner with the four major trading countries given the differences in the scale of trade. In what follows, we present the figures for ASEAN countries separately.

Figure 2 presents the changes in the overall trade for ASEAN countries for

⁹Taiwan is not included in the *Direction of Trade Statistics*.

¹⁰These four major trading countries have been ranked in the top four countries in PageRank centrality in the world trade network since 2001 (Kiyota, 2021b). We focus on the period from January 2015 to highlight the pandemic period. Figure A1 presents the results for full sample period (i.e., from January 2000 to March 2021).

Figure 1: Trade Patterns for Major Trading Countries, January 2015 to March 2021

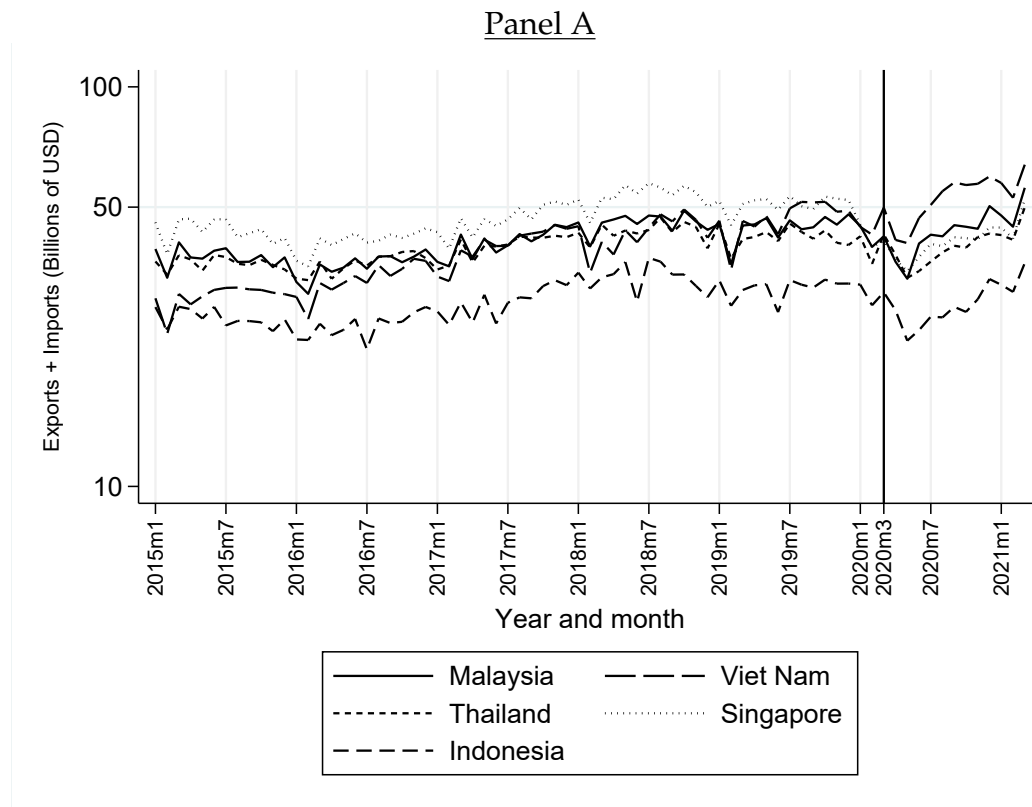


Note: The vertical axis indicates the value of overall trade (exports + imports) in log terms. The solid line indicates March 2020, when the COVID-19 pandemic commenced in many countries.

Source: IMF (2021a).

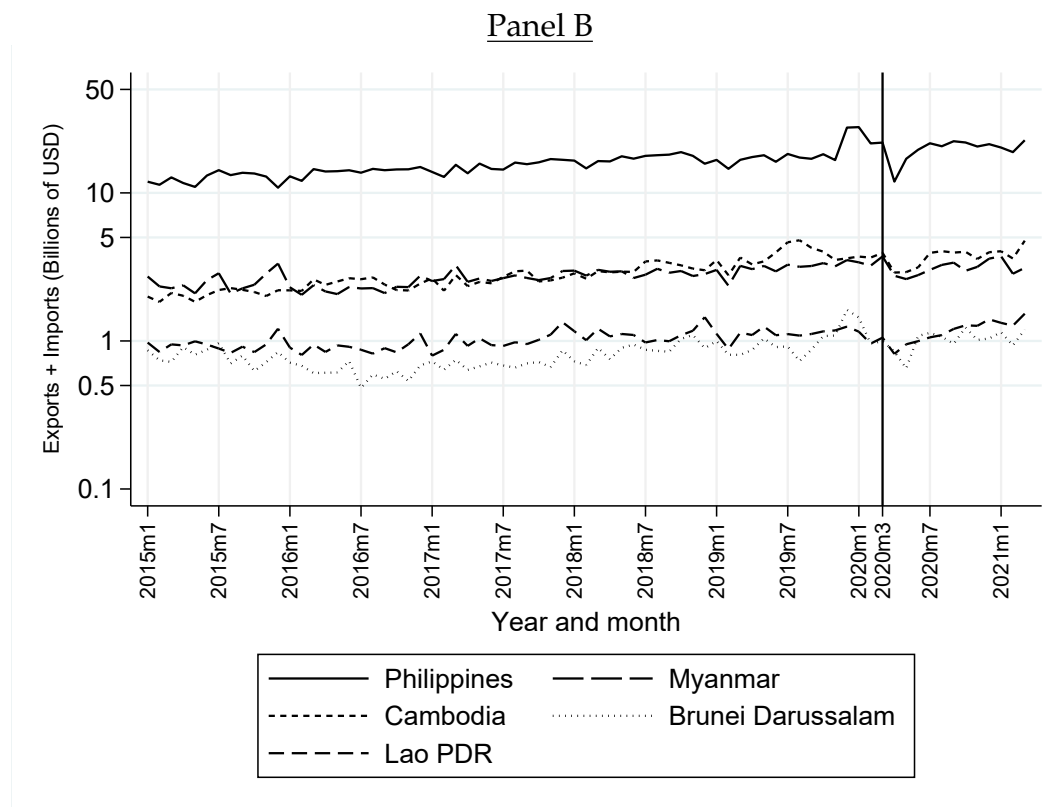
January 2015 to March 2021.¹¹ For ease of exposition, we divide the 10 ASEAN countries into two groups based on the scale of trade.¹² Panel A indicates the overall trade for Indonesia, Malaysia, Singapore, Thailand, and Viet Nam, while Panel B presents the overall trade for Brunei Darussalam, Cambodia, the Lao PDR, Myanmar, and the Philippines. Similar to Figure 1, we find increases in trade value after the sharp drop when the pandemic started for all ASEAN countries. It is interesting to note that the overall trade for Myanmar has large values in September–October 2014. Although this is due to increases in exports to China, we could not identify the specific reason for this, and, thus, we must be cautious in interpreting the changes in trade patterns for Myanmar during this period.

Figure 2: Trade Patterns for ASEAN Countries, January 2015 to March 2021



¹¹Figure A2 presents the results for the full sample period (i.e., from January 2000 to March 2021).

¹²As the vertical axis indicates, the scale of trade differs between the four major trading countries and the ASEAN countries, and between the ASEAN countries in Panels A and B.



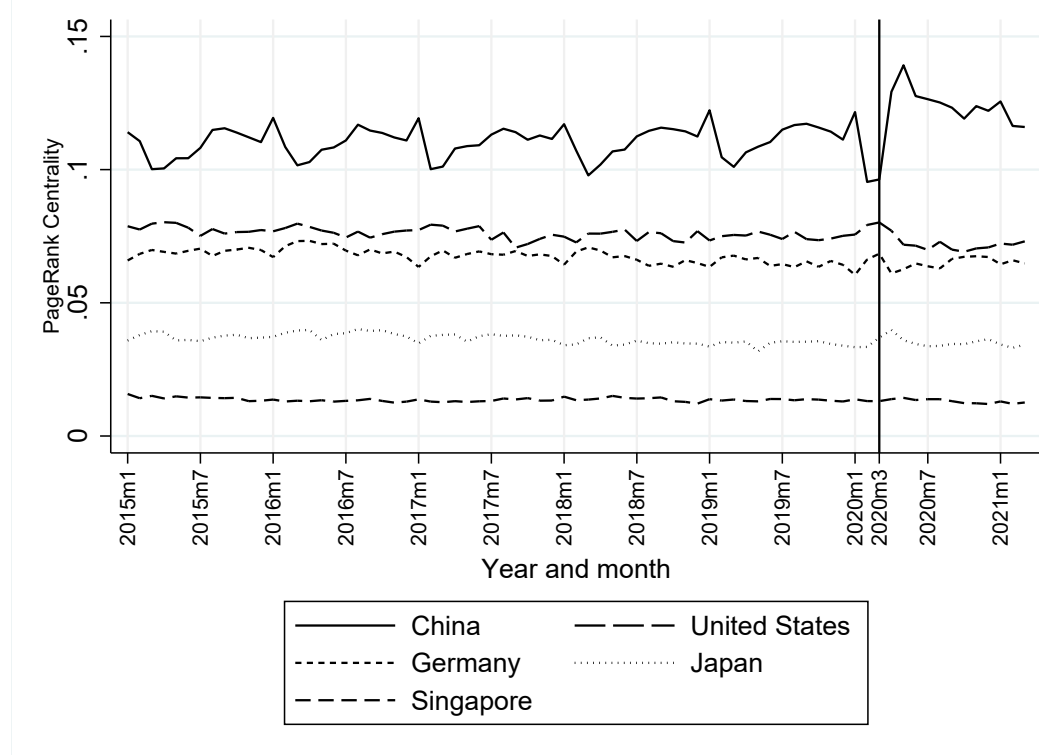
Note: The vertical axis indicates the value of overall trade (exports + imports) in log terms. The solid line indicates March 2020, when the COVID-19 pandemic commenced in many countries.

Source: IMF (2021a).

Figure 3 presents PageRank centrality for the four major countries and Singapore between January 2015 and March 2021.¹³ This figure indicates that the changes in PageRank centrality differ across countries after the start of the pandemic. For China and Germany, PageRank centrality dropped around the time that the pandemic began but increased around June 2020. By contrast, for Japan and the United States, PageRank centrality dropped and did not increase after the start of the pandemic. For Singapore, it is difficult to determine the change because the value is small compared with the four major countries. Thus, we report the results for the ASEAN countries separately from the four major trading partners as follows.

¹³Figure A3 presents the results for the full sample period (i.e., from January 2000 to March 2021).

Figure 3: PageRank Centrality for Major Trading Countries, January 2015 to March 2021



Note: The vertical axis indicates PageRank centrality. The solid line indicates March 2020, when the COVID-19 pandemic commenced in many countries.

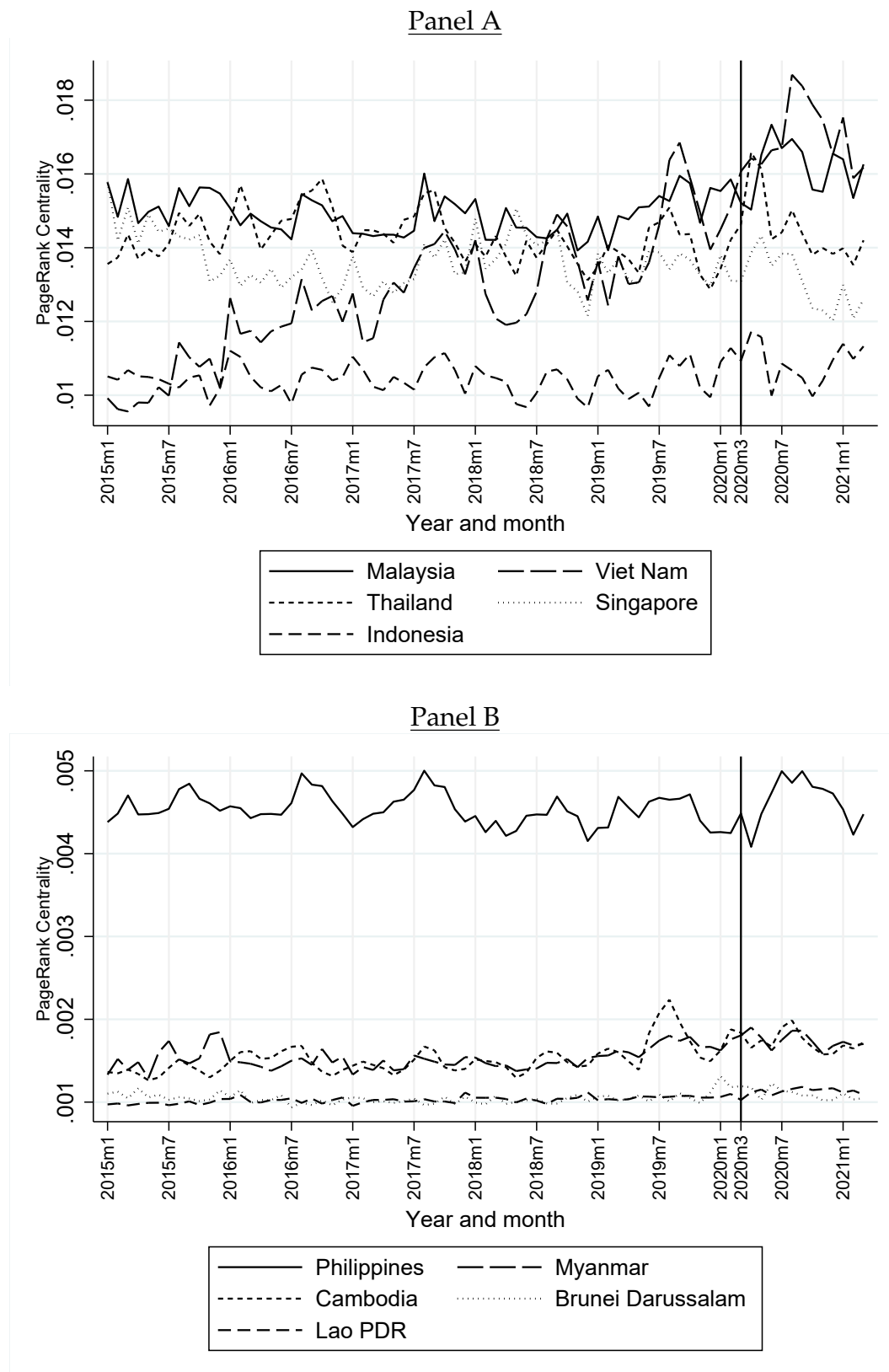
Source: Author's estimation based on IMF (2021a).

Figure 4 presents PageRank centrality for the ASEAN countries for January 2015 to March 2021.¹⁴ Similar to overall trade, we divide the 10 ASEAN countries into two groups based on the scale of centrality for ease of exposition.¹⁵ Panel A indicates the PageRank centrality for Indonesia, Malaysia, Singapore, Thailand, and Viet Nam, while Panel B presents the PageRank centrality for Brunei Darussalam, Cambodia, the Lao PDR, Myanmar, and the Philippines. Figure 4 also indicates that the changes in PageRank centrality differ and do not present any common patterns between ASEAN countries. This result implies that it is not necessarily clear whether the relative importance of ASEAN countries in the world trade network changed after the pandemic. To address this issue further, the next section employs regression analyses. For Myanmar, it is important to note that PageRank centrality exhibits extremely high values for September–October 2014, which should be treated with caution.

¹⁴Figure A4 presents the results for full sample period (i.e., from January 2000 to March 2021).

¹⁵As was the case for the size of trade, PageRank centrality differs between the four major trading countries and the ASEAN countries, and between ASEAN countries in Panels A and B.

Figure 4: PageRank Centrality for ASEAN Countries, January 2015 to March 2021



Note: The vertical axis indicates PageRank centrality. The solid line indicates March 2020, when the COVID-19 pandemic commenced in many countries.

Source: Author's estimation based on IMF (2021a).

3 Estimation Results

3.1 Structural break in trade

Before analyzing centrality, we determine whether a structural break in trade is observed after the pandemic. We estimate equations (4) and (6) for the AO model and equation (8) for the IO model using aggregate bilateral trade (exports + imports) as an outcome variable.¹⁶ This enables us to investigate whether the structural break in the centrality coincides with the changes in the aggregate trade volume.

Table 1 presents the results for the AO model. We highlight two findings. First, a structural break is confirmed in all countries, as indicated by the significant coefficients. Moreover, all the coefficients are positive. These results imply that the ASEAN countries experienced a positive structural change in trade in the sample period. Second, the breakpoint varies across countries, ranging from December 2004 (Singapore) to October 2015 (the Philippines). All the breakpoints are located before 2020. This result implies that the trade shock from the pandemic is not necessarily regarded as a point of structural change.

Table 1: Estimation Results: Additive Outlier Model for Trade					
	BRN	KHM	IDN	LAO	MYS
Break point	2005m4	2012m4	2006m12	2008m10	2005m12
y_{t-1}	0.312*** [19.339]	0.680*** [27.614]	0.432*** [32.031]	0.771*** [30.840]	0.310*** [27.760]
	MMR	PHL	SGP	THA	VNM
Break point	2010m12	2015m10	2004m12	2006m12	2010m12
y_{t-1}	0.583*** [32.004]	0.242*** [16.694]	0.347*** [29.254]	0.389*** [30.025]	0.729*** [26.351]

Note: Countries are represented by their International Organization for Standardization (ISO) codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated month and year when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Table 2 presents the results for the IO model. There are two notable findings. First, the significantly positive coefficient is estimated for nine of the 10 countries. For Viet Nam, the estimated coefficient is insignificant. This means that the IO model did not identify a structural break for Viet Nam during the sample period. Second, similar to the IO model, the breakpoint is different between

¹⁶The estimation is based on the Stata commands `clemao1` and `clemio1` developed by Baum (2005).

countries, ranging from January 2004 (Singapore) to January 2010 (Myanmar). However, the estimated breakpoints in the IO model are different from those in the AO model. For example, for the Philippines, the estimated breakpoint is October 2015 in the AO model, whereas it is March 2009 in the IO model. The results suggest that the estimated breakpoints could vary between the AO and IO models. Nevertheless, all the breakpoints are located before 2020, suggesting that the trade shock during the pandemic is not regarded as a breakpoint during the period.

Table 2: Estimation Results: Innovative Outlier Model for Trade					
	BRN	KHM	IDN	LAO	MYS
Break point	2005m1	2010m1	2003m11	2005m1	2009m1
y_{t-1}	0.033* [1.822]	0.028*** [3.230]	0.017** [2.135]	0.035*** [2.795]	0.015** [2.448]
	MMR	PHL	SGP	THA	VNM
Break point	2010m1	2009m3	2004m1	2009m1	2009m1
y_{t-1}	0.048** [2.425]	0.015** [2.205]	0.021** [2.438]	0.013* [1.900]	0.008 [0.992]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

These results together suggest that although there was a large decline in overall trade after the pandemic, it is not necessarily regarded as a breakpoint between January 2000 and March 2021. Thus, the shock from the pandemic can be regarded as a temporary one. However, the relative importance of the ASEAN countries in overall trade may still change after the pandemic. The next section addresses this issue.

3.2 Structural break in centrality

3.2.1 Single structural break

Now, we estimate equations (4) and (6) for the AO model and equation (8) for the IO model, using PageRank centrality as an outcome variable. Table 3 presents the results for the AO model. There are four notable findings. First, the structural break is confirmed in all countries, as indicated by the significant coefficients. However, the signs of the coefficients vary across countries. Whereas seven countries have positive signs, Brunei Darussalam, the Philippines, and Singapore have negative signs. The results suggest that the direction

of structural change is different between countries.

Table 3: Estimation Results: Additive Outlier Model for Centrality

	BRN	KHM	IDN	LAO	MYS
Break point	2013m12	2014m9	2008m9	2013m8	2020m2
y_{t-1}	-0.0003*** [-21.147]	0.0006*** [30.815]	0.0005*** [8.496]	0.0002*** [31.727]	0.0014*** [7.926]
	MMR	PHL	SGP	THA	VNM
Break point	2014m7	2007m7	2015m8	2008m2	2015m2
y_{t-1}	0.0005*** [14.665]	-0.0013*** [-24.278]	-0.0016*** [-16.171]	0.0019*** [16.989]	0.0088*** [35.232]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Second, in line with the results for trade in Table 1, the breakpoint varies between countries, ranging from July 2007 (the Philippines) to February 2020 (Malaysia). Among the 10 countries, only Malaysia has a breakpoint in 2020. This result seems to suggest that Malaysia experienced a structural change when the pandemic started. However, note that the shock is positive rather than negative. We will discuss this point again with the results of the IO model.

Third, the estimated breakpoints differ for the trade and centrality results. For example, for Brunei Darussalam (see Table 1), the estimated breakpoint in trade is April 2005, whereas for centrality it is December 2013. Indeed, none of the countries has the same breakpoint for trade and centrality. The results imply that significant changes in the aggregate bilateral trade do not necessarily mean changes in the relative importance of the country.

Finally, it is interesting to note that the estimated breakpoint for Myanmar is July 2014, which is close to the period when the outliers are confirmed (Figure 4). Thus, the estimated structural break for Myanmar may be affected by the existence of outliers.

Table 4 indicates the results for the IO model. For one of the 10 countries, the coefficient is insignificant. Nevertheless, all the signs of the IO model in Table 4 are the same as those of the AO model in Table 3. Moreover, although the estimated breakpoints in the IO model for each country are different from those in the AO model, they are very similar. For example, for Brunei Darussalam, the breakpoints are December 2013 and January 2014 for the AO and IO models, respectively. Similarly, those for Cambodia are September 2014 and October 2014 for the AO and IO models, respectively. These results suggest that, in

contrast to aggregate bilateral trade, for centrality, both the AO and IO models estimate similar breakpoints.

Table 4: Estimation Results: Innovative Outlier Model for Centrality

	BRN	KHM	IDN	LAO	MYS
Break point	2014m1	2014m10	2008m5	2013m4	2019m1
y_{t-1}	-0.0001*** [-3.069]	0.00004** [2.173]	0.0001* [1.747]	0.00001** [2.091]	0.0004*** [3.640]
	MMR	PHL	SGP	THA	VNM
Break point	2014m8	2007m8	2015m7	2008m3	2014m2
y_{t-1}	0.0001*** [3.845]	-0.0002*** [-4.565]	-0.0005*** [-3.240]	0.0001 [1.335]	0.0003** [2.380]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

For Malaysia, in contrast to the AO model results, the IO model estimated that the breakpoint occurred in January 2019. This indicates that the structural break occurred before the pandemic started if it involves a gradual rather than a sudden change. Although we confirmed that a structural break occurred in February 2020 in the AO model, it is sensitive to the choice of model. Thus, it is difficult to assert definitively that a structural change occurred after the pandemic started.

It is interesting to note that the breakpoints are concentrated in 2007–2008 for three countries (Indonesia, the Philippines, and Thailand) and in 2013–2014 for five countries (Brunei Darussalam, Cambodia, the Lao PDR, Myanmar, and Viet Nam). The world economy experienced the global financial crisis around 2008, while Cambodia, the Lao PDR, Myanmar, and Viet Nam enacted zero tariff rates on virtually all imports for ASEAN members between 2008 and 2015 (Okabe and Urata, 2014). The results suggest that significant changes for our 10 countries are more likely to be related to the global financial crisis and trade liberalization than to the pandemic.

As mentioned above, one of the key advantages of network analysis is the ability to present the results visually. However, it is difficult to present meaningful results for the trade network for all ASEAN countries and their partner countries, given that each country trades with many countries. Therefore, we focus on the top 20 partner countries for each ASEAN country and compute their PageRank centrality. Trade between non-ASEAN countries is excluded to focus on trade by ASEAN countries.

Figures 5 and 6 present the trade networks of the ASEAN countries in March 2000, 2010, 2019, and 2020.¹⁷ The visualization is based on the circle layout algorithm. Each country is located on the circle in alphabetical order by International Organization for Standardization (ISO) codes. The location of the countries changes over the period because of changes in the top 20 partner countries. The size of the ISO code and node represent the size of the country's gross domestic product (GDP) and per capita GDP, respectively.¹⁸ Note that the location of nodes and the length of edges do not have any meaning because they depend upon the algorithm employed to depict the figure. The important issue here is which nodes are connected with each other.

Figure 5 indicates that the connection with China increased from March 2000 to March 2010 in many ASEAN countries, including Indonesia, Malaysia, Singapore, and Thailand. Figure 6 indicates that such connections with China became much larger in March 2019. The network graphs in March 2019 and March 2020 are almost identical. This supports our result that there is no significant change in the trade network of the ASEAN countries before or after the pandemic.

3.2.2 Multiple structural breaks

A concern with the analysis in the previous subsection is that both the AO and IO models assume a single structural change during the sample period. However, because the sample covers more than 20 years, there may be more than one structural change in each country. To address this issue, we employ the test developed by Clemente, Montañés, and Reyes (1998) that allows for the estimation of two events within the observed history of a time series. The estimation procedure for the double-break model is almost the same as that for the single-break model. For the AO model, the first-step regression equation is written as:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \tilde{y}_t, \quad (9)$$

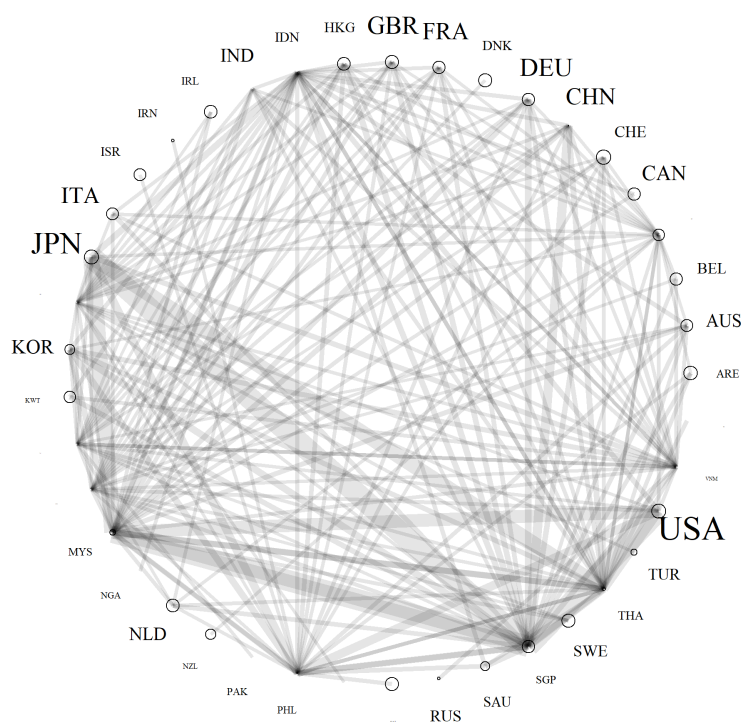
where

$$DU_{mt} = \begin{cases} 1 & \text{if } t > T_{bm}; \\ 0 & \text{otherwise,} \end{cases} \quad (10)$$

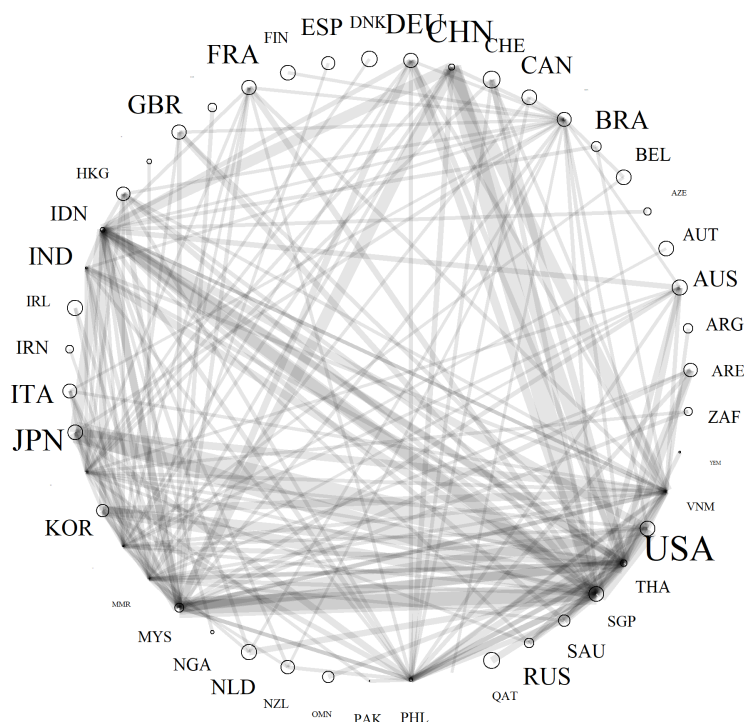
¹⁷We choose March because the latest available month is March (2021). We also present the results for March 2021 in Figure A5 in the Appendix for reference.

¹⁸For the ISO code, see Table A1 in the Appendix. When data for a given year were not available, the data for the latest available year were used.

Figure 5: Trade Network of ASEAN Countries, March 2000 and March 2010
March 2000

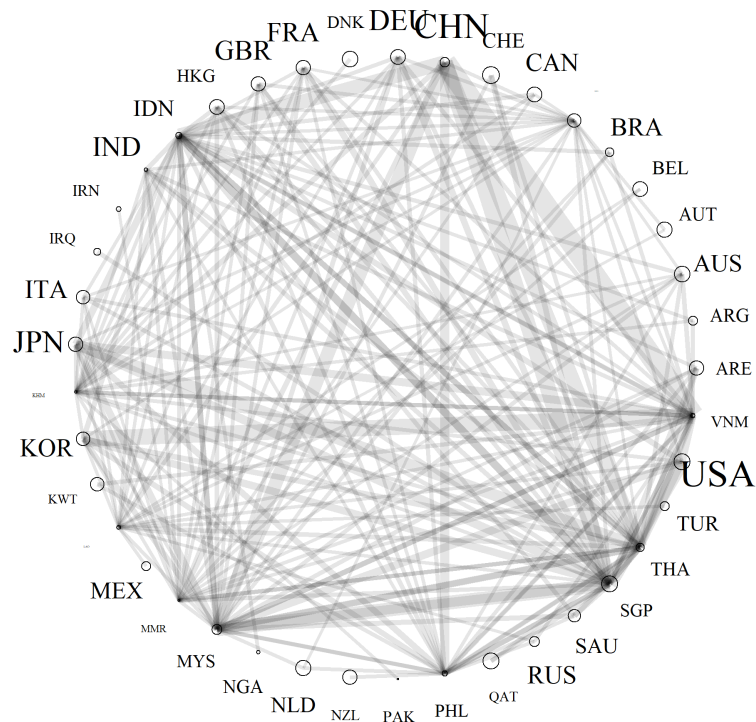


March 2010

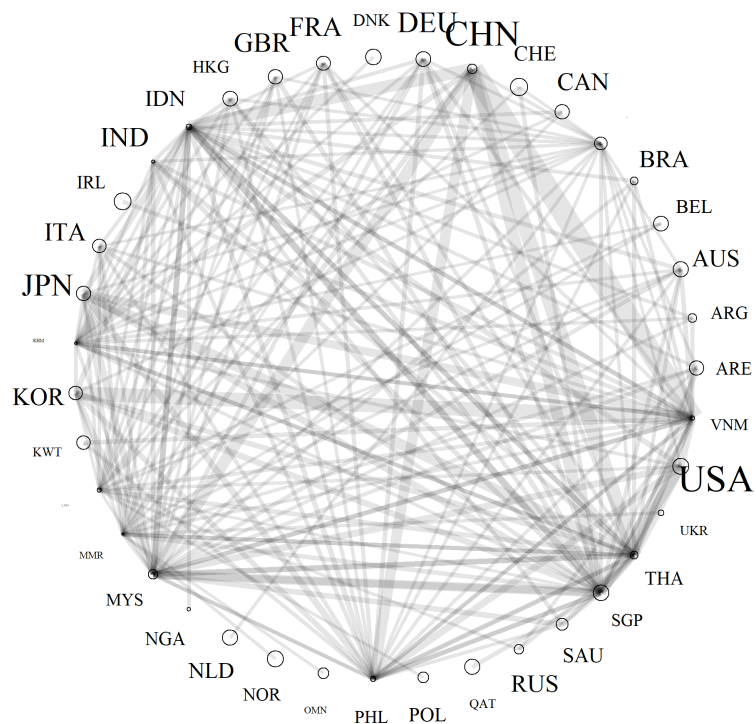


Note: The size of the ISO code and node represent the size of each country's GDP and per capita GDP, respectively. The network is based on three major trading partners. Source: Author's estimation based on IMF (2021a).

Figure 6: Trade Network of ASEAN Countries, March 2019 and March 2020
March 2019



March 2020



Note: The size of the ISO code and node represent the size of each country's GDP and per capita GDP, respectively. The network is based on three major trading partners. Source: Author's estimation based on IMF (2021a).

for $m = 1, 2$. As for the single breakpoint model, T_{b1} and T_{b2} are the breakpoints to be located by grid search. The corresponding second step equation is:

$$\tilde{y}_t = \sum_{\tau=1}^d \omega_{1\tau} DT_{b1,t-\tau} + \sum_{\tau=1}^d \omega_{2\tau} DT_{b2,t-\tau} + \alpha \tilde{y}_{t-1} + \sum_{\tau=1}^d \theta_{\tau} \Delta \tilde{y}_{t-\tau} + \varepsilon_t, \quad (11)$$

where

$$DT_{bm,t} = \begin{cases} 1 & \text{if } t = T_{bm} + 1; \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

for $m = 1, 2$. The second regression is estimated over feasible values of $T_{bm,t}$ and d . For the IO model, the regression equation is written as:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \phi_1 DT_{b1,t} + \phi_2 DT_{b2,t} + \alpha y_{t-1} + \sum_{\tau=1}^d \theta_{\tau} \Delta y_{t-\tau} + \varepsilon_t. \quad (13)$$

The locations of T_{bm} and d are determined by the grid search. As in the baseline single-break analysis, we drop the first and last observations, which is equivalent to setting the trimming value at 0.5% for the beginning and the end of the sample period.

Table 5 presents the estimation results of the AO model with two breaks.¹⁹ There are two notable findings. First, the significance and the signs of the estimated coefficients vary across countries. Second, the breakpoints are different between countries. Moreover, the two breakpoints do not necessarily coincide with the breakpoint estimated by the single-break AO model. Nonetheless, all but one breakpoint is confirmed before 2020. This means that even if we allow for two structural breaks, the trade shock after the pandemic is not identified as a structural breakpoint.

Table 6 presents the results for the IO model. As for the results of the AO model, the signs and significance levels of the estimated coefficients differ between countries, and the breakpoints vary across countries. The estimated breakpoints are not necessarily the same between the single- and double-break models. Here, all the estimated breakpoints are located prior to 2020. In short, the estimated breakpoints are sensitive to the choice of the models and the number of possible breaks. However, we cannot find evidence to support changes in the relative importance of the ASEAN countries in world trade after the pandemic. Thus, our main messages continue to hold even when the analysis takes into account the existence of two structural breaks.

¹⁹The estimation is based on the Stata commands `clemao2` and `clemio2` developed by Baum (2005).

Table 5: Estimation Results for Two Structural Breaks: Additive Outlier Model for Centrality

	BRN	KHM	IDN	LAO	MYS
Break point 1	2004m9	2014m9	2009m9	2013m8	2012m2
y_{t-1}	0.0001*** [3.620]	0.0005*** [27.173]	0.0009*** [10.970]	0.0002*** [32.191]	-0.0002** [-2.493]
Break point 2	2013m12	2019m3	2012m10	2020m1	2019m10
y_{t-1}	-0.0003*** [-21.367]	0.0003*** [10.582]	-0.0006*** [-6.878]	0.0001*** [10.025]	0.0014*** [8.453]
	MMR	PHL	SGP	THA	VNM
Break point 1	2013m11	2008m5	2005m10	2006m4	2014m10
y_{t-1}	0.0004*** [4.392]	-0.0016*** [-31.292]	0.0001 [0.538]	0.0015*** [15.310]	0.0078*** [33.802]
Break point 2	2014m7	2014m10	2015m8	2015m4	2019m10
y_{t-1}	0.0001 [1.436]	0.0004*** [8.044]	-0.0016*** [-15.217]	0.0014*** [13.423]	0.0040*** [9.413]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Table 6: Estimation Results for Two Structural Breaks: Innovative Outlier Model for Centrality

	BRN	KHM	IDN	LAO	MYS
Break point 1	2013m4	2014m5	2009m10	2013m4	2010m7
y_{t-1}	-0.0001*** [-3.024]	0.0001*** [3.654]	0.0003*** [3.130]	0.00002*** [2.703]	-0.0001 [-1.188]
Break point 2	2014m7	2019m4	2012m1	2018m7	2019m1
y_{t-1}	0.0000 [-1.038]	0.0001*** [2.791]	-0.0003*** [-2.879]	0.00001** [1.996]	0.0005*** [4.015]
	MMR	PHL	SGP	THA	VNM
Break point 1	2014m1	2007m8	2012m12	2006m5	2011m4
y_{t-1}	0.0003*** [5.553]	-0.0003*** [-5.777]	-0.0003** [-2.206]	0.0003*** [2.705]	0.0003*** [2.840]
Break point 2	2014m8	2014m3	2015m9	2014m10	2014m11
y_{t-1}	-0.0001 [-1.590]	0.0001*** [3.485]	-0.0004** [-2.156]	0.0003*** [3.046]	0.0003** [2.375]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

3.3 Implications of the results

In sum, although we found statistically significant breakpoints in the changes in centrality between February 2000 and March 2021 for most ASEAN countries, they generally occur prior to 2020, which supports our hypothesis. These results suggest that the trade shock following the pandemic is temporary rather than perpetual. This indicates the resilience of the trade pattern for almost all the ASEAN countries.

One may ask why we did not find a breakpoint during the pandemic. There are several possible reasons. First, as Hayakawa and Mukunoki (2021c) pointed out, many Asian countries permitted factory operations for specific industries if firms took adequate infection control measures. Second, inventory adjustment might enable firms in ASEAN countries to export without the need for production operations.

Third, strong monetary and fiscal policies by many governments helped prevent a larger drop in global demand (WTO, 2021). Fourth, lockdowns and travel restrictions caused consumers to shift their spending from non-traded services to goods, while innovation and adaptation by businesses and households kept economic activity from falling even more. These are some possible reasons why we did not find a breakpoint during the pandemic, although more rigorous analyses are required for further discussions.

4 Robustness Check

4.1 Results for major trading countries

In Section 3, we found that the structural changes in centrality occurred prior to 2020. There may be concerns regarding the external validity of this result; that is, the results may change if we focus on major trading countries. To address this concern, we estimate the same AO and IO models for the four major trading countries mentioned in Subsection 2.2: China, Germany, Japan, and the United States.

Table 7 presents the estimation results. The upper part of the table shows the results of the AO model, and the lower part contains those for the IO model. We highlight four findings. First, the estimated coefficients of the AO model are significantly positive for China, and significantly negative for the United States, Germany, and Japan. This result implies that except for China, the major trading countries experienced negative structural changes in centrality during the sample period. Second, for the IO model, the estimated coefficients become

insignificant for China, but the same signs are maintained for the other countries. Moreover, similar to the results for ASEAN countries in Tables 3 and 4, the estimated breakpoints are quite similar between the AO and IO models. This suggests that the results of the IO model are generally consistent with those of the AO model.

Table 7: Estimation Results: Major Trading Countries				
Additive Outliers Model				
	CHN	USA	DEU	JPN
Break point	2009m2	2003m3	2008m2	2010m6
y_{t-1}	0.0394*** [24.022]	-0.0267*** [-31.450]	-0.0083*** [-21.190]	-0.0149*** [-27.452]
Innovative Outliers Model				
	CHN	USA	DEU	JPN
Break point	2008m3	2002m3	2009m10	2010m9
y_{t-1}	-0.0001 [-0.092]	-0.0018** [-2.542]	-0.0013*** [-3.426]	-0.0009*** [-3.013]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Third, all the estimated breakpoints occur prior to 2020 for these four countries. This result means that the trade shock following the pandemic is not regarded as a breakpoint in terms of changes in centrality. In the previous subsection, we found that the majority of breakpoints occurred prior to 2020 for the ASEAN countries. Thus, our results suggest that the same is true for the major trading countries.

Finally, it is interesting to note that the estimated breakpoints were between February 2008 and September 2010 for China, Germany, and Japan. The global financial crisis may have significant effects on the importance of these countries in the world trade network. This result is in line with the results of the IO model for the ASEAN countries (Table 4). By contrast, the estimated breakpoints for the United States were March 2003 and March 2002 in the IO and AO models, respectively. Although we cannot argue for causality in a precise manner, this result seems to suggest that China's entry into the WTO, which occurred in December 2001, immediately before these breakpoint dates, may have influenced the decline in the relative importance of the United States in the world trade network.

4.2 Shorter period

We use a relatively longer time series (i.e., January 2000 to March 2021) to examine a structural break in centrality measures. One possible concern is that the longer time series may make it harder to determine structural breaks during the pandemic. To address this concern, we focus on a shorter period of analysis, namely a five-year period, starting from January 2015, and then estimate the AO and IO models.

Tables 8 and 9 present the estimation results for the AO and IO models, respectively. Table 8 indicates that among the 10 countries, Indonesia, Lao PDR, Malaysia, the Philippines, and Singapore have a breakpoint in 2020. Although these countries appear to experience a structural change when the pandemic commenced, the shock is positive rather than negative except for Singapore. It is interesting to note that the result for Malaysia is consistent with the finding of the results of the single structural break model for the longer time period in (Table 3).

Table 8: Estimation Results for Shorter Analysis Period: Additive Outlier Model for Centrality

	BRN	KHM	IDN	LAO	MYS
Break point	2019m9	2019m3	2020m2	2020m1	2020m2
y_{t-1}	0.00007*** [4.361]	0.00027*** [7.566]	0.00043*** [3.239]	0.00010*** [9.029]	0.00124*** [7.033]
	MMR	PHL	SGP	THA	VNM
Break point	2019m3	2020m2	2020m6	2017m12	2019m10
y_{t-1}	0.00023*** [8.960]	0.00009 [1.509]	-0.00085*** [-3.477]	-0.00042** [-2.614]	0.00388*** [8.867]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are *t*-statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Table 9 indicates that for Indonesia and Singapore, in contrast to the AO model results, the IO model estimated that breakpoints occurred in 2019 for Indonesia and in 2015 for Singapore. Similar to the baseline results, the structural break occurred before the pandemic commenced, if the structural change is gradual rather than sudden. Although we confirmed that a structural break occurred for Indonesia and Singapore when the pandemic started in the AO model, this result is sensitive to the choice of model.

Table 9 also indicates that for Lao PDR, Malaysia and the Philippines, the estimated breakpoint in the IO model was March 2020, which is close to the

Table 9: Estimation Results for Shorter Period: Innovative Outlier Model for Centrality

	BRN	KHM	IDN	LAO	MYS
Break point	2019m10	2019m4	2019m5	2020m3	2020m3
y_{t-1}	0.00007*** [3.788]	0.00036*** [6.414]	0.00034*** [2.823]	0.00005*** [2.740]	0.00117*** [3.202]
	MMR	PHL	SGP	THA	VNM
Break point	2019m4	2020m3	2015m9	2017m8	2019m5
y_{t-1}	0.00017*** [3.753]	0.00010** [2.154]	-0.00061** [-2.421]	-0.00029** [-2.161]	0.00097*** [2.830]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

points in the AO model. For these countries, the pandemic has had a significant impact if we limit the analysis to the sample period between January 2015 and March 2021. These results suggest that, even if we focus on the shorter period, seven of 10 countries indicate the breakpoint before 2020. Moreover, the shock is positive rather than negative for the other three countries (i.e., Lao PDR, Malaysia and the Philippines). Thus, we can argue that the relative importance of ASEAN countries in the world trade network did not decline as a consequence of the pandemic.

5 Extensions

5.1 Alternative approach

A further concern with our analysis is that the changes in centrality follow non-linear trends. Because our baseline analysis accommodates only a linear trend, the main results may not hold if the analysis accounts for nonlinear trends. To address this issue, following Ben-David and Papell (1997) and Abu-Bader and Abu-Qarn (2010), we estimate the following version of the augmented Dickey-Fuller regression, which accommodates both linear and nonlinear trends:

$$y_t = \mu + \beta_1 t + \beta_2 t^2 + \delta DU_t + \phi_1 DT_t + \phi_2 DT_t^2 + \sum_{\tau=1}^d \theta_\tau y_{t-\tau} + \varepsilon_t, \quad (14)$$

where y_t is PageRank centrality, DU_t is the break dummy variable, which is the same as in the baseline analysis, and DT_t captures the changes in the trend after

the breakpoint. Then, we have:

$$DT_t = \begin{cases} t - T_b & \text{if } t > T_b; \\ 0 & \text{otherwise,} \end{cases} \quad (15)$$

where T_b is the time of the breakpoint, that is, the period in which the change in the trend function parameters occurs. For the lag d , we use a 12-month lag (i.e., $d = 12$) to account for seasonality.

Conducting the test involves the following steps. First, before estimating equation (14), we examine whether PageRank centrality contains a unit root based on the Phillips–Perron test (Phillips and Perron, 1988), the null hypothesis of which is that PageRank centrality does contain a unit root.²⁰ We find that the null hypothesis is rejected for all ASEAN countries except for Viet Nam. Second, we conducted Vogelsang’s (1997) sup-Wald (or sup W_t) test, estimating equation (14). Sup W_t is the maximum of the standard F -test statistics times three for each year for testing the null hypothesis $\delta = \phi_1 = \phi_2 = 0$ over all possible trend breaks. The month and year when the maximum is identified are regarded as the breakpoint. Finally, we investigate the significance level of sup W_t based on the critical values calculated in Vogelsang (1997).²¹

Table 10 presents the regression results of equation (14). Breakpoints are found in 2020 only for the Lao PDR. For other countries, breakpoints occur prior to 2020. This implies that relative importance did not change just before or after the pandemic for most ASEAN countries. In short, our main messages are largely unchanged even if we employ an alternative approach.

5.2 Exports and imports

In Section 3, we estimated equations (4) and (6) for the AO model and equation (8) for the IO model using aggregate bilateral trade (exports + imports) as an outcome variable. One question that may arise is how the results change if the analysis utilizes exports or imports only. To answer this question, we use aggregate bilateral exports and imports separately as outcome variables and reestimate equations (4) and (6) for the AO model and equation (8) for the IO model.

Tables 11 and 12 present the results of exports and imports, respectively, for

²⁰The alternative is that PageRank is generated by a stationary process. We include a trend variable in the regression. The test is based on the Stata command `pperron`.

²¹For Viet Nam, the critical values are obtained from Vogelsang (1997, Table 2, $p = 2$ & $\lambda^* = 0.01$). For other countries, the critical values are obtained from Vogelsang (1997, Table 1, $p = 2$ & $\lambda^* = 0.01$).

Table 10: Regression Results: Alternative Approach

	BRN	KHM	IDN	LAO	MYS
Unit-root test	Reject***	Reject**	Reject***	Reject***	Reject***
Break point	2011m8	2019m6	2009m12	2020m4	2014m12
Sup W_t	22.0***	61.0***	19.3**	20.4**	21.7***
	MMR	PHL	SGP	THA	VNM
Unit-root test	Reject***	Reject*	Reject***	Reject***	Not reject
Break point	2014m9	2007m10	2006m2	2014m12	2018m2
Sup W_t	92.8***	27.0***	15.0	24.0***	39.7***

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Author's estimation based on IMF (2021a).

the AO model, whereas Tables 13 and 14 indicate the results of exports and imports, respectively, for the IO model. We highlight two findings. First, estimated breakpoints are different between exports and imports for all countries but Singapore. Nevertheless, estimated breakpoints in Table 1 are consistent with both Tables 11 and 12. For example, the estimated breakpoints in Tables 1 and 11 are the same for Malaysia, Singapore, Thailand, and Viet Nam, whereas the estimated breakpoints in Tables 1 and 12 are the same for Indonesia, Myanmar, the Philippines, and Singapore. Similar patterns are confirmed for the IO model in Tables 13 and 14.

Table 11: Estimation Results: Additive Outlier Model for Exports

	BRN	KHM	IDN	LAO	MYS
Break point	2004m9	2012m3	2005m10	2009m9	2005m12
y_{t-1}	0.295*** [14.813]	0.668*** [26.395]	0.370*** [30.458]	0.844*** [30.475]	0.315*** [28.171]
	MMR	PHL	SGP	THA	VNM
Break point	2008m3	2004m12	2004m12	2006m12	2010m12
y_{t-1}	0.556*** [23.236]	0.191*** [18.203]	0.336*** [29.370]	0.386*** [31.685]	0.786*** [27.969]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Second, the results confirm that none of the estimated breakpoints occurred after the pandemic started. This in turn implies that the changes in exports and imports of the ASEAN countries before and after the pandemic cannot be

Table 12: Estimation Results: Additive Outlier Model for Imports

	BRN	KHM	IDN	LAO	MYS
Break point	2007m8	2011m12	2006m12	2007m7	2008m12
y_{t-1}	0.356*** [16.935]	0.692*** [27.568]	0.563*** [32.891]	0.757*** [32.696]	0.252*** [20.140]
	MMR	PHL	SGP	THA	VNM
Break point	2010m12	2015m10	2004m12	2008m12	2008m11
y_{t-1}	0.621*** [36.569]	0.337*** [19.119]	0.354*** [27.489]	0.348*** [21.709]	0.683*** [24.582]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Table 13: Estimation Results: Innovative Outlier Model for Exports

	BRN	KHM	IDN	LAO	MYS
Break point	2004m5	2010m4	2002m1	2005m4	2009m1
y_{t-1}	0.030* [1.898]	0.035*** [3.429]	0.027*** [3.060]	0.055*** [3.167]	0.014** [2.110]
	MMR	PHL	SGP	THA	VNM
Break point	2007m12	2008m12	2005m1	2005m1	2010m1
y_{t-1}	0.054** [2.001]	0.012** [2.288]	0.019** [2.169]	0.012 [1.572]	0.013* [1.790]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

Table 14: Estimation Results: Innovative Outlier Model for Imports

	BRN	KHM	IDN	LAO	MYS
Break point	2007m2	2010m1	2007m1	2005m7	2009m1
y_{t-1}	0.036 [1.009]	0.029** [2.346]	0.037*** [2.758]	0.039*** [2.662]	0.019** [2.563]
	MMR	PHL	SGP	THA	VNM
Break point	2010m7	2015m4	2004m1	2009m1	2009m1
y_{t-1}	0.074*** [3.543]	0.027** [2.343]	0.025** [2.473]	0.015* [1.731]	0.008 [0.686]

Note: Countries are represented by their ISO codes (see Table A1 in the Appendix). The symbols ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are t -statistics. The breakpoints indicate the estimated year and month when the structural breaks are identified.

Source: Author's estimation based on IMF (2021a).

regarded as structural breaks. This result reinforces the resilience of the trade pattern for all ASEAN countries. Thus, our main messages remain unchanged even when we analyze exports and imports separately.

6 Concluding Remarks

Global trade was expected to suffer a significant contraction as a result of the COVID-19 pandemic. However, as such negative impacts on trade could vary between countries, we wished to investigate whether the relative importance of countries in the world trade network changed as a result of the pandemic. We consider that the answer to this question is particularly important for ASEAN countries because of their strong trade linkages with China, where the COVID-19 virus originated. More generally, the answer to this question is important because of the complexity of the world trade network and the heterogeneous impacts of the pandemic across countries.

This paper examined how the world trade network changed after the COVID-19 pandemic, particularly focusing on ASEAN countries. Tracking the changes in centrality from January 2000 to March 2021, we found no evidence that centrality changed significantly after the pandemic started for most ASEAN countries. Our results suggest that the relative importance of the ASEAN countries in the world trade network remains unchanged even after the pandemic.

If we view the results optimistically, the COVID-19 pandemic has not had a destructive impact on the world trade network. Rather, the effects are temporary and limited. World trade is strong enough to resist the threat from the pandemic. In particular, the pattern of trade is resilient to the pandemic for almost all the ASEAN countries. This seems to be a positive message, although caution is required because our analysis focuses on a short period after the pandemic owing to the limited availability of data.

Before closing this study, we point out several directions for future research. First, extending the analysis to a longer period is an important avenue for future research. As mentioned above, this study covers only a short period after the pandemic started (i.e., March 2020 to March 2021) owing to the limited availability of data. However, the effect of the pandemic may be more evident in the medium to long run. For example, Jordà, Singh, and Taylor (2020) argued that significant macroeconomic aftereffects of pandemics persist for decades as a result of reductions in the relative labor supply and/or a shift to greater precautionary savings. It may be premature to reach definitive conclusions at this point, and it remains essential to carefully monitor the effects of the pandemic

on global trade.

Second, it is important to examine the impact of the pandemic at a more detailed product level. Our analysis focused on the aggregate bilateral trade, but even if aggregate trade did not change significantly, the pandemic might have influenced the composition of trade. Finally, it would be interesting to investigate the effects on services trade. As a result of the pandemic, the mobility of people has been restricted to a greater degree than that of goods, with more limits between countries than within each country. Such restrictions would have significant effects on some services trade, such as tourism services. We plan to include these issues in our future research agenda.

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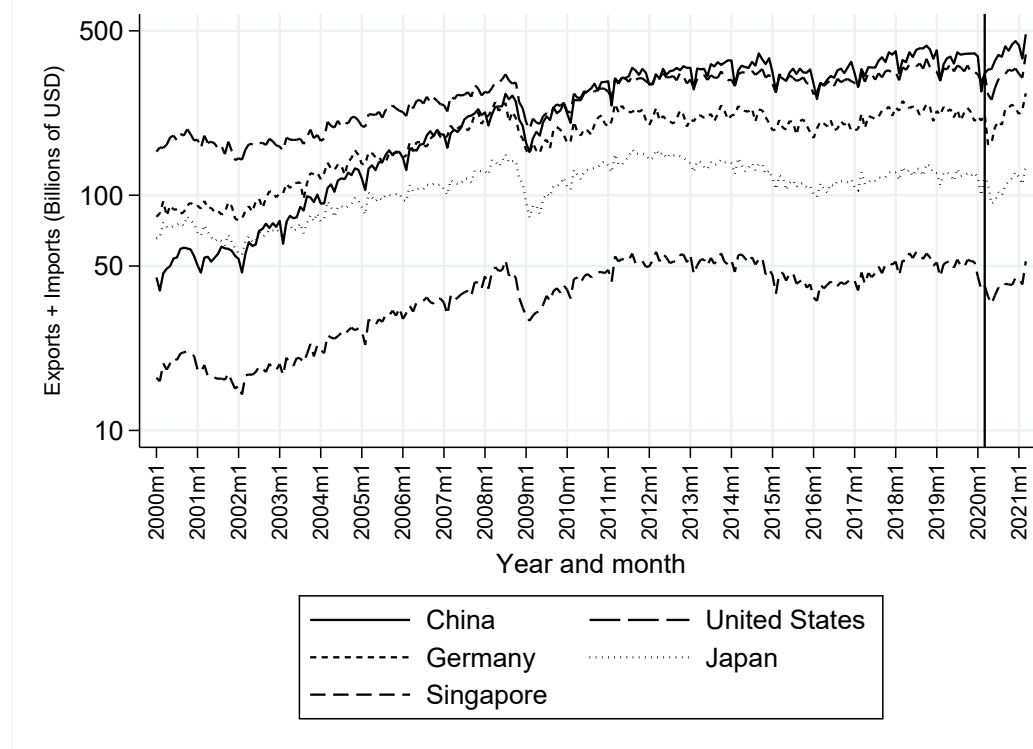
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Appendix

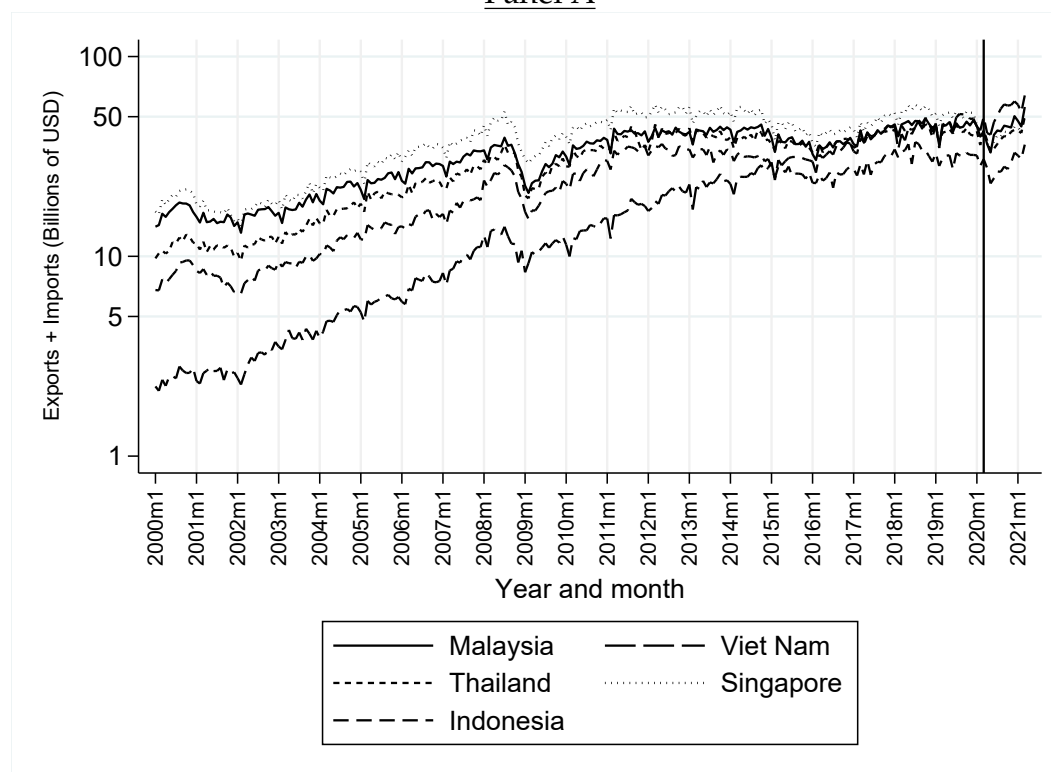
Figure A1: Trade Patterns for Major Trading Countries, January 2000–March 2021



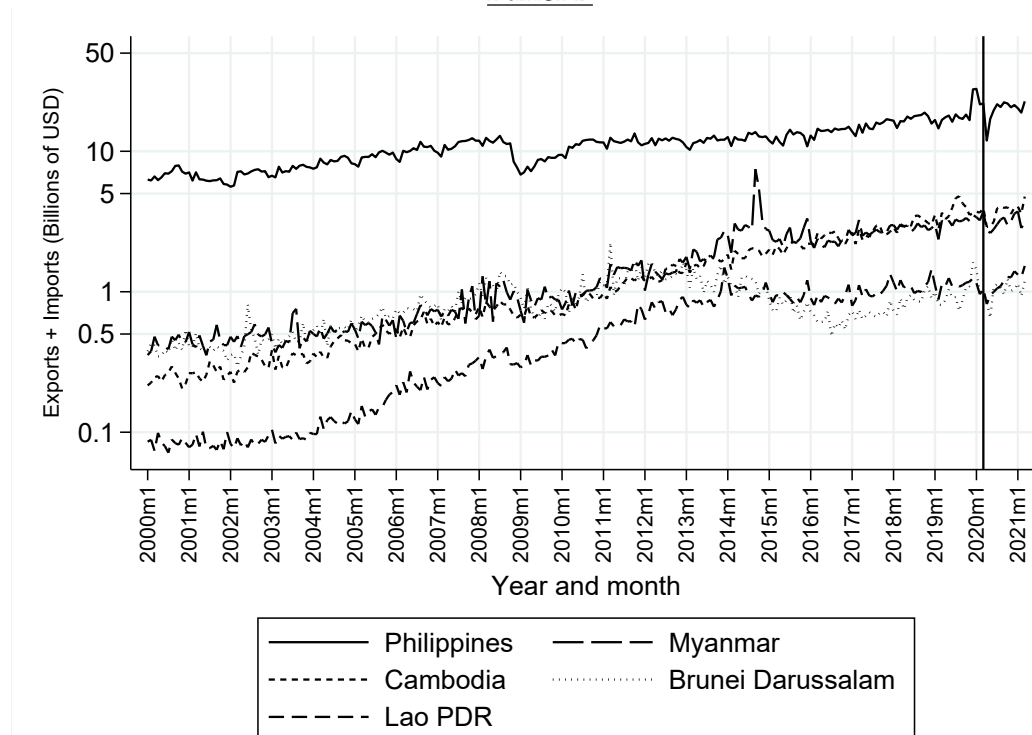
Note: The vertical axis indicates the value of overall trade (exports + imports) in log terms. The solid line indicates March 2020, when the COVID-19 pandemic started in many countries.

Source: IMF (2021a).

Figure A2: Trade Patterns for ASEAN Countries, January 2000–March 2021
Panel A



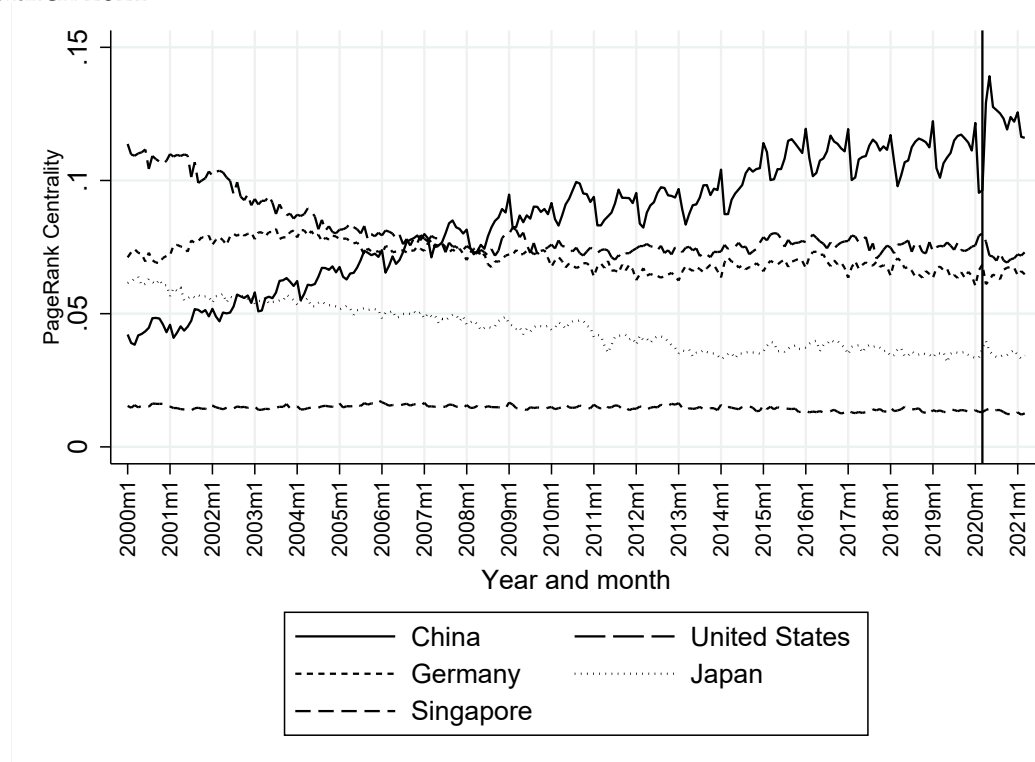
Panel B



Note: The vertical axis indicates the value of overall trade (exports + imports) in log terms. The solid line indicates March 2020, when the COVID-19 pandemic started in many countries.

Source: IMF (2021a).

Figure A3: PageRank Centrality for Major Trading Countries, January 2000–March 2021



Note: The vertical axis indicates PageRank centrality. The solid line indicates March 2020, when the COVID-19 pandemic started in many countries.

Source: Author's estimation based on IMF (2021a).

Table A1: Country Code

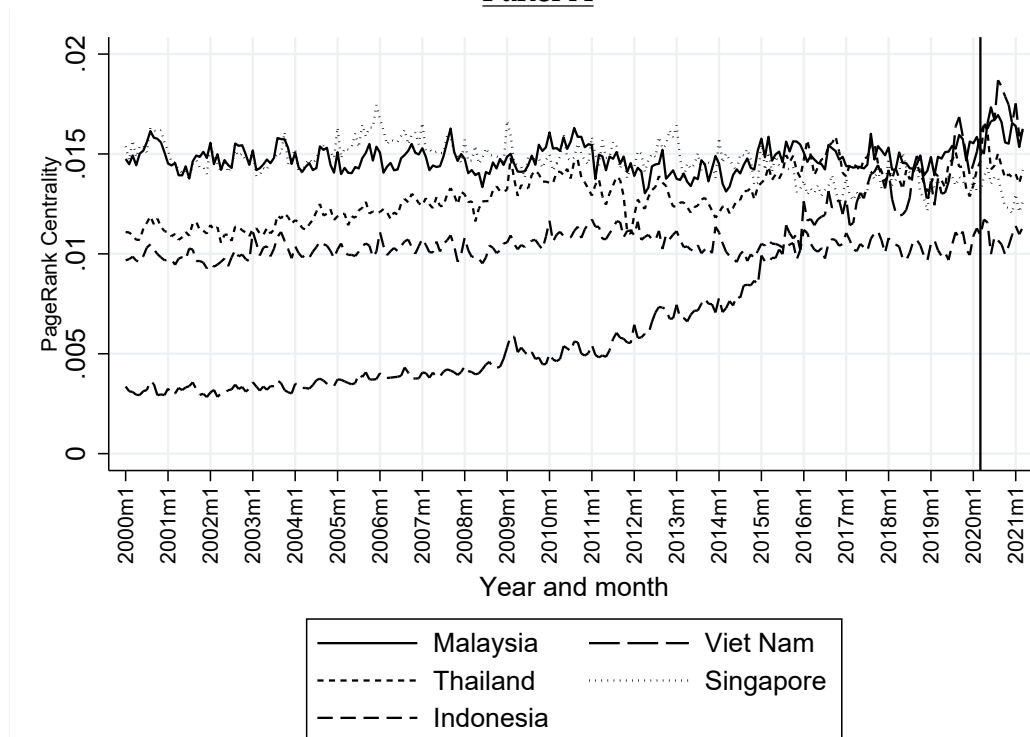
ISO	Country	ISO	Country
ASEAN countries			
BRN	Brunei Darussalam	MMR	Myanmar
KHM	Cambodia	PHL	Philippines
IDN	Indonesia	SGP	Singapore
LAO	Lao People's Democratic Republic	THA	Thailand
MYS	Malaysia	VNM	Viet Nam
Major trading countries			
CHN	China	JPN	Japan
DEU	Germany	USA	United States

Note: ISO indicates the 3-digit code developed by International Organization for Standardization.

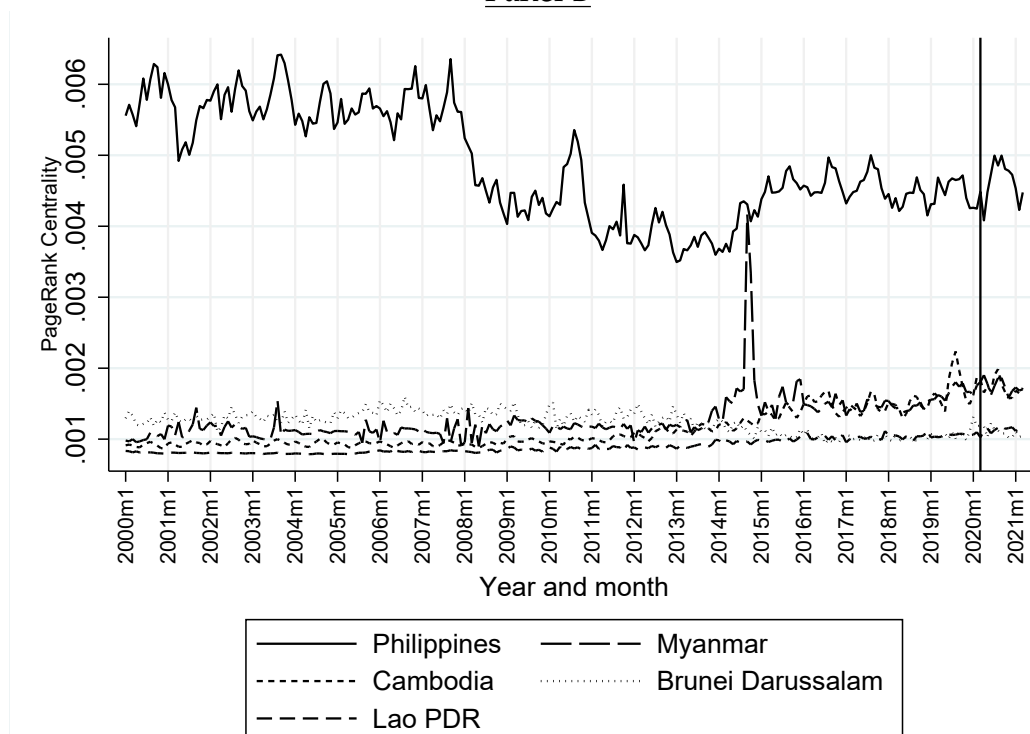
Source: International Organization for Standardization's website (<https://www.iso.org/>).

Figure A4: PageRank Centrality for ASEAN Countries, January 2000–March 2021

Panel A



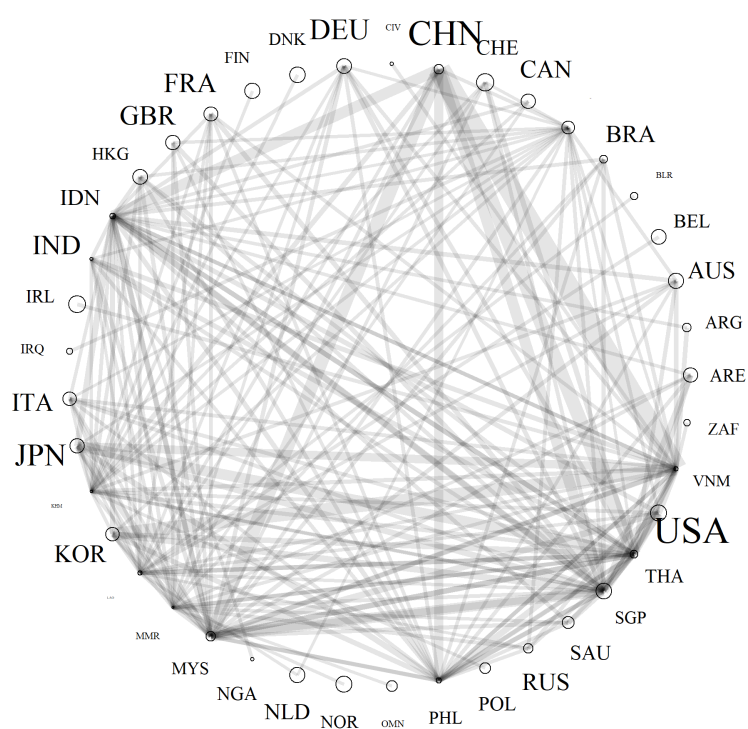
Panel B



Note: The vertical axis indicates PageRank centrality. The solid line indicates March 2020, when the COVID-19 pandemic started in many countries.

Source: Author's estimation based on IMF (2021a).

Figure A5: Trade Network of ASEAN Countries, March 2021



Note: The size of the ISO code and node represent the size of country's GDP and per-capita GDP, respectively. The network is based on three major trading partners. We use the data for the latest available year because the data for 2021 are not available (as of September 2021).

Source: Author's estimation based on IMF (2021a).