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Has the COVID-19 Pandemic Affected Maritime Connectivity? An Estimation for China and the Polar Silk Road Countries

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Abstract: In light of about 80% of international freight traffic carried by sea, maritime supply chains' stability is pivotal to global connectivity. For over a year now, the transboundary mobility of vessels and cargoes has been restricted by diverse forms of the COVID-19 containment measures applied by national governments, while the lockdowns of people, businesses, and economic activities have significantly affected the growth prospects of various maritime connectivity initiatives. This study investigates how the pandemic-related public health, trade, and market factors have shifted the connectivity patterns in the Polar Silk Road (PSR) transport corridor between China, South Korea, Japan, Russia, and four economies of Northern Europe. The causality links between the Shipping Connectivity Index (SCI) and the number of COVID-19 cases and deaths, trade volumes with China and the rest of the world, and price indexes of minerals, fuels, food, and agricultural products are revealed separately for eight countries and thirty-five ports. The study algorithm is built on the consecutive application of the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) stationarity tests, the Autoregressive Distributed Lag (ARDL) method, the Fully-Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) robustness checks, and the Toda-Yamamoto causality test. Tight trade-connectivity links are recorded in all locations along the China-PSR transport corridor in 2015–2019, but in 2020, the relationships weakened. Bidirectional influences between the number of COVID-19 cases and connectivity parameters demonstrate the maritime sector's sensitivity to safety regulations and bring into focus the role of cargo shipping in the transboundary spread of the virus. The authors' four-stage approach contributes to the establishment of a methodology framework that may equip stakeholders with insights about potential risks to maritime connectivity in the China-PSR maritime trade in the course of the pandemic.

Keywords: China; connectivity; COVID-19 pandemic; maritime trade; Polar Silk Road; shipping

1. Introduction

In just a few months, the COVID-19 outbreak has turned upside down nearly all kinds of economic activities and everyday interactions between people, businesses, and countries. By the first quarter of 2020, the disease had emerged from a health issue to a complex of economic and social problems, almost stopping travel and transboundary mobility and causing unprecedented lockdowns and other painful disruptions to supply chains and global trade [1]. According to the United Nations [2], by the second quarter of 2020, 90% of the world economy had suffered from various kinds of lockdowns. At about the same time, the International Energy Agency [3] reported that nearly 54% of the global population was affected by restrictions to mobility and other forms of social activities and mass gatherings [4]. To a greater or lesser extent, most countries closed their national borders—not only for tourists but also for various types of products [5–7]. Since the bulk of intercountry freight traffic is accounted for by maritime transport [1,8], the

maritime community has particularly severely suffered from the pandemic. The United Nations Conference on Trade and Development (UNCTAD) [1] expects the volume of international maritime trade to decline by 4.1% in 2020 amid the projected fall of the world GDP from 2.5% (the best-case scenario from the Word Trade Organization (WTO) [9]) to 6.0% forecasted by the Organization for Economic Co-operation and Development (OECD) [10]. On the other hand, as emphasized by the UNCTAD [1], Notteboom et al. [11], Van Tatenhove [12], Kolesnikova [13], and many other scholars, the pandemic has brought to the fore the utmost significance of maritime transport as an essential mean for ensuring the stability of global supply chains, continuing the delivery of major products across continents, and supporting connectivity between disjointed markets.

The OECD [14] allows about 70% of international trade for global value chains, with China predominating in many of them as either a producer, exporter, or importer of resources, intermediate commodities, or final products. Today, China makes up 16% of global GDP and accounts for 20% of world imports by sea [1]. Since the early 2000s, the shipping sector's increase has been tightly linked to China's skyrocketing economic growth. Considering the fact that China has been hit by the COVID-19 outbreak longer than any other country and practiced the world's strictest virus containment measures (and even total lockdowns in the first half of 2020) it is conceivable that maritime trade has experienced a crushing loss [15]. The UNCTAD [1] records shockwaves across ports in China and worldwide in the forms of declined vessel movements, deployed port operations and warehousing capacities, and quarantine restrictions on vessels and crew [16].

These disruptions may cause shifts in the overall patterns of global maritime trade and value chains [17,18] and suspend China's initiatives in the sphere of maritime connectivity. In 2013, China's President Xi Jinping [19] proposed the Belt and Road Initiative (BRI) with the view to improve logistics, increase trade, and enhance market integration between participating countries [20]. The initial vision of the two constituent parts of the BRI (the Silk Road Economic Belt and the 21st Century Maritime Silk Road) was then expanded in the 2017 Vision for Maritime Cooperation under the Belt and Road Initiative [21] by designating three "blue economic passages"—the China-Indian Ocean-Africa-Mediterranean Sea Blue Economic Passage, the China-Oceania-South Pacific Blue Economic Passage, and the Polar Silk Road (PSR) via the Arctic Ocean [22].

Among the blue passages, the latter has remained the least explored in terms of its potential impact on changing the landscape of maritime trade and potential losses or gains for global maritime connectivity in the course of the pandemic. China's Arctic Policy states that the PSR "facilitates connectivity and sustainable economic and social development of the Arctic" [23] by opening up an economic passage between China and Europe through Russia's Northern Sea Route (NSR) [24,25]. Many scholars have studied the conditions and requirements for trans-Arctic shipping routes to be economically feasible [26–28], analyzed freight traffic between Europe, Russia, China, and other countries of Asia [29–31], and modeled future volumes of transit and cabotage cargo flows with account for climate change [32–36], exploration of mineral and hydrocarbon resources in the High North [37–42], and perspectives of bulk and container transport [35,43–46]. Before the COVID-19 outbreak hit the world, China had planned to redirect up to 1% of its maritime trade to the PSR by the early 2020s [47]. However, with the pandemic emerging into a global economic threat, there have emerged a number of new issues that could derail the PSR initiative [48]. The effects of these new contributing factors must be adequately studied. While the overall impact of the COVID-19 outbreak on maritime trade remains clouded, the PSR-related estimates have appeared to be particularly scarce and fragmented. The China-PSR maritime trade studies have not comprehensively broken trade flows down by categories of cargo. A breakdown by ports along the route from China to Europe (including Russia's NSR ports) is almost missing. Against this background, we attempted to fill the existing lacunas by revealing the pandemic's implications for maritime connectivity and trade in the High North.

2. Materials and Methods

2.1. Countries and Ports

This study includes China and seven countries of Northeast Asia and Northern Europe (in alphabetical order, Denmark (including Greenland), Iceland, Japan, Norway, Russia, South Korea, and Sweden). In each country, we selected major ports located along the potential PSR corridor (in China—largest ports in the northeastern coastal provinces) (Figure 1).
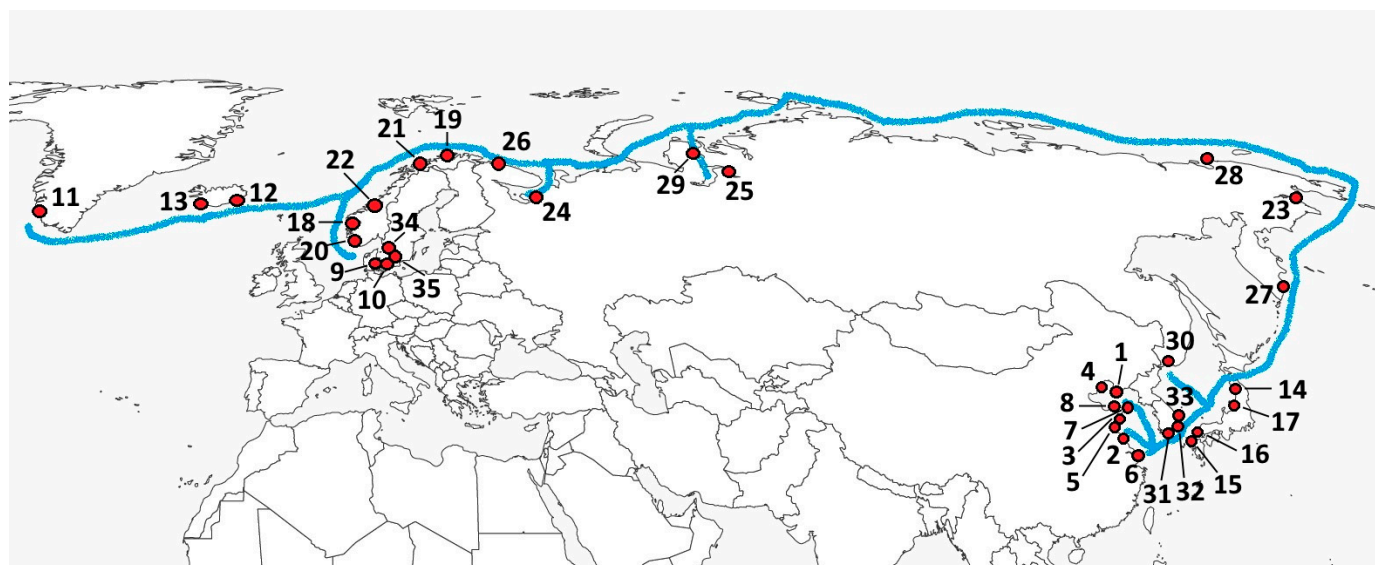

Figure 1. Countries and ports included in the study. Note: 1 = China: Dalian; 2= China: Lianyungang; 3 = China: Qingdao; 4 = China: Qinhuangdao; 5 = China: Rizhao; 6 = China: Shanghai; 7 = China: Weihai; 8 = China: Yantai; 9 = Denmark: Aarhus; 10 = Denmark: Copenhagen; 11 = Greenland: Nuuk; 12 = Iceland: Reydharfjordur; 13 = Iceland: Reykjavik; 14 = Japan: Akita; 15 = Japan: Hakata; 16 = Japan: Kitakyushu; 17 = Japan: Niigata; 18 = Norway: Bergen; 19 = Norway: Hammerfest; 20 = Norway: Stavanger; 21 = Norway: Tromso; 22 = Norway: Trondheim; 23 = Russia: Anadyr; 24 = Russia: Arkhangelsk; 25 = Russia: Dudinka; 26 = Russia: Murmansk; 27 = Russia: Petropavlovsk; 28 = Russia: Pevek; 29 = Russia: Sabetta; 30 = Russia: Vladivostok; 31 = South Korea: Gwangyang; 32 = South Korea: Pusan; 33 = South Korea: Ulsan; 34 = Sweden: Gothenburg; 35 = Sweden: Halmstad. Source: Authors' development.

2.2. Variables and Data

Across the established array of localities, we aim to estimate the possible economic effects of the COVID-19 pandemic on the integration of individual countries and ports into shipping networks with China (in the case of China—into the PSR shipping network). A country's integration level into global shipping networks is commonly measured by the shipping connectivity index (SCI). According to the UNCTAD [49] and the MDS Transmodal [50], the SCI captures the transport connectivity of a country with its counterparts through maritime trade. The index aggregates six parameters of a country's maritime connectivity, such as the number of ship calls per month, deployed capacity of transport vessels, the number of regular shipping services to and from the country, the number of shipping companies that provide such services, the average deadweight of the vessels deployed by shipping services, and the number of countries that are connected to the country through shipping. The SCI is set at 100 for the maximum value of a country's connectivity in the first quarter of 2006, which was China. Respectively, transport connectivity of individual ports is measured by the port shipping connectivity index (PSCI) [49]. Previously, neither the SCI nor the PSCI has been employed to study transport connectivity in the PSR. Still, both indexes have been extensively used as reliable reflections of maritime connectivity in many global-scale studies [17,51–53], as well as local estimations of maritime trade in Asia [54–56] and Europe [57–59].

To reflect the complexity of the pandemic-related factors and their possible influences on the SCI and the PSCI, we used three dimensions of independent variables: direct effects of the pandemic, effects of trade, and market effects (Table 1).

- As the pandemic is still progressing (at the time of this writing, January 2021), it is hardly possible to establish an unambiguous relationship between the spread of the disease, lockdown and containment measures, market fluctuations, economic slowdown, and trade activities. Nevertheless, many scholars, including Ding et al. [60], Baber [61], Erokhin and Gao [62], Ceylan et al. [63], and Mityakov [64], demonstrated the applicability of the number of registered COVID-19 cases in international comparisons of the economic effects of the pandemic. In earlier studies of other outbreaks (SARS, MERS, etc.), Bakalis et al. [65], Poudel et al. [66], and Bhargava et al. [67] also found that economic and trade activities could be associated with morbidity and mortality rates. The confirmed COVID-19 cases and death counts were employed by Nallon [16] to calculate the potential risk of COVID-19 spread related to individual ports. Therefore, we use the monthly number of new confirmed COVID-19 cases (X_1) and the monthly number of new confirmed COVID-19 deaths (X_2) to capture the pandemic's direct effects on the degree of maritime connectivity.

- Regarding the effects of trade on maritime connectivity, we avoid using UNCTAD's seaborne trade measure to ensure the cointegration between the variables. As reported by Liang and Liu [68], Hu et al. [69], Bertho et al. [70], and Chang et al. [56], seaborne trade directly relates to maritime connectivity, and thus it cannot be used as an independent variable in our study. Instead, the influences of trade activities on the SCI and the PSCI are reflected by the country's monthly total exports and imports. Apart from preventing the multicollinearity problem, taking total outbound and inbound trade flows as variables allows us to check whether the role of maritime trade in the total trade turnover of a country has changed during the pandemic. Expressly, we can assume that stronger relationships between shipping connectivity indexes from one side and export and imports from the other can mean a reorientation of total trade towards the maritime sector. To differentiate between the total trade with the world and intra-PSR trade flows, we employ the parameters of total exports to the world (X_3) and exports to China (X_5) (for China, X_5 designates exports to PSR countries) along with total imports from the world (X_4) and imports from China (X_6) (for China, X_6 specifies imports from PSR countries).

- The pandemic has dramatically affected daily economic activities and transportation worldwide [71–73]. Generally, as reported by Černikovaitė and Karazijienė [74], Leach et al. [75], Egger et al. [76], and other scholars, the COVID-driven transformations of the economic environment have been reflected in the behavior patterns of businesses and consumers, i.e., supply and demand shifts in the global market. The most common approach to tracking market volatilities is to monitor prices. That is why we employed the Commodity Price Index (CPI), an average of monthly quotations at a commodity's main marketplace. According to the UNCTAD [77], the CPI is a fixed-base Laspeyres index, where the weights are proportional to the individual commodities' shares in total merchandise exports of a country in the base period (2014–2016). Four independent variables are included in the study to capture the categories of cargo that dominate in the Asia-Russia-Europe transit via the Northern Sea Route (NSR), the so-far primary operating transport passage in the Arctic Ocean [78]: X_7–minerals, ores, and metals; X_8–fuels; X_9–food products; X_{10}–agricultural raw materials and oilseeds.

To reveal the pandemic-driven effects of the independent variables on maritime connectivity, the calculations are made separately for the two periods. First, we find the Y-X_{3-10} relationships in 2015–2019 (January–September in each year, 45 observations in total). Then, we add variables X_1 and X_2 and calculate the Y-X_{1-10} model for the period from January 2020 (when COVID-19 cases were first confirmed outside China) till the end of September 2020 (availability of data for all variables included in the study). In

addition to differentiating between the pre-pandemic and pandemic periods, we make separate country-level (eight countries) and port-level (thirty-five ports) calculations, as described below.

Table 1. Variables included in the study.

Index	Variable	Unit of Measure	Definition	Source of Data
Y	Shipping Connectivity Index (SCI) or Port Shipping Connectivity Index (PSCI)	Points	A degree of a country's (port's) integration into global shipping networks	UNCTAD [49,79], MDS Transmodal [50]
X_1	Number of new confirmed COVID-19 cases	Number of cases	Monthly new confirmed COVID-19 cases in a country	Johns Hopkins University of Medicine [80], Our World in Data [81]
X_2	Number of new confirmed COVID-19 deaths	Number of deaths	Monthly new confirmed COVID-19 deaths in a country	Johns Hopkins University of Medicine [80], Our World in Data [81]
X_3	Exports to the world	$ million	Monthly total exports from a country to the world	UNCTAD [79]
X_4	Imports from the world	$ million	Monthly total imports to a country from the world	UNCTAD [79]
X_5	Exports to a country	$ million	Monthly total exports from a country to China (for China–monthly total exports to PSR countries)	UNCTAD [79]
X_6	Imports from a country	$ million	Monthly total imports to a country from China (for China–monthly total imports from PSR countries	UNCTAD [79]
X_7	Commodity Price Index: minerals	Points	Index of monthly prices of minerals, ores, and non-precious metals exported by a country (aluminum, copper, iron ore, lead, manganese ore, nickel, phosphate rock, tin, zinc)	UNCTAD [79]
X_8	Commodity Price Index: fuels	Points	Index of monthly prices of fuels exported by a country (coal, crude oil, natural gas, including liquefied natural gas)	UNCTAD [79]
X_9	Commodity Price Index: food	Points	Index of monthly prices of food products exported by a country (meat and meat products, milk and dairy products, fish and seafood products, sugar, wheat)	UNCTAD [79]
X_{10}	Commodity Price Index: agriculture	Points	Index of monthly prices of agricultural raw materials and oilseeds exported by a country (palm oil, soybean meal, soybean oil, soybeans, sunflower oil)	UNCTAD [79]

Source: Authors' development.

2.3. Methodology Framework

The study goes along the four stages as depicted in Figure 2. We start with checking a cointegration in the established datasets, then investigate short-run and long-run interactions between dependent and independent variables, test the robustness of the results, and complete the study by revealing the causality directions between Y and each of X_{1-10} variables.

Before the dataset is used in the analysis, it is crucial to confirm the stationarity of the dataset and the cointegration between the selected variables [82,83]. At Stage 1, we check the dataset's stationarity by implementing two commonly used methods, the Augmented Dickey-Fuller (ADF) test [84] and the Phillips-Perron (PP) test [85]. The applicability of the combination of the two methods to the short-run and long-run inter-country comparisons of trade parameters and prices have been demonstrated by many scholars, including Chang et al. [82,86], Hoarau [87], Herwartz and Reimer [88], and Aliyev et al. [89].
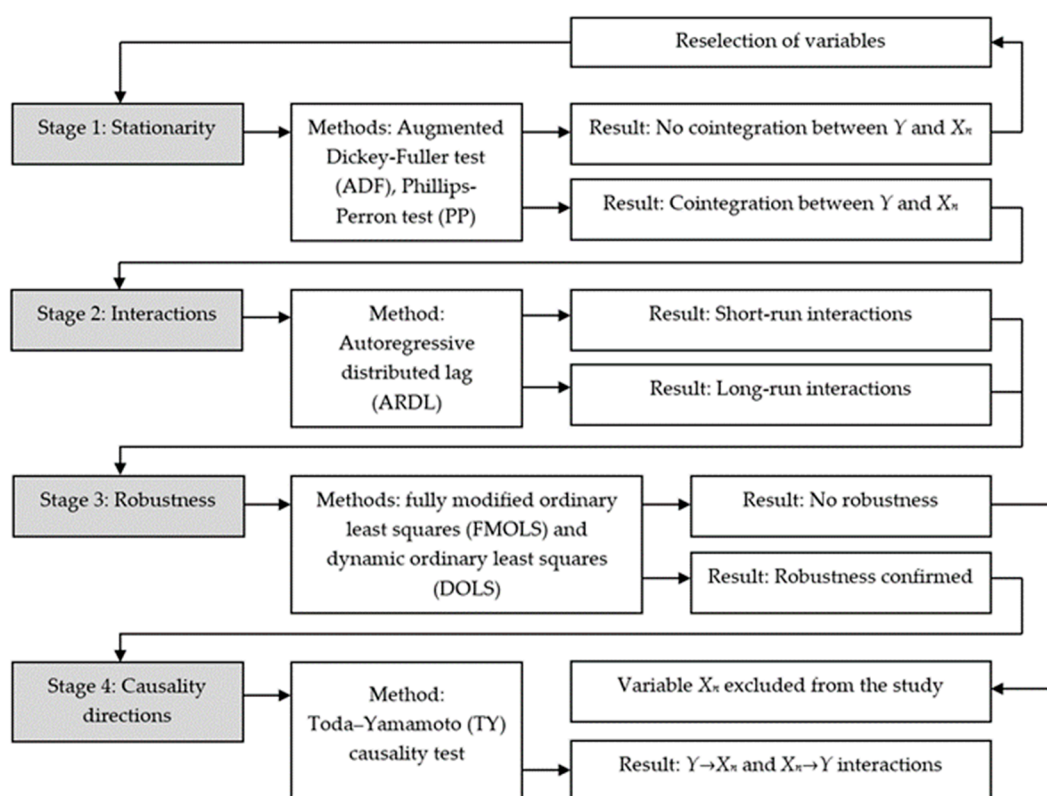
Figure 2. Study algorithm. Source: Authors' development.

Having confirmed the cointegration between Y and independent variables, we apply the autoregressive distributed lag (ARDL) method [90]. Since the early 2000s, this technique has been extensively used in revealing short- and long-run relationships between various macroeconomic parameters, including in trade-related studies [91–95], investigations of market volatilities [96–99], and, most recently, estimations of the economic effects of the COVID-19 pandemic and other outbreaks [62,100]. Two ARDL models are established for studying the Y-$X_{3–10}$ relationships in 2015–2019 (Equation (1)) and the Y-$X_{1–10}$ interactions in 2020 (Equation (2)). If F-statistics is larger than the upper critical bounds value [I(1)], the series are cointegrated. If it is below the lower critical bounds [I(0)], the variables are not cointegrated.

$$
\begin{aligned}
\Delta Y_t &= \delta_0 + \sum_{i=1}^{l} \delta_{1i}\Delta Y_{t-i} + \sum_{i=1}^{l} \delta_2 i\, \Delta X3_{t-i} + \sum_{i=1}^{l} \delta_3 i\Delta X4_{t-i} + \sum_{i=1}^{l} \delta_{4i}\, \Delta X5_{t-i} \\
&+ \sum_{i=1}^{l} \delta_{5i}\, \Delta X6_{t-i} + \sum_{i=1}^{l} \delta_{6i}\, \Delta X7_{t-i} + \sum_{i=1}^{l} \delta_{7i}\, \Delta X8_{t-i} + \sum_{i=1}^{l} \delta_{8i}\, \Delta X9_{t-i} \\
&+ \sum_{i=1}^{l} \delta_{9i}\, \Delta X10_{t-i} + \varpi ECT_{t-1} + \varepsilon_{t-i}
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
\Delta Y_t &= \delta_0 + \sum_{i=1}^{l} \delta_{1i}\Delta Y_{t-i} + \sum_{i=1}^{l} \delta_2 i\, \Delta X1_{t-i} + \sum_{i=1}^{l} \delta_3 i\Delta X2_{t-i} + \sum_{i=1}^{l} \delta_{4i}\, \Delta X3_{t-i} \\
&+ \sum_{i=1}^{l} \delta_5 i\, \Delta X4_{t-i} + \sum_{i=1}^{l} \delta_6 i\, \Delta X5_{t-i} + \sum_{i=1}^{l} \delta_7 i\, \Delta X6_{t-i} + \sum_{i=1}^{l} \delta_8 i\, \Delta X7_{t-i} \\
&+ \sum_{i=1}^{l} \delta_9 i\, \Delta X8_{t-i} + \sum_{i=1}^{l} \delta_{10} i\, \Delta X9_{t-i} + \sum_{i=1}^{l} \delta_{11} i\, \Delta X10_{t-i} + \varpi ECT_{t-1} \\
&+ \varepsilon_{t-i}
\end{aligned}
\tag{2}
$$

where Δ = first difference operator; δ_0 = constant term; $\delta_{1–10}$ = short-run elasticities of the variables; i = ARDL model lag order; ϖECT_{t-1} = error correction term; ε_t = error disturbance; t = time.

At Stage 3, robustness checks of the short-run and long-run ARDL results are made by implementing a combination of the fully-modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS) methods, which is an approach previously tested by Yuzbashkandi and Sadi [101], Pasha and Ramzan [102], Erokhin and Gao [62], Adebayo [95], and many other authors. The selection of the FMOLS is explained by the fact that the method allows one to receive consistent parameters even in the small samples in the short-run [62]. For the 2020 array with nine observations, it is a particularly valuable characteristic of the method. Furthermore, as evidenced by Priyankara [103] and Bashier and Siam [104], the FMOLS effectively addresses the problems of endogeneity and serial correlation, which ensures heterogeneity in the variables. The use of the DOLS in combination with the FMOLS helps to estimate the equilibrium that is corrected for potential simultaneity bias among explanatory variables [105]. The use of the DOLS is also advantageous in our study since it applies to small samples in the short term [106].

Stage 4 completes the study's calculation by finding the direction of causalities between Y and X_{3-10} (2015–2019 model) and Y and X_{1-10} (2020 model). The Toda-Yamamoto causality test [107] is used, as previously practiced in investigating causal linkages between economic parameters and non-economic influences of exogenous factors, including the COVID-19 pandemic, by Belaid et al. [108], Erokhin and Gao [62], Ben Amar et al. [109], Amiri and Ventelou [110], and Soytas et al. [111]. The TY value demonstrates a strong causality link between the variables in case of the significance at 1% level (5%—above average, 10%—average, all other cases–weak). In a $[Y \rightarrow X_n; X_n \rightarrow Y]$ pair, the causality can be unidirectional (direct or reverse), bidirectional, or neutral. Based on the parameters of strength and direction of the causality link, we compare the 2015–2019 and the 2020 models to reveal changes in the Y-X_n relationships that can be attributed to the influence of the COVID-19 pandemic on maritime connectivity.

3. Results

3.1. Stationarity of Data

The values of the SCI (eight countries) and the PSCI (35 ports) are calculated separately for the 2015–2019 model (45 observations) and the 2020 model (nine observations) (Appendix A, Table A1). The X_{3-10} and X_{1-10} arrays are established accordingly. The implementation of the ADF and the PP methods to the two arrays of data (2015–2019— see Appendix B, Table A2; 2020—see Appendix B, Table A3) allows us to confirm that all selected variables are stationary at a level of either I(0) or I(1). In both models, the parameter of F-statistics is above the upper bound (Table 2). Therefore, at Stage 1, we find that the preconditions for co-integration between Y and X_{3-10} (2015–2019 dataset) and Y and X_{1-10} (2020 dataset) exist in all countries and ports included in the study. The datasets' stationarity and the co-integration between the variables justify the appropriateness of the models for further analysis.

Table 2. Bound test results, countries.

Countries	F-Statistics	
	2015–2019	**2020**
China	13.5743	14.0719
Denmark	10.1720	9.1427
Iceland	11.4866	8.3820
Japan	20.0552	21.5932
Norway	9.4003	10.6315
Russia	7.1465	8.4988
South Korea	14.9028	13.1100
Sweden	8.4991	9.1451

Source: Authors' calculation.

3.2. Interactions between Variables

Since the study aims to reveal the fluctuations in Y-X_n relations caused by the pandemic in 2020, the ARDL analysis starts with estimating the short-run patterns. In 2015–2019, the strongest effect on the growth of Y is caused by an increase in trade volumes with the world. For both exports X_3 and imports X_4, this effect is the most significant in Japan, Iceland, and South Korea (Table 3), where the contribution of maritime transport to overall trade turnover was exceptionally high. In China, the influence on maritime connectivity of trade activities with PSR countries is statistically significant, especially in Shanghai, Qingdao, and Dalian (Appendix C, Table A4). When other variables remain constant, a growth of aggregate exports from China to the seven PSR countries by 5% results in the increase in the SCI by 0.25% (0.22% in the case of imports, respectively). Among PSR countries included in the study, maritime connectivity strongly depends on trade with China in Japan, South Korea, and Norway.

The influences of $X_{7–10}$ on Y in the 2015–2019 model are divergent. Thus, we see a relatively strong direct relationship between maritime connectivity and mineral prices in Iceland, Norway, and Russia (major exporters of ores and other minerals) and Japan and South Korea (importers of scarce mineral resources). The strongest Y-X_7 link is recorded in Nuuk (Greenland), Reydharfjordur (Iceland), and Niigata (Japan). The impact of oil prices on Y is weaker than that of mineral prices, along with a reverse relationship in China, Japan, and South Korea. In these countries, a decline in the fuels CPI is associated with more imports and, consequently, an increase in the SCI (the PSCI in Dalian, Lianyungang, Qingdao, Gwangyang, Pusan, and Ulsan). Similar negative relationships between prices and maritime connectivity are observed in $[Y; X_9]$ and $[Y; X_{10}]$ pairs in China, South Korea, and Japan, who are net importers of food and agricultural products.

In 2020, the strengths of many Y-X_n linkages declined. Weaker associations are recorded between maritime connectivity on one side and exports and imports on the other in China, Russia, and Nordic countries (Table 4). Smaller ports experience more considerable losses, for example, Rizhao, Lianyungang, Qinhuangdao, and Weihai in China, Hammerfest and Tromso in Norway, and most of Russia's ports in the Northern Sea Route (Appendix C, Table A5). In Japan and South Korea, whose foreign trade primarily relies on maritime transport, the Y-X_3 and Y-X_4 links became tighter in January–September 2020 compared to the average values in January–September 2015–2019. However, the strengthening of the trade-connectivity linkage is specific to bigger ports (Niigata and Pusan), while in smaller ones, the Y-$X_{3–4}$ association has been weakened (Hakata and Kitakyushu in Japan and Gwangyang and Ulsan in South Korea).

A downward trend is also observed for the influence of China-PSR trade on maritime connectivity. Across all seven countries, exports to China and imports from China contribute less to the SCI index in 2020 than in 2015–2019. In China, an increase in the value of exports to PSR countries by 5% is associated with a growth of maritime connectivity by 0.24%, a decline by 0.01 percentage point compared to the 2015–2019 model. An equal increase in imports results in a growth of the SCI value by 0.20%—a loss of 0.02 percentage points. The most profound drops occur in Shanghai (0.28 percentage points for X_5 and 0.36 percentage points for X_6), Qingdao (0.11 and 0.13 percentage points, respectively), and Yantai (0.10 and 0.08 percentage points, respectively).

The long-run ARDL models confirm the short-run estimates with very few exceptions. In 2015–2019, the long-run contribution of trade with PSR countries to the value of China's maritime connectivity is weaker compared to the short-run estimations (Table 5). In 2020, however, the relationship between China's SCI score and $X_{5–6}$ becomes tighter (Table 6). On the other hand, in some PSR countries, the role of either exports to China (Iceland, Sweden) or imports from China (South Korea) in 2020 increases compared to the average 2015–2019 values. Thus, the Y-X5 link becomes stronger in Reydharfjordur (Iceland), Kitakyushu (Japan), and Ulsan (South Korea), while the strength of the Y-X_6 relationship increases in Reykjavik and Reydharfjordur (Iceland), Gwangyang and Pusan (South Korea), Gothenburg (Sweden), Murmansk (Russia), and Dalian (China) (Appendix D, Tables A6 and A7).

Table 3. ARDL short-run estimates, countries, 2015–2019.

Country	Parameter	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
China	Coefficient	0.1311	0.1785	0.2524	0.2206	0.0411	−0.1552	−0.0207	−0.0561	0.2301
	t-stat	3.2059	−4.0693	2.9733	−3.5291	1.5634	2.0591	3.1298	3.8298	2.7428
	Prob	0.4052 **	0.2951 **	0.6021 **	0.4904 **	0.2830 **	0.2756 **	0.2885 ***	0.1407 ***	0.1082 **
Denmark	Coefficient	0.0820	0.1694	0.0846	0.0337	0.1029	−0.0147	0.0759	0.0934	−0.0503
	t-stat	2.4392	−2.2942	3.0920	−3.1108	1.1406	−4.8388	3.0746	4.5055	1.5509
	Prob	0.3501 **	0.2909 **	0.1701 **	0.2235 *	0.1773 **	0.0440 *	0.0005 **	0.0122 **	0.2182 *
Iceland	Coefficient	0.5100	0.4535	0.3335	0.1609	0.5002	−0.0609	0.0642	0.0316	0.0335
	t-stat	−2.4027	3.5400	−2.2852	2.5574	−1.0043	−3.6201	1.3866	2.0434	4.5820
	Prob	0.1823 ***	0.7512 **	0.3977 **	0.1000 **	0.1904 ***	0.0003 *	0.0013 **	0.0608 **	0.0444 **
Japan	Coefficient	0.7544	0.6524	0.3144	0.3207	0.5194	0.2451	−0.1018	−0.1527	−0.1607
	t-stat	1.4156	2.1003	−3.5023	−2.2909	1.3663	1.2945	2.4083	2.4091	−2.3076
	Prob	0.3723 ***	0.8201 ***	0.4141 ***	0.3410 ***	0.3065 ***	0.1777 **	0.3091 ***	0.4866 ***	0.6389 ***
Norway	Coefficient	0.0942	0.0805	0.1507	0.2154	0.2011	0.5519	0.0504	0.0238	0.2492
	t-stat	2.2709	2.2664	−1.1578	−1.2388	1.7747	3.0004	−2.4025	−2.0777	−1.4883
	Prob	0.1114 **	0.2005 **	0.1942 **	0.0000 **	0.3029 **	0.7035 ***	0.0412 **	0.0561 **	0.1994 **
Russia	Coefficient	0.0826	0.1904	0.0549	0.0662	0.1413	−0.0501	0.0152	0.0105	−0.3596
	t-stat	−2.1527	−1.5388	−2.0285	−2.4019	2.0285	−2.0483	3.7498	3.1023	3.8537
	Prob	0.3491 *	0.4021 **	0.0083 **	0.2898 *	0.2474 **	0.0015 **	0.1753 **	0.1591 *	0.4374 *
South Korea	Coefficient	0.2409	0.3502	0.3046	0.2326	0.4140	0.0930	−0.0502	−0.1287	0.1665
	t-stat	1.3000	1.5556	3.1774	1.5092	2.8287	−1.6282	3.0006	2.4272	1.6097
	Prob	0.3917 ***	0.4834 ***	0.2395 ***	0.3316 ***	0.5286 **	0.0101 **	0.1284 ***	0.1485 ***	0.1116 ***
Sweden	Coefficient	0.2003	0.2013	0.2090	0.1700	0.1104	−0.0674	0.0166	0.0903	−0.2208
	t-stat	−4.4627	−3.5508	−1.3286	−2.0446	2.0537	−2.1260	2.0845	1.5396	−2.2754
	Prob	0.2509 **	0.3627 **	0.1298 **	0.2679 *	0.2952 **	0.1305 *	0.0127 *	0.1877 *	0.1377 *

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table 4. ARDL short-run estimates, countries, 2020.

Country	Parameter	ΔX_1	ΔX_2	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
China	Coefficient	−0.0172	0.0029	0.1205	0.1693	0.2412	0.1984	0.0255	−0.1303	−0.0145	−0.0403	0.1977
	t-stat	1.1928	2.4802	4.2918	−5.4827	3.6980	−4.0015	1.1983	2.4550	3.0961	4.9522	3.9584
	Prob	0.0193 *	0.0337 **	0.5891 **	0.4094 **	0.2295 **	0.3791 **	0.0142 *	0.1876 **	0.0198 ***	0.0361 ***	0.2951 **
Denmark	Coefficient	−0.0040	−0.0101	0.0977	0.1185	0.0381	0.0270	0.1309	−0.0095	0.0842	0.0720	−0.0303
	t-stat	3.2801	2.1798	2.9063	−1.0391	3.8555	−4.0053	2.6178	−3.9487	4.4275	5.2973	2.4981
	Prob	0.1225 *	0.3415 *	0.2988 **	0.0794 **	0.1862 *	0.2062 *	0.0526 **	0.0293 *	0.0860 *	0.0056 *	0.0922 *
Iceland	Coefficient	0.0027	0.0064	0.4954	0.4286	0.3004	0.1487	0.4550	−0.0008	0.0555	0.0064	0.0193
	t-stat	2.9024	3.0540	−3.1171	4.6032	−3.0978	3.8684	−1.2095	−2.5365	1.4736	2.9021	3.6466
	Prob	0.2870 *	0.1996 *	0.2095 ***	0.3117 ***	0.2719 **	0.1396 **	0.0281 ***	0.0000 *	0.0001 **	0.0003 **	0.0295 **
Japan	Coefficient	−0.3015	−0.1855	0.7926	0.6860	0.2981	0.3106	0.5527	0.2117	−0.1204	−0.1835	−0.1320
	t-stat	−3.5523	−2.8473	1.5930	2.4877	−3.9615	−2.5493	1.4902	2.0836	3.9223	2.8504	−1.4955
	Prob	0.4984 ***	0.3861 ***	0.5983 ***	0.6994 ***	0.2755 ***	0.3987 ***	0.2653 ***	0.0584 **	0.1887 ***	0.2309 ***	0.3091 ***
Norway	Coefficient	−0.0452	−0.0384	0.0527	0.0695	0.1141	0.2095	0.1844	0.5763	0.0646	0.0053	0.2094
	t-stat	−1.0836	−2.3918	3.1951	2.7070	−1.0479	−1.1704	2.0596	3.4609	−1.2984	−2.5918	−1.0672
	Prob	0.1179 **	0.3251 **	0.0592 **	0.0486 **	0.0185 *	0.0278 *	0.1035 **	0.8848 ***	0.0390 **	0.0442 **	0.0333 **
Russia	Coefficient	0.0041	0.0292	0.0689	0.1274	0.0202	0.0385	0.1300	−0.0487	0.0053	0.0127	−0.3890
	t-stat	4.8560	3.6005	−2.0576	−1.7066	−2.2367	−1.5092	2.5982	−3.1052	1.5295	2.0004	4.1987
	Prob	0.2957 **	0.3146 **	0.2208 *	0.3517 *	0.1985 *	0.0188 *	0.2397 *	0.0006 *	0.0049 *	0.1156 *	0.4912 *
South Korea	Coefficient	0.0666	0.0718	0.2985	0.3020	0.2563	0.1900	0.4005	0.0825	−0.0415	−0.0923	0.1475
	t-stat	−2.1947	−2.0987	1.6096	1.8044	2.0054	1.4553	2.6360	−1.4044	2.4986	2.8921	1.8259
	Prob	0.3021 ***	0.2451 ***	0.1239 ***	0.2508 ***	0.1946 ***	0.3409 ***	0.6931 **	0.0036 **	0.0318 ***	0.0197 ***	0.0504 ***
Sweden	Coefficient	0.0003	0.0036	0.1753	0.2113	0.2291	0.1486	0.1054	−0.0592	0.0014	0.0965	−0.2095
	t-stat	1.6398	2.4019	−5.5094	−4.3005	−1.1982	−2.3075	1.9945	−3.0758	1.7095	2.0349	−3.1199
	Prob	0.0520 *	0.0481 *	0.1398 **	0.1864 **	0.0097 *	0.0392 *	0.1708 **	0.0505 *	0.0000 *	0.0038 *	0.0008 *

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table 5. ARDL long-run estimates, countries, 2015–2019.

Country	Parameter	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
China	Coefficient	0.1523	0.1620	0.2208	0.2019	0.0506	−0.1713	−0.0499	−0.0668	3.2612
	t-stat	3.4128 **	−3.5982 **	2.5052 **	−3.0276 **	1.3049 **	2.1445 **	3.4091 ***	2.1367 ***	2.1553
Denmark	Coefficient	0.1859	0.1415	0.1100	0.0542	0.1233	−0.0285	0.0521	0.0840	−2.0788
	t-stat	2.0024 **	−2.1387 **	2.4719 **	−3.6528 *	1.5621 **	−4.2872 *	2.4865 **	4.1726 **	−1.7262
Iceland	Coefficient	0.5724	0.4736	0.3004	0.1811	0.6376	−0.0883	0.0404	0.0551	5.1285
	t-stat	−2.3182 ***	3.1671 **	−1.8638 **	2.9512 **	−1.8170 ***	−3.9166 *	1.6523 **	2.6600 **	3.4109
Japan	Coefficient	0.7169	0.6882	0.3230	0.3592	0.5441	0.2610	−0.1332	−0.1775	−3.2458
	t-stat	2.0584 ***	2.8509 ***	−3.2099 ***	−2.6091 ***	1.6730 ***	1.5094 **	2.9615 ***	1.3409 ***	−4.5091
Norway	Coefficient	0.1002	0.0995	0.1784	0.2592	0.2240	0.5607	0.0612	0.0309	2.2493
	t-stat	2.4081 **	2.1682 **	−1.2955 **	−1.4187 **	2.1483 **	3.3021 ***	−2.5443 **	−2.3183 **	2.6991
Russia	Coefficient	0.0995	0.2309	0.0707	0.0831	0.1715	−0.0773	0.0170	0.0148	−3.3399
	t-stat	−2.5023 *	−1.7192 **	−2.1973 **	−2.6886 *	2.3091 **	−2.4088 **	2.0493 **	4.8122 *	−3.2942
South Korea	Coefficient	0.2677	0.3069	0.3330	0.2045	0.4509	0.0847	−0.0742	−0.1309	5.2700
	t-stat	1.3920 ***	1.8491 ***	3.8186 ***	2.2353 ***	3.5412 **	−2.0596 **	4.1827 ***	2.5511 ***	2.3818
Sweden	Coefficient	0.2145	0.2346	0.2155	0.1764	0.1399	−0.0472	0.0334	0.0916	−5.0376
	t-stat	−4.8921 **	−3.0830 **	−1.9188 **	−2.5616 *	2.3984 **	−1.0001 *	3.5925 *	1.6810 *	−3.5922

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table 6. ARDL long-run estimates, countries, 2020.

Country	Parameter	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
China	Coefficient	−0.0209	0.0045	0.1018	0.1576	0.2665	0.2301	0.0305	−0.1447	−0.0160	−0.0562	5.2815
	t-stat	1.5622 *	1.9832 **	3.3090 **	−5.8935 **	4.4587 **	−4.5634 **	1.4986 *	3.5981 **	3.2999 ***	3.6645 ***	3.1874
Denmark	Coefficient	−0.0113	−0.0222	0.0626	0.1409	0.0453	0.0465	0.1003	−0.0160	0.0764	0.0650	−6.2966
	t-stat	3.5620 *	2.6874 *	3.5527 **	−1.5412 **	3.3300 *	−4.1384 *	2.7056 **	−3.4885 *	4.6081 *	5.4817 *	−1.1383
Iceland	Coefficient	0.0098	0.0100	0.4215	0.4005	0.3196	0.1350	0.4084	−0.0023	0.0508	0.0053	4.2650
	t-stat	2.4091 *	3.3958 *	−3.7402 ***	3.7756 ***	−3.2091 **	3.4987 **	−2.6019 ***	−2.9044 *	1.7750 **	2.3601 **	2.5948
Japan	Coefficient	−0.3349	−0.1505	0.7414	0.6629	0.2448	0.3231	0.5367	0.2340	−0.1506	−0.2064	−3.4896
	t-stat	−3.0072 ***	−2.2061 ***	1.7750 ***	2.0026 ***	−3.5093 ***	−2.2297 ***	1.5873 ***	2.3851 **	4.6095 ***	2.3091 ***	−4.7750
Norway	Coefficient	−0.0506	−0.0512	0.0680	0.0804	0.1237	0.2095	0.2066	0.5391	0.0572	0.0088	3.2409
	t-stat	−1.2347 **	−2.1985 **	3.0221 **	2.5875 **	−1.2091 *	−1.1986 *	2.3914 **	3.0056 ***	−2.4095 **	−2.7093 **	2.1778
Russia	Coefficient	0.0059	0.0308	0.0735	0.1509	0.0334	0.0405	0.1276	−0.0627	0.0084	0.0103	−4.0516
	t-stat	4.0692 **	3.4813 **	−2.3918 *	−1.5601 *	−2.5963 *	−1.2761 *	2.1052 *	−3.6091 *	1.0016 *	2.3967 *	−3.0793
South Korea	Coefficient	−0.0987	−0.0570	0.3408	0.2694	0.2409	0.2063	0.4168	0.0705	−0.0506	−0.0848	2.5908
	t-stat	−2.4094 ***	−2.3091 ***	1.4915 ***	1.6021 ***	2.5710 ***	1.7092 ***	2.0594 **	−2.9776 **	2.1741 ***	2.3999 ***	2.0007
Sweden	Coefficient	0.0010	0.0052	0.1529	0.2073	0.2196	0.1500	0.1234	−0.0601	0.0025	0.0807	−4.0675
	t-stat	2.3881 *	2.0655 *	−4.1884 **	−3.8996 **	−1.3609 *	−2.4861 *	1.8602 **	−3.1498 *	1.4082 *	2.2061 *	−3.2981

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

In both short-run and long-run ARDL estimations for the 2020 model (Tables 4 and 6), we see how the values of the maritime connectivity at the country and port levels are affected by the number of confirmed COVID-19 cases and deaths (or rather lockdowns and restrictions imposed to maritime transportation due to the pandemic). It is safe to assume that the pandemic-related logistics constraints are reflected in the connectivity index body through a decrease in the number of ship calls at ports or a breakdown of shipping services between countries. Still, we identify associations between X_{1-2} and Y in all eight countries, though of varying strength and direction. The strongest negative link between Y and X_1 (an increase in the number of COVID-19 cases is associated with a decrease in maritime connectivity) is observed in Japan and South Korea, the two countries that have been most severely hit by the COVID-19 outbreak among those included in the study. In China, where the number of COVID-19 cases has been much lower compared to that in the countries of Asia, Northern Europe, and Russia (while the spread of the virus was curbed in the first half of 2020), an adverse effect of X_1 on Y is negligible. In those countries where the lockdowns have been relatively mild (Sweden, Russia) or the number of COVID-19 cases has remained low (Iceland, Greenland), the Y-X_{1-2} linkages are weak.

3.3. Robustness Test

The employment of the FMOLS and DOLS tests demonstrates the ARDL estimates' robustness in both the 2015–2019 and the 2020 models. The number of new confirmed COVID-19 cases is confirmed to result in lower maritime connectivity levels in Japan and South Korea (significance at 1% level) and, to a lesser extent, in Norway, Denmark, and China (Table 7).

The impact of the number of new confirmed COVID-19 deaths on the SCI is noticeably lower across all eight economies. This difference can be attributed to the fact that governments have been attempting to curb the transboundary spread of the virus by introducing restrictions based on the number of new cases. The number of deaths is an indicator of how national health care systems have coped with the pandemic, rather than a parameter of stringency of logistics and economic restrictions.

When comparing the 2020 estimations with the 2015–2019 FMOLS and DOLS test results (Table 8), we should emphasize tighter linkages between maritime connectivity and trade-related variables in the pre-pandemic period. The prevalence of statistically strong interplays between Y and X_{3-4} is confirmed in Japan, South Korea, and Iceland. The China-PSR trade paradigm is particularly relevant for maritime connectivity in Japan and South Korea (significance at 1% level for both exports and imports), Norway and Iceland (significance at 5% level), and Denmark, Russia, and Sweden (significance at 5% level for exports to China). In the case of China, the robustness test does not show an essential strengthening of Y-X_{5-6} linkages in 2020 compared to 2015–2019, but the interplays in $[Y; X_5]$ and $[Y; X_6]$ pairs remain statistically strong both before and during the pandemic.

Regarding prices of minerals, fuels, and food and agricultural products, the FMOLS-DOLS test confirms earlier revealed ARDL estimates. We see that in net importing economies, a decrease in prices exerts a reverse influence on the maritime connectivity. The strongest effects of this kind are observed in Japan, South Korea, and China for food and agricultural products, as well as in China, Denmark, Iceland, Sweden, and South Korea for oil, natural gas, and coal. In net exporting countries, the prices-connectivity relationship is commonly direct, for example, in Iceland, Russia, Norway, Sweden, and Denmark for minerals, Norway and Russia for fuels, and Denmark, Iceland, Norway, Sweden, and Russia for food and agricultural products.

3.4. Causality Directions

The TY test demonstrates the most significant causality flowing from the number of new confirmed COVID-19 cases to maritime connectivity in South Korea, Japan, and China. As revealed earlier, the number of COVID-19 deaths has no real impact on changes in the SCI score (Table 9).

Table 7. FMOLS and DOLS tests results, countries, 2020.

Country	Parameter	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
China	FMOLS coefficient	−0.0187	0.0041	0.1156	0.1344	0.2406	0.2220	0.0243	−0.1316	−0.0153	−0.0504	5.1438
	FMOLS t-stat	1.4153 *	1.5385 **	3.0287 **	−5.6193 **	4.2857 **	−4.3451 **	1.0054 *	3.2852 **	3.1709 ***	3.3572 ***	4.2065
	DOLS coefficient	−0.0130	0.0054	0.0983	0.1197	0.2181	0.1956	0.0250	−0.1247	−0.0147	−0.0427	5.0032
	DOLS t-stat	1.6831 *	1.2042 **	2.4321 **	−4.3852 **	4.0729 **	−4.1328 **	1.0396 *	2.7953	3.0865 ***	3.1845 ***	4.1739
Denmark	FMOLS coefficient	−0.0105	−0.0016	0.0578	0.1354	0.0412	0.0424	0.0975	−0.0140	0.0723	0.0631	−6.3945
	FMOLS t-stat	3.1548 *	2.2000 *	3.3132 **	−1.3805 **	3.1844 *	−4.0538 *	2.5214 **	−3.2481 *	4.4808 *	5.1536 *	−3.0082
	DOLS coefficient	−0.0127	−0.0088	0.0615	0.1442	0.0383	0.0415	0.0827	−0.0125	0.639	0.0528	−5.2631
	DOLS t-stat	3.2740 *	2.3523 *	3.2057 **	−1.2790 **	3.2567 *	−4.1782 *	2.6064 **	−3.1225 *	4.2055 *	5.2552 *	−4.3994
Iceland	FMOLS coefficient	0.0084	0.0097	0.4153	0.3886	0.3093	0.1290	0.4158	−0.0014	0.0457	0.0049	4.1486
	FMOLS t-stat	2.1095 *	3.1684 *	−3.2584 ***	3.5940 ***	−3.1875 **	3.2368 **	−2.3362 ***	−2.0740 **	1.6521 **	2.0748 **	3.5509
	DOLS coefficient	0.0069	0.0080	0.3968	0.3732	0.3149	0.1321	0.3967	−0.0035	0.0553	0.0037	4.0043
	DOLS t-stat	2.3804 *	3.2515 *	0.4251 ***	3.2049 ***	−3.2648 **	3.3489 **	−2.1680 ***	−1.8589 **	1.4474 **	2.1485 **	3.2817
Japan	FMOLS coefficient	−0.3077	−0.0339	0.6826	0.6537	0.2234	0.3006	0.5163	−0.1144	−0.1361	−0.1750	−4.6700
	FMOLS t-stat	−2.4985 ***	−2.0376 ***	1.5485 ***	2.1940 ***	−3.1555 ***	−2.1348 ***	1.2850 ***	2.0379 **	4.2683 ***	2.1322 ***	−3.3574
	DOLS coefficient	−0.3150	−0.0532	0.7038	0.6218	0.2165	0.2872	0.4734	−0.1352	−0.1075	−0.1894	−4.2382
	DOLS t-stat	−3.0064 ***	−2.1011 ***	1.4624 ***	2.0741 ***	−3.2902 ***	−2.3641 ***	1.3258 ***	2.1567 **	4.1954 ***	2.2051 ***	−3.8595
Norway	FMOLS coefficient	−0.0487	−0.0094	0.0635	0.0746	0.1053	0.2140	0.1846	0.5250	0.0495	0.0082	3.1570
	FMOLS t-stat	−1.0039 **	−2.0830 **	3.0000 **	2.2566 **	−1.1845 *	−1.1283 *	2.2952 **	3.1227 ***	−2.2211 **	−2.3549 **	2.2064
	DOLS coefficient	−0.0406	−0.0113	0.0597	0.7212	0.1190	0.2036	0.1703	0.4942	0.0468	0.0074	3.1282
	DOLS t-stat	−1.0158 **	−2.1947 **	3.0516 **	2.1337 **	−1.0698 **	−1.2562 **	2.1784 **	3.1396 ***	−2.1690 **	−2.1513 **	2.3975
Russia	FMOLS coefficient	0.0047	0.0286	0.0744	0.1368	0.0312	0.0395	0.1069	0.0648	0.0076	0.0114	−4.0373
	FMOLS t-stat	4.0254 **	3.3485 **	−2.1586 *	−1.4195 *	−2.1877 *	−1.2136 *	2.0625 *	−3.5351 *	1.0350 *	2.1538 *	−3.2480
	DOLS coefficient	0.0039	0.0251	0.0600	0.1206	0.0290	0.0253	0.1123	−0.0774	0.0137	0.0152	−4.1488
	DOLS t-stat	4.0160 **	3.1492 **	−2.1173 **	−1.3017 **	−2.2184 *	−1.1545 *	1.9258 *	−3.1695 *	1.2594 *	2.2705 *	−3.3694
South Korea	FMOLS coefficient	−0.0916	−0.0134	0.3142	0.2355	0.2138	0.1850	0.3867	−0.1684	−0.0482	−0.0758	2.6212
	FMOLS t-stat	−2.2475 ***	−2.4872 ***	1.2676 ***	1.4772 ***	2.2754 ***	1.4431 ***	2.0258 **	−2.4376 **	2.0863 ***	2.1450 ***	2.3597
	DOLS coefficient	−0.0723	−0.0165	0.2890	0.2142	0.1849	0.1942	0.4250	−0.1593	−0.0490	−0.0649	2.5073
	DOLS t-stat	−2.0649 ***	−2.1840 ***	1.3574 ***	1.2095 ***	2.0687 ***	1.5185 ***	1.8637 **	−2.5499 **	1.9317 ***	2.2478 ***	2.4826
Sweden	FMOLS coefficient	0.0013	0.0048	0.1349	0.2146	0.1960	0.1414	0.1066	−0.0583	0.0021	0.0796	−4.0918
	FMOLS t-stat	2.2454 *	1.7487 *	−4.0268 **	−3.6384 **	−1.2694 *	−2.1342 *	1.5284 **	−3.0574 *	1.3780 *	2.1347 *	−3.4275
	DOLS coefficient	0.0017	0.0030	0.1253	0.1852	0.1775	0.1286	0.1127	−0.0439	0.0033	0.0625	−4.1207
	DOLS t-stat	2.1056 **	1.5389 **	−3.7995 **	−3.2591 **	−1.3038 **	−2.2963 *	1.6435 **	−2.5665 **	1.2684 *	2.0000 **	−3.3590

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table 8. FMOLS and DOLS tests results, countries, 2015–2019.

Country	Parameter	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
China	FMOLS coefficient	0.1862	0.1527	0.2418	0.2135	0.0542	−0.1893	−0.0536	−0.0624	3.3891
	FMOLS t-stat	2.7265 **	−3.8184 **	2.4633 **	−3.1632 **	1.3490 **	2.2002 **	3.6289 ***	2.2016 ***	2.4400
	DOLS coefficient	0.1900	0.1301	0.2147	0.2470	0.0584	−0.1625	−0.0577	−0.0680	3.1576
	DOLS t-stat	3.5528 **	−2.3710 **	2.3592 **	−3.0083 **	1.5746 **	2.0371 **	3.5825 ***	2.4672 ***	2.5965
Denmark	FMOLS coefficient	0.1753	0.1569	0.1251	0.0536	0.1285	−0.0310	0.0531	0.0865	−2.1327
	FMOLS t-stat	1.9791 **	−2.1062 **	2.4604 **	−3.7518 *	1.5703 **	−4.2592 *	2.6094 **	4.1541 **	−1.6056
	DOLS coefficient	0.1684	0.1638	0.1309	0.0522	0.1052	−0.0286	0.0627	0.0970	−2.1594
	DOLS t-stat	2.1550 **	−2.0571 **	2.3700 **	−3.6295 *	1.6481 **	−4.0007 *	2.4862 **	3.8253 **	−1.7380
Iceland	FMOLS coefficient	0.5562	0.4506	0.3185	0.1900	0.6673	−0.0924	0.0458	0.0586	5.2462
	FMOLS t-stat	−2.3673 ***	3.0021 **	−1.7370 **	2.8725 **	−1.7241 ***	−3.8712 *	1.7004 **	2.5432 **	3.5117
	DOLS coefficient	0.5159	0.4425	0.3213	0.1747	0.6208	−0.0853	0.0573	0.0594	5.2085
	DOLS t-stat	−2.4851 ***	3.2174 **	−1.6536 **	2.7582 **	−1.6532 ***	−3.6905 *	1.6841 **	2.6709 **	3.2439
Japan	FMOLS coefficient	0.7083	0.6910	0.3057	0.3447	0.5613	−0.1342	−0.1463	−0.1800	−3.0557
	FMOLS t-stat	2.1360 ***	2.7382 ***	−3.1725 ***	−2.5184 ***	1.7481 ***	1.5397 ***	3.1205 ***	1.2941 ***	−4.4186
	DOLS coefficient	0.6749	0.6425	0.3158	0.3085	0.5357	−0.1308	−0.1738	−0.1752	−3.7305
	DOLS t-stat	2.5261 ***	2.6957 ***	−3.2621 ***	−2.4850 ***	1.6232 ***	1.4841 ***	3.3463 ***	1.5384 ***	−3.8419
Norway	FMOLS coefficient	0.1106	0.0844	0.1625	0.2492	0.2383	0.5325	0.0676	0.0375	2.3568
	FMOLS t-stat	2.4295 **	2.2598 **	−1.2463 **	−1.3051 **	2.3966 **	3.2692 ***	−2.3315 **	−2.1632 **	2.2571
	DOLS coefficient	0.0918	0.0793	0.1792	0.2174	0.2157	0.5046	0.0582	0.0491	2.4915
	DOLS t-stat	2.3704 ***	2.3201 ***	−1.3758 **	−1.2593 **	2.0582 **	3.0001 ***	−2.4071 **	−2.0586 **	2.0868
Russia	FMOLS coefficient	0.0937	0.2257	0.0759	0.0890	0.1693	0.0728	0.0185	0.0257	−3.4036
	FMOLS t-stat	−2.7251 *	−1.8942 **	−2.3682 **	−2.4173 *	2.5256 **	−2.2735 **	2.1263 **	4.6280 *	−3.0157
	DOLS coefficient	0.0863	0.2084	0.0483	0.0752	0.1508	−0.0594	0.0242	0.0199	−3.3885
	DOLS t-stat	−2.4009 **	−1.7511 **	−2.7500 **	−2.1845 *	2.4775 **	−2.5002 **	2.0736 **	3.2875 **	−2.8730
South Korea	FMOLS coefficient	0.2416	0.2897	0.3149	0.1746	0.4369	−0.1715	−0.0695	−0.1488	5.1404
	FMOLS t-stat	1.1875 ***	1.5096 ***	3.7490 ***	2.0289 ***	3.1830 **	−1.8154 **	4.0051 ***	2.3269 ***	3.9748
	DOLS coefficient	0.2193	0.2795	0.3287	0.1980	0.4068	−0.1729	−0.5704	−0.1267	4.2541
	DOLS t-stat	1.0632 ***	1.6006 ***	3.4211 ***	1.7176 ***	3.0127 **	−1.9952 **	3.9827 ***	2.0946 ***	3.8826
Sweden	FMOLS coefficient	0.1709	0.2053	0.1900	0.1538	0.1247	−0.0414	0.0285	0.0874	−5.0107
	FMOLS t-stat	−4.5286 **	−3.1602 **	−1.7396 **	−2.3871 *	2.0093 **	−1.1987 *	3.1994 *	1.3086 *	−3.2485
	DOLS coefficient	0.1047	0.1886	0.1794	0.1604	0.1309	−0.0355	0.0305	0.0500	−4.7526
	DOLS t-stat	−3.9405 ***	−3.2943 ***	−1.5708 **	−2.0175 *	1.8548 **	−1.2893 **	2.4685 **	1.4429 *	−3.5982

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table 9. TY causality test results, countries, 2015–2019 and 2020.

Causality Directions	Parameter	China		Denmark		Iceland		Japan		Norway		Russia		South Korea		Sweden	
		2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020
$Y \to X_1$	TS		3.05		4.66		0.85		7.31		0.46		3.02		6.11		1.06
	P		0.09 *		0.08 *		0.66		0.04 **		0.77		0.09 *		0.04 **		0.49
$X_1 \to Y$	TS		5.58		1.53		0.64		3.04		0.58		0.39		5.80		0.90
	P		0.08 *		0.27		0.79		0.08 *		0.69		0.50		0.04 **		0.53
$Y \to X_2$	TS		1.86		1.04		0.62		1.10		0.37		0.86		0.83		1.01
	P		0.45		0.35		0.80		0.26		0.80		0.44		0.37		0.50
$X_2 \to Y$	TS		0.72		0.90		0.55		1.39		0.51		0.30		3.25		0.86
	P		0.68		0.44		0.83		0.15		0.72		0.59		0.09 *		0.54
$Y \to X_3$	TS	13.07	15.46	3.65	1.75	2.18	1.94	9.15	16.22	7.37	9.70	0.85	0.98	12.69	10.26	0.77	4.05
	P	0.00 ***	0.00 ***	0.15	0.22	0.27	0.36	0.01 **	0.00 ***	0.05 *	0.03 **	0.44	0.40	0.02 **	0.01 **	0.37	0.06 *
$X_3 \to Y$	TS	8.88	6.84	6.46	7.15	9.09	9.95	13.56	13.25	5.29	5.83	0.63	3.21	19.67	7.42	3.88	2.23
	P	0.03 **	0.06 *	0.07 *	0.07 *	0.02 **	0.03 **	0.00 ***	0.00 ***	0.08 *	0.07 *	0.52	0.09 *	0.00 ***	0.03 **	0.06 *	0.12
$Y \to X_4$	TS	10.50	13.09	2.98	1.26	2.00	1.14	10.95	14.40	4.31	8.88	1.14	1.18	12.25	15.42	0.66	1.47
	P	0.02 **	0.00 ***	0.28	0.30	0.31	0.57	0.00 ***	0.00 ***	0.09 *	0.04 **	0.29	0.36	0.02 **	0.00 ***	0.42	0.30
$X_4 \to Y$	TS	10.98	7.25	6.12	7.00	8.16	8.52	12.04	13.13	7.02	7.69	1.66	3.90	17.50	6.84	2.79	3.79
	P	0.02 **	0.05 *	0.07 *	0.07 *	0.03 **	0.04 **	0.00 ***	0.00 ***	0.05 *	0.05 *	0.15	0.07 *	0.00 ***	0.04 **	0.08 *	0.07 *
$Y \to X_5$	TS	11.35	12.96	0.51	3.46	1.37	4.44	2.82	7.27	0.58	2.06	0.43	0.34	8.74	13.70	0.58	1.86
	P	0.00 ***	0.00 ***	0.76	0.08 *	0.40	0.09 *	0.08 *	0.04 **	0.79	0.22	0.62	0.52	0.05 *	0.00 ***	0.45	0.22
$X_5 \to Y$	TS	6.72	5.24	7.84	9.41	11.24	11.17	9.55	4.54	10.13	5.20	1.00	1.41	10.01	4.95	3.13	3.54
	P	0.04 **	0.08 *	0.03 **	0.02 **	0.01 **	0.01 **	0.01 **	0.06 *	0.01 **	0.07 *	0.35	0.27	0.03 **	0.07 *	0.07 *	0.08 *
$Y \to X_6$	TS	7.46	12.41	0.79	3.08	1.25	1.92	4.38	6.92	0.85	3.99	0.79	1.11	7.07	10.14	0.83	1.65
	P	0.03 **	0.00 ***	0.61	0.09 *	0.43	0.37	0.05 *	0.04 **	0.56	0.09 *	0.48	0.38	0.06 *	0.01 **	0.33	0.27
$X_6 \to Y$	TS	6.05	7.77	5.40	5.99	6.28	6.03	7.47	3.80	6.55	7.05	0.27	0.24	14.32	4.37	2.04	2.12
	P	0.04 **	0.04 **	0.08 *	0.07 *	0.06 *	0.07 *	0.02 **	0.07 *	0.06 *	0.05 *	0.80	0.66	0.01 **	0.07 *	0.09 *	0.15
$Y \to X_7$	TS	3.22	2.23	3.47	0.95	0.97	0.90	0.68	0.70	2.83	2.10	3.71	4.78	1.13	0.74	1.14	3.11
	P	0.09 *	0.25	0.23	0.42	0.51	0.63	0.49	0.54	0.14	0.21	0.08 *	0.05 *	0.60	0.43	0.19	0.09 *
$X_7 \to Y$	TS	5.13	2.41	8.55	6.53	1.14	1.20	1.04	0.96	4.90	2.16	6.58	4.22	1.93	0.48	3.00	2.05
	P	0.04 **	0.20	0.02 **	0.07 *	0.48	0.55	0.30	0.49	0.08 *	0.19	0.00 ***	0.06 *	0.41	0.52	0.07 *	0.16
$Y \to X_8$	TS	1.37	1.29	2.20	0.49	0.76	0.73	0.41	0.22	4.27	11.71	2.84	3.78	1.74	1.06	0.93	1.18
	P	0.43	0.51	0.37	0.68	0.59	0.71	0.62	0.83	0.09 *	0.02 **	0.09 *	0.07 *	0.46	0.20	0.26	0.45
$X_8 \to Y$	TS	5.90	4.97	3.14	0.82	1.27	0.88	2.24	5.37	21.40	18.48	5.97	6.16	9.84	9.99	1.07	0.97
	P	0.04 **	0.08 *	0.28	0.50	0.44	0.64	0.09 *	0.04 **	0.00 ***	0.00 ***	0.03 **	0.02 **	0.04 **	0.01 **	0.21	0.51
$Y \to X_9$	TS	2.98	8.47	0.84	1.93	4.25	5.47	1.45	2.71	1.22	8.25	3.02	5.85	2.59	4.60	0.85	5.28
	P	0.09 *	0.03 **	0.55	0.16	0.15	0.08 *	0.23	0.09 *	0.32	0.04 **	0.09 *	0.03 **	0.30	0.07 *	0.32	0.03 **
$X_9 \to Y$	TS	7.01	10.73	6.90	4.25	15.37	13.06	6.19	6.25	17.53	13.06	5.25	4.15	11.97	12.53	4.12	2.97
	P	0.03 **	0.02 **	0.04 **	0.08 *	0.00 ***	0.00 ***	0.03 **	0.04 **	0.00 ***	0.01 **	0.04 **	0.06 *	0.02 **	0.00 ***	0.04 **	0.09 *
$Y \to X_{10}$	TS	1.01	4.84	1.55	0.36	0.53	0.60	0.77	0.48	0.64	0.61	3.58	5.26	0.95	3.58	0.30	1.62
	P	0.56	0.08 *	0.47	0.70	0.68	0.81	0.45	0.77	0.71	0.64	0.08 *	0.04 **	0.64	0.09 *	0.59	0.28
$X_{10} \to Y$		9.67	11.86	5.02	1.61	0.82	0.66	4.30	9.96	0.73	0.42	5.01	3.69	5.33	7.27	0.69	0.50
	P	0.02 **	0.01 **	0.09 *	0.27	0.57	0.77	0.05 *	0.03 **	0.69	0.79	0.04 **	0.07 *	0.08 *	0.03 **	0.41	0.74

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively; TS = test statistics; P = *p* value. Source: Authors' calculation.

Among the ten X_n variables included in the study, the most decisive influence on Y is exerted by exports to and imports from the world, particularly in countries where maritime transport dominates as a means of freight traffic (Japan, South Korea, Iceland). In some $[Y; X_3]$ and $[Y; X_4]$ pairs, we see bidirectional interactions between the variables with a particularly strong influence of Y on either exports or imports in 2020. Reasoning from this finding, we can assume that the parameters that compose the SCI have gained significance amid the pandemic and have directly affected the value of foreign trade operations at ports (for example, through restrictions to some shipping services, quarantine requirements to vessels, cargo, and crew, or reduced number of ship calls). We should also stress the reverse $Y \rightarrow X_1$ causality link in Japan, South Korea, China, Russia, and Denmark, which could signify the role maritime transportation has played in the transboundary spread of the virus.

To a considerable degree, causality links in the $[Y; X_5]$ and $[Y; X_6]$ pairs iterate those between maritime connectivity and trade with the world—the impact of Y on the China-PSR trade grows, while the reverse causality flowing from trade to connectivity weakens. In 2020, trade with China still exerts a statistically strong influence on the SCI score in Northern Europe (Denmark, Iceland, Norway) and Russia. In Japan and South Korea, the impact of connectivity on trade with China surpasses that of trade on connectivity evidenced in 2015–2019. A similar trend is observed on China's side in trade with PSR countries, but both $X_5 \rightarrow Y$ and $X_6 \rightarrow Y$ causality links remain strong.

The causalities between prices and maritime connectivity become weaker in January–September 2020 compared to 2015–2019. Among X_{7-10} variables, we see the weakest influence of minerals prices on the SCI across all eight countries. The $X_8 \rightarrow Y$ causality link strengthens in Japan, South Korea, and China, which could probably designate the increase in fuel purchases amid falling global prices to establish reserves. The reasons, directions, and strengths of particular causality links in 2020 compared to the pre-pandemic period are detailed and discussed in the next section.

4. Discussion

Possible consequences of the COVID-19 pandemic to maritime connectivity are addressed as changes in causality linkages between variables in the 2020 model compared to the 2015–2019 model. As the TY framework assumes, these changes can be reflected through either the direction of causality, the strength of causality, or both (Table 10).

Proceeding from breaking the array of independent variables down to the pandemic-related, trade, and market segments (X_{1-2}, X_{3-6}, and X_{7-10}, respectively), possible influences on maritime connectivity in the course of the COVID-19 outbreak are further addressed separately.

4.1. Pandemic Effects

Unsurprisingly, both the ARDL analysis and the TY causality test show that the COVID-19 outbreak can be associated with monthly changes in the SCI scores that have been observed by the UNCTAD [1], research and statistics entities [112–114], and many scholars worldwide [16,115–117]. However, in contrast to Samli [118], Koyuncu et al. [119], and some other authors who estimated the pandemic impacts on commerce at container ports, we do not observe strong linkages between the number of COVID-19 cases and the overall SCI score. Across the countries and ports included in the study, the causality flowing from the number of new COVID-19 cases to maritime connectivity is either weak or average (Japan and China). Only in South Korea, the strength of the causality is estimated as above average, but it is bidirectional at the same time. Bidirectional links are also observed in China and Japan, while in Denmark and Russia, connectivity parameters affect the spread of the virus, and not the other way around.

Table 10. Strengths and directions of the Y-X_n causality links in 2015–2019 and 2020.

Causality Directions	China		Denmark		Iceland		Japan		Norway		Russia		South Korea		Sweden	
	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020	2015-19	2020
$Y \to X_1$		A/BC		A/UC		W/NC		AA/BC		W/NC		A/UC		AA/BC		W/NC
$X_1 \to Y$		A/BC		W/RC		W/NC		A/BC		W/NC		W/RC		AA/BC		W/NC
$Y \to X_2$		W/NC		W/NC		W/NC		W/NC		W/NC		W/NC		W/RC		W/NC
$X_2 \to Y$		W/NC		W/NC		W/NC		W/NC		W/NC		W/NC		A/UC		W/NC
$Y \to X_3$	S/BC	S/BC	W/RC	W/RC	W/RC	W/RC	AA/BC	S/BC	A/BC	AA/BC	W/NC	W/RC	AA/BC	AA/BC	W/RC	A/UC
$X_3 \to Y$	AA/BC	A/BC	A/UC	A/UC	AA/UC	AA/UC	S/BC	S/BC	A/BC	A/BC	W/NC	A/UC	S/BC	AA/BC	A/UC	W/RC
$Y \to X_4$	AA/BC	S/BC	W/RC	W/RC	W/RC	W/RC	S/BC	S/BC	A/BC	AA/BC	W/NC	W/RC	AA/BC	S/BC	W/RC	W/RC
$X_4 \to Y$	AA/BC	A/BC	A/UC	A/UC	AA/UC	AA/UC	S/BC	S/BC	A/BC	A/BC	W/NC	A/UC	S/BC	AA/BC	A/UC	A/UC
$Y \to X_5$	S/BC	S/BC	W/RC	A/BC	W/RC	A/BC	A/BC	AA/BC	W/RC	W/RC	W/NC	W/NC	A/BC	S/BC	W/RC	W/RC
$X_5 \to Y$	AA/BC	A/BC	AA/UC	AA/BC	AA/UC	AA/BC	AA/BC	A/BC	AA/UC	A/UC	W/NC	W/NC	AA/BC	A/BC	A/UC	A/UC
$Y \to X_6$	AA/BC	S/BC	W/RC	A/BC	W/RC	W/RC	A/BC	AA/BC	W/RC	A/BC	W/NC	W/NC	A/BC	AA/BC	W/RC	W/NC
$X_6 \to Y$	AA/BC	AA/BC	A/UC	A/BC	A/UC	A/UC	AA/BC	A/BC	A/UC	A/BC	W/NC	W/NC	AA/BC	A/BC	A/UC	W/NC
$Y \to X_7$	A/BC	W/NC	W/RC	W/RC	W/NC	W/NC	W/NC	W/NC	W/RC	W/NC	A/BC	A/BC	W/NC	W/NC	W/RC	A/UC
$X_7 \to Y$	AA/BC	W/NC	AA/UC	A/UC	W/NC	W/NC	W/NC	W/NC	A/UC	W/NC	S/BC	A/BC	W/NC	W/NC	A/UC	W/RC
$Y \to X_8$	W/RC	W/RC	W/NC	W/NC	W/NC	W/NC	W/RC	W/RC	A/BC	AA/BC	A/BC	A/BC	W/RC	W/RC	W/NC	W/NC
$X_8 \to Y$	AA/UC	A/UC	W/NC	W/NC	W/NC	W/NC	A/UC	AA/UC	S/BC	S/BC	AA/BC	AA/BC	AA/UC	AA/UC	W/NC	W/NC
$Y \to X_9$	A/BC	AA/BC	W/RC	W/RC	W/RC	A/BC	W/RC	A/BC	W/RC	AA/BC	A/BC	AA/BC	W/RC	A/BC	W/RC	AA/BC
$X_9 \to Y$	AA/BC	AA/BC	AA/UC	A/UC	S/UC	S/BC	AA/UC	AA/BC	S/UC	AA/BC	AA/BC	A/BC	AA/UC	S/BC	AA/UC	A/BC
$Y \to X_{10}$	W/RC	A/BC	W/RC	W/NC	W/NC	W/NC	W/RC	W/RC	W/NC	W/NC	A/BC	AA/BC	W/RC	A/BC	W/NC	W/NC
$X_{10} \to Y$	AA/UC	AA/BC	A/UC	W/NC	W/NC	W/NC	A/UC	AA/UC	W/NC	W/NC	AA/BC	A/BC	A/UC	AA/BC	W/NC	W/NC

Note: S = strong causality link; AA = above average strength of causality link; A = average strength of causality link; W = weak causality link; UC = unidirectional causality; BC = bidirectional causality; RC = reverse causality; NC = neutral causality. Source: Authors' calculation.

It is safe to assume that the reverse or bidirectional interactions between the number of COVID-19 cases in a country and the maritime connectivity are attributed to the roles that certain constituents of the SCI (the number of ship calls, the number of regular shipping services from and to the country, the number of countries that are connected to the country through shipping) could play in the transboundary spread of the virus. According to the UNCTAD [1], the pandemic led to fewer port calls for most vessel types during the first half of 2020, which contributed to a breaking of virus transmission chains, but resulted in significant drops in maritime connectivity scores in China, Norway, Iceland, Russia, South Korea, and Sweden in January–June 2020 (Appendix A, Table A1). As demonstrated by Hsiang et al. [7], Deb et al. [120], and Chinazzi et al. [121], travel restrictions, mandatory quarantines, and other containment measures applied to maritime transportation have had a decisive influence on the reduction of the rate of virus transmission. Nevertheless, in South Korea and Japan (to a lesser extent, in Denmark, Russia, and China), we observe a distinct causality flowing from the SCI parameters to the number of new confirmed COVID-19 cases.

A new concern has emerged as researchers confirmed that the virus could survive on frozen foods [122]. Since fall 2020, Chinese sanitary authorities have been tracing the presence of viral genetic material in meat, fish, and seafood cold chains across the country [123,124]. Most of the local outbreaks since then (Qingdao, Dalian, Shanghai) have been directly associated with imported cold-chain products at ports (fish and seafood products from Russia, Norway, Indonesia, and Ecuador and beef and chicken wings from Brazil) [123]. In September 2020, China introduced precautionary measures against aquatic products from Norway [125] and then closed all ports to fish imports from Russia in December 2020 [126] to prevent the spread of the virus. It should be expected that the SCI scores for Chinese, Russian, and other PSR ports will continue to be depressed until import bans and other COVID-19 containment measures are lifted.

4.2. Trade Effects

Some experts argue that such safety-related restrictions to maritime trade significantly add to the deglobalization shift that has accelerated in recent years amid trade tensions between China and the USA, and a new rise of protectionist policies across the world [127–131]. Minárik and Čiderová [54], Ibn-Mohammed et al. [132], and Qin et al. [133] demonstrate how trade has succumbed to regional loci in the course of the pandemic, while supply chains have been reshaped, fragmented, and geographically dispersed due to restrictions to transboundary transportation. The Flock Freight [134] provides a growing number of examples of shortened supply chains with elements of nearshoring, reshoring, and redundancy (maintaining excess inventory). The UNCTAD [1] even forecasts a shift away from single country-centric sourcing and China's weaker role in certain maritime supply chains that both could happen due to the disruptions brought by the COVID-19 outbreak.

In support of these estimations, our results show much weaker $X_3 \rightarrow Y$ and $X_4 \rightarrow Y$ causality links in 2020 compared to 2015–2019 in some countries and ports included in the study. In China (mainly in smaller ports like Rizhao, Lianyungang, Qinhuangdao, and Weihai), the impacts of exports and imports on the SCI score drop from above average to average. South Korea's Ulsan also goes down from strong to above average causality link between trade volumes and the maritime connectivity index. Simultaneously, we do not record substantial changes in trade-connectivity causality across Northern Europe, while in Russia, both exports and imports have strengthened their contribution to the overall national SCI score. This can be explained by the fact that supplies of minerals and fuels from Russia, Norway, and Nordic countries have not been so much disrupted in 2020 compared to South Korea's, Japan's, or China's hi-tech and manufacture exports [133]. In most of the NSR ports in Russia, as well as in Norway, Iceland, Denmark, and Sweden, we see the SCI rebounds in Q3 2020 compared to the first half of the year.

A good part of these exports go to China, which designates above average or average causalities flowing from both X_5 and X_6 to Y in all PSR countries except Russia—which

extensively trades with China's northwestern provinces through land border crossing points in Siberia and the Far East. Our calculations thus allow us to support the findings of Vidya and Prabheesh [135], who conclude that in many maritime supply chains, China's central position has not been as affected by the pandemic. According to Qin et al. [133], even in the course of the COVID-19 outbreak, China has remained one of the major sources of foreign value-add in total gross exports in Japan, South Korea, Russia, and other countries. Although Che et al. [136] evidenced a decline in China's trade with countries that suffered the most from the pandemic, we see that in Japan and South Korea, a contribution of trade with China to maritime connectivity has remained strong. The UNCTAD [1] emphasizes that China's maritime supply chains have appeared to be more resilient throughout the pandemic experience than other locations. In this sense, tighter connectivity between China and PSR economies contradicts many of the pandemic-related deglobalization and fragmentation fears, and instead establishes a foundation for China to continue developing the PSR initiative in the post-COVID era.

4.3. Market Effects

Minerals, fuels, and agricultural products are major categories of cargo transported via the Asia-Russia-Europe maritime corridor, but their influences on maritime connectivity in PSR countries are markedly different. For minerals, we observe insignificant changes in the already weak causality linkages between prices and the SCI scores. This well agrees with UNCTAD's estimation [1] that the pandemic-related reductions in mining and industrial activity had a minor impact on dry bulk trade in iron ore (78% of transit shipping in the NSR in 2020 [78]). Sand [137] associated slumps in construction and steel manufacturing in 2020 with declines in bulk trade in steel products, cement, and scrap metal. However, since China-PSR maritime trade in these commodities is negligible, we do not record visible changes in the $X_7 \rightarrow Y$ causality link. The causality link's strength decreases down to average in Russia and Denmark and weak in Sweden and Norway.

Trade in fuels, on the contrary, has been severely affected by the pandemic, while oil prices have turned out to be far more perceptible to the slowdown of economic activities compared to mineral prices [138–140]. Global oil demand has been depressed with restrictions on travel and transport and industrial activity cuts across the world [1]. China's imports of coal declined due to weaker power demand and lower oil and gas prices that have reduced the competitiveness of coal power generation. Global demand for liquefied natural gas has also come under pressure during the first quarter of 2020, while simultaneously the UNCTAD [1] reported that liquefied natural gas and liquefied petroleum gas carriers and tankers continued to record increases in port calls. A surplus in fuel production has filled oil and gas inventories to such an extent that many vessels were used as floating storage [1]. The latter accords with strengthening the $X_8 \rightarrow Y$ causality link revealed in Japan and South Korea, which established reserves of oil and gas amid lower prices [141,142]. For instance, in Pusan, South Korea, the SCI score lost only two points in Q2 2020 and then restored in Q3 2020 amid the increase in port and terminal utilization due to a rise in demand for storage capacities.

This trend is clearly traced in the case of the relationship between maritime connectivity and prices of food and agricultural products. The causality links between Y and X_9 and X_{10} become more assertive in 2020 compared to 2015–2019, with causalities flowing in both directions from prices to connectivity and backward. The most significant gains are observed in South Korea and Japan, the net importers of food products and agricultural raw materials. As reported by the UNCTAD [1], many shippers used advance yard storage in South Korea's, Japan's, and China's ports not only for fuels, but consumer commodities, food products, and grains. They then started moving goods early in spring and summer 2020, in anticipation of a resumption in demand and future commodity price developments. Large transit hubs like Pusan, Shanghai, Qingdao, Gothenburg, and Hakata have even benefited from lockdowns when storage space at ports has been used in cases where transit shipping has been suspended. Many studies have demonstrated emerging threats to global

food security [62,143] and tremendous disruptions in agricultural supply chains [144,145] due to the pandemic. Notwithstanding that Wang et al. [146] and Cao et al. [147] expect that the impacts of supply disruption would be short-lived, development of warehousing and storage capacities at ports along the PSR should be considered a fundamental issue to ensure the sufficiency of safety stocks and inventories. The improvement of port infrastructure connectivity, logistics performance [68], and diversification in maritime routes [1] will allow China and its counterparts to avoid localized disruptions, establish a multiple-location trade network in the High North, and enhance the resilience of supply chains globally.

5. Conclusions

The COVID-19 outbreak has caused unprecedented disruption to global supply chains. Lockdowns of people and businesses along with restrictions on transboundary mobility and transport have resulted in a significant loss in international trade, much of which has manifested itself in the maritime sector. Assessing the pandemic's influence on maritime connectivity entails a great deal of uncertainty due to a variety of public health, economic, social, logistics, political, and other factors that take on new significance. This is why segmentation of maritime trade landscape and modeling causality links between maritime connectivity and smaller arrays of contributing factors could become viable analysis options.

In the case of the China-PSR trade corridor, we attempted to investigate how different maritime connectivity parameters have been affected in January–September 2020 compared to the respective periods in 2015–2019. The study was performed at two levels in eight countries and thirty-five ports. The changes in the SCI (national level) and the PSCI (port level) were studied against ten independent variables, including the number of COVID-19 cases and deaths, trade volumes with China and the rest of the world, and price indexes of major categories of products transported via the NSR as the major throughway in the Arctic (minerals, fuels, and food and agricultural products). The consecutive application of the ADF and the PP tests, the ARDL method, the FMOLS and the DOLS robustness checks, and the TY causality test in 2015–2019 and 2020 allowed us to investigate differences in the short-run and long-run interactions and reveal the pandemic-related transformations in the causality directions between the variables. Major findings flowing from this study can be summarized as follows.

- The number of COVID-19 cases is found to exert a more decisive influence on the maritime connectivity in South Korea, Japan, and China, which experienced the outbreak earlier compared to Nordic countries and Russia, as well as introduced stricter containment measures. The bidirectional relationship between the number of cases and the SCI allows us to assume the contribution of maritime connectivity factors to the transboundary spread of the virus.
- The number of COVID-19 deaths has a negligible impact on the maritime connectivity that can be explained by the fact that governments have been introducing restrictions based on the number of new cases rather than deaths.
- Tight links between the value of trade with the world and the SCI index are revealed across all locations included in the study in the pre-pandemic period, but in 2020, the relationships become weaker amid the influence of non-economic factors.
- The China-PSR trade patterns significantly affect the maritime connectivity in all countries except Russia, where a bulk of trade with China is carried by rail through the land border. Similar to trade with the world, the influence of trade with China on maritime connectivity has weakened in the course of the pandemic.
- While the trade-SCI linkages have become less noticeable, the reverse causality flowing from the connectivity parameters to trade value has intensified with a reduced number of ship calls at ports, quarantine requirements to vessels and crew, and other virus containment measures applied to shipping services.

- Bigger hubs have been able to rebound sooner in their PSCI scores, rising in demand for storage capacity during shipping suspension, while smaller ports continue experiencing depressing effects of restrictions to transit shipping even in the third quarter of 2020. Therefore, we can assume that in times of sudden disruptions in logistics chains, ports with scarcer connections suffer more compared to diversified hubs. However, that depends on how the market situation matches the specialization of a particular port. For instance, in most of the NSR ports, the PSCI has not been much affected due to their narrow specialization on outbound freights (minerals and fuels, for which trade has declined to a lesser degree compared to manufacture and consumer products).
- Prices have exerted divergent influence on maritime connectivity for exporters and importers. In net importers, the SCI score has been supported by more intensive imports amid falling global prices, while net exporters have experienced a negative influence of consumption slowdown on their maritime connectivity indexes.

It is tough to tell when exactly the pandemic will be curbed, restrictions on transboundary travels and transportation will be lifted, and the global economy will recover. Nevertheless, we see that the China-PSR trade pattern has a substantial potential in terms of the maritime connectivity between countries and ports and the reliance of counterparts on trade with each other. In the 2020 model, the calculation was made for a short array of data covering only three quarters of the year, but the COVID-19 pandemic will obviously have a lasting impact on freight shipping. With the updates of the data on the number of COVID-19 cases, market information, and dynamics of maritime trade between China, Russia, Northern Europe, and Asia, the estimations could become more precise. The adjustments of calculations along with the continuous monitoring of causal interactions between variables will equip stakeholders with insights about the status of maritime connectivity in the China-PSR trade, potential risks, and implications on trade and commerce.

Author Contributions: G.T. and V.E. designed the research framework; G.T. conceptualized the materials and methods; A.A. and M.K. performed the data collection; V.E., A.A., and M.K. analyzed the data; V.E. wrote the paper. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Appendix A

Table A1. Shipping connectivity and Port shipping connectivity indexes, 2015–2019 and 2020.

Countries/Ports	2015–2019, Average			2020		
	January–March	April–June	July–September	January–March	April–June	July–September
China	144.25600	146.40976	147.93279	158.37064	156.22624	160.29146
China: Dalian	60.93514	61.86997	61.57053	62.50721	62.87025	62.95251
China: Lianyungang	33.31145	35.07333	34.77936	41.43848	46.19355	41.28514
China: Qingdao	86.18790	87.76649	90.39664	97.98079	95.50218	96.02562
China: Qinhuangdao	6.99576	7.58951	8.90611	8.11250	8.11250	8.11250
China: Rizhao	11.56061	11.86857	12.41058	14.76849	14.66254	13.20044
China: Shanghai	127.02952	129.25465	130.75849	136.85170	134.51027	138.91384
China: Weihai	2.41896	2.43323	2.05983	2.00949	2.00949	2.00949
China: Yantai	14.92416	14.10571	13.91985	13.04158	13.04158	12.51689
Denmark	45.09137	45.06750	45.65967	46.58867	46.23473	46.33711
Denmark: Aarhus	42.61198	42.66091	43.46878	44.91011	44.92916	44.83680
Denmark: Copenhagen	5.19696	4.73303	4.56877	4.33206	4.52781	4.72332
Denmark, Greenland: Nuuk	2.00112	2.00106	2.01526	2.02933	2.02933	5.08021
Iceland	5.31360	5.29465	5.31737	6.13933	6.01947	6.96187
Iceland: Reydharfjordur	3.79390	3.66378	3.91174	3.82918	4.62143	4.62143
Iceland: Reykjavik	5.20064	5.21542	5.17170	5.80252	5.53034	6.47786
Japan	75.34626	72.88415	71.77790	78.78389	88.64641	88.70137
Japan: Akita	3.34431	3.32231	3.67081	3.81099	4.02925	4.46471
Japan: Hakata	19.33510	19.04703	19.40562	18.41141	17.49040	17.45937
Japan: Kitakyushu	3.60891	3.94439	3.84279	7.40050	5.79934	3.64653
Japan: Niigata	5.75781	5.66677	5.77444	5.79424	5.60332	5.61266
Norway	9.71469	9.86324	10.22606	10.63827	9.63687	10.16871
Norway: Bergen	5.04260	5.16227	5.21057	5.87044	4.87413	5.05370
Norway: Hammerfest	1.57109	1.57109	1.57109	1.51746	1.17813	1.17813
Norway: Stavanger	2.32561	2.31488	2.29814	2.55296	2.55296	3.07447
Norway: Tromso	1.96436	1.96436	1.96436	1.91074	1.17813	1.17813
Norway: Trondheim	1.75531	1.79821	1.79821	1.17973	1.17813	2.06056
Russia	46.07389	43.19898	42.36271	35.98139	33.90037	33.46525
Russia: Anadyr	0.96594	0.96594	0.96633	0.73057	0.73056	0.73054
Russia: Arkhangelsk	0.56784	0.55588	0.55588	0.55586	0.55583	0.55580
Russia: Dudinka	1.63985	1.63982	1.63979	1.63980	1.63982	1.62975
Russia: Murmansk	3.17882	3.18298	3.17740	3.16982	3.17005	3.17249
Russia: Petropavlovsk	2.13561	2.14458	2.07056	1.78557	1.78504	1.78592
Russia: Pevek	1.13678	1.13679	1.13672	1.13668	1.13670	1.13674
Russia: Sabetta	0.49093	0.50922	0.50922	0.51891	0.50478	0.51293
Russia: Vladivostok	16.14067	14.07223	14.00720	13.93689	13.45200	13.78345
South Korea	98.44056	99.90325	101.46473	108.39640	106.95343	107.55277
South Korea: Gwangyang	60.50077	60.79394	61.83644	66.80079	65.30716	60.35533
South Korea: Pusan	108.68804	110.22309	111.70417	118.73122	116.39475	117.09869
South Korea: Ulsan	18.87085	18.95059	19.09108	23.73320	20.69843	19.27688
Sweden	46.62914	46.01937	47.93833	48.59986	47.64887	48.41985
Sweden: Gothenburg	41.34901	40.80150	42.72292	42.28518	42.34241	41.79951
Sweden: Halmstad	2.93740	3.58594	3.27535	3.16433	1.99846	2.72541

Source: Authors' development based on [79].

Appendix B

Table A2. ADF and PP results, countries, 2015–2019.

Country	Parameter	Y	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
China	ADF level	−1.46 **	−4.18 **	−2.43 ***	−0.28 **	−1.36 *	−2.40 **	−3.12 ***	−0.97 *	−2.57 ***
	ADF first difference	−3.17 **	−2.64 ***	−3.29 **	−1.27 *	−3.18	−1.97 ***	−1.80 **	−1.23 *	−3.60 **
	PP level	−4.20 *	−3.80 **	−2.15 ***	−0.94 **	−1.15 *	−2.86 **	−4.23 ***	−1.74	−2.08 ***
	PP first difference	−3.88 **	−2.95 ***	−3.50 **	−2.23 *	−2.94	−1.05 ***	−2.95 **	−0.60 **	−3.15 **
Denmark	ADF level	−2.47	−3.43 *	−1.26 *	−1.48 ***	−0.62 **	−3.48 ***	−0.19 *	−2.15 *	−2.42 *
	ADF first difference	−1.63 *	−2.19 **	−0.80 **	−2.03 **	−1.23 *	−4.62 ***	−1.28	−1.96 *	−1.69 **
	PP level	−1.94 **	−3.51 **	−1.38 *	−1.93 ***	−0.80 **	−3.23 **	−0.56 *	−0.48 **	−2.81 *
	PP first difference	−1.05 *	−2.58 *	−0.57 **	−2.66 **	−1.75 *	−4.19 ***	−1.44	−1.57 *	−1.85 **
Iceland	ADF level	−0.56 ***	−1.33 **	−2.00 ***	−0.49 ***	−0.55 ***	−2.48 ***	−0.75 *	−0.73 *	−1.33
	ADF first difference	−1.18 **	−0.87 ***	−1.69 **	−1.11 **	−2.17 *	−3.70 ***	−2.52	−0.95 *	−2.02 *
	PP level	−0.97 ***	−2.46 **	−2.93 ***	−0.85 ***	−1.36 **	−2.57 **	−0.48 *	−0.22 *	−1.94
	PP first difference	−1.42 **	−1.39 **	−1.02 **	−2.34 **	−2.19 *	−4.64 **	−1.76	−1.08	−0.76 **
Japan	ADF level	−2.14 *	−4.40 **	−3.42 **	−2.30 ***	−3.03 **	−0.86 *	−0.41 **	−2.16 **	−0.30
	ADF first difference	−2.71 **	−3.81 ***	−2.91 ***	−4.18 **	−2.48 *	−1.43 **	−1.03 *	−1.94 *	−1.00 *
	PP level	−1.85 **	−4.28 **	−1.48 **	−2.45 ***	−2.22 **	−0.90 *	−0.69 **	−2.37 **	−0.95
	PP first difference	−2.06 **	−2.65 ***	−2.05 ***	−3.13 **	−1.40 *	−2.16	−2.17	−0.66 ***	−1.38 *
Norway	ADF level	−0.97	−1.94 *	−0.73 **	−1.76 **	−1.14	−3.25 ***	−4.90 ***	−2.05 ***	−2.73 **
	ADF first difference	−1.23	−3.12 **	−1.34 *	−2.39 ***	−2.37 *	−2.98 **	−2.38 **	−4.78 ***	−1.49 ***
	PP level	−1.01 *	−2.83 *	−0.49 ***	−1.97 **	−1.28 *	−4.42 ***	−3.45 ***	−2.64 ***	−2.04 **
	PP first difference	−1.30 *	−1.47 **	−1.05 *	−3.00 ***	−1.63 **	−3.11 **	−2.06 **	−3.19 ***	−1.12 ***
Russia	ADF level	−3.58 **	−2.20 ***	−3.10 ***	−4.01 *	−2.35 *	−4.66 ***	−4.77 ***	−2.57 **	−3.46 **
	ADF first difference	−2.74 **	−1.95 **	−2.53 **	−3.22 **	−1.46 **	−3.85 ***	−3.83 ***	−3.33 *	−2.98 **
	PP level	−3.99 **	−2.41 ***	−4.24 ***	−4.29 *	−2.97 *	−3.79 ***	−4.50 ***	−2.41 **	−2.35 **
	PP first difference	−1.16 *	−1.53 **	−2.17 **	−3.06 **	−1.09 **	−4.52 **	−4.91 ***	−2.84 ***	−3.81 ***
South Korea	ADF level	−2.86 ***	−4.46 *	−2.03 *	−1.21 ***	−3.14 *	−0.78 *	−1.25 *	−4.12 *	−1.06 ***
	ADF first difference	−3.42 ***	−3.82 *	−1.75 **	−2.35 **	−2.22 **	−0.97 **	−2.42 **	−3.90 *	−2.93 **
	PP level	−3.11 **	−2.17	−2.84 *	−1.94 ***	−3.85 *	−1.49	−1.38 *	−3.65 **	−1.17 ***
	PP first difference	−2.95 ***	−3.04	−1.15 **	−2.70 **	−2.37 **	−1.05	−0.57 ***	−4.08 *	−2.36 **
Sweden	ADF level	−0.87 ***	−2.43 **	−0.99 **	−1.27	−1.79 ***	−2.30 **	−1.12 **	−1.40 ***	−1.68 *
	ADF first difference	−1.59 ***	−1.95 **	−2.53 *	−3.15	−0.96 **	−3.21 **	−2.09 *	−0.73 ***	−2.00 **
	PP level	−1.28 **	−1.37 ***	−1.74 **	−0.44 *	−1.45 ***	−2.58 *	−1.50 **	−1.99 **	−1.55 *
	PP first difference	−0.94 **	−2.18 ***	−2.06 *	−2.96	−2.13 **	−3.42	−2.86 *	−1.54 **	−2.42 **

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table A3. ADF and PP results, countries, 2020.

Country	Parameter	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
China	ADF level	−1.20 **	−1.54 ***	−1.05 ***	−3.14 **	−2.95 **	−0.47 **	−1.55 *	−2.14 **	−3.43 **	−1.12 **	−2.93 ***
	ADF first difference	−2.78 *	−1.09 **	−1.36 **	−3.03 ***	−2.03 **	−1.51 *	−4.20	−2.01 ***	−2.74 ***	−1.48 *	−3.00 **
	PP level	−3.35 *	−2.42 **	−2.28 ***	−2.50 ***	−1.90 ***	−1.90 **	−1.26 *	−1.70 ***	−3.05 **	−1.07	−2.21 ***
	PP first difference	−2.36 **	−1.76 **	−1.25 **	−3.27 **	−2.86 **	−2.02 *	−2.81	−1.97 **	−3.19 **	−0.83 **	−3.44 **
Denmark	ADF level	−2.12	−0.98 *	−1.37 *	−2.98 **	−1.12 *	−1.37 ***	−0.78 **	−3.18 ***	−0.88 *	−2.36 *	−2.58 *
	ADF first difference	−1.28 *	−1.41 *	−1.29	−1.43 **	−0.73 **	−2.34 **	−1.05 *	−4.04 **	−1.51	−1.45 *	−1.92 **
	PP level	−1.51 **	−0.72 *	−1.94 *	−2.04 **	−1.84 *	−1.85 ***	−0.92 **	−3.22 **	−0.62 *	−0.55 ***	−2.04 *
	PP first difference	−1.23 *	−1.15	−0.38 **	−3.19 *	−0.91 **	−2.04 **	−1.64 *	−4.85 **	−1.75	−1.76 *	−1.71 **
Iceland	ADF level	−1.17 **	−0.57	−1.44 *	−1.95 **	−1.66 **	−0.99 ***	−0.88 ***	−2.13 ***	−0.93 *	−0.94 *	−1.03
	ADF first difference	−1.32 **	−2.28	−0.80 **	−1.01 **	−1.09 **	−1.26 **	−2.53 *	−3.54 ***	−2.71 *	−0.82 *	−2.35 *
	PP level	−1.58 **	−0.46 *	−0.95	−2.30 **	−2.17 ***	−1.80 **	−1.70 **	−2.02 **	−0.80 *	−0.35 *	−1.74
	PP first difference	−1.67 **	−1.30	−0.46 *	−1.26 **	−1.40 **	−2.25 **	−2.01 *	−4.36 **	−1.44	−1.14 *	−0.65 **
Japan	ADF level	−2.40 **	−2.43 **	−1.82 **	−3.72 **	−3.19 **	−2.00 ***	−3.34 **	−1.18 *	−0.39 **	−2.42 **	−0.86
	ADF first difference	−2.05 **	−3.58 **	−2.13 *	−3.29 ***	−2.22 ***	−4.44 **	−2.27 *	−1.27 **	−1.27 *	−1.83 *	−1.12 *
	PP level	−1.62 **	−2.94 ***	−1.50 **	−2.14 ***	−1.00 **	−2.51 ***	−2.18 **	−1.22 *	−0.95 **	−2.04 **	−0.90
	PP first difference	−1.98 **	−1.56 ***	−2.74 *	−3.00 **	−1.49 ***	−3.01 **	−2.00 *	−2.39	−1.91 *	−0.97 ***	−1.27 *
Norway	ADF level	−0.85	−1.16 *	−0.66 **	−2.23 *	−0.86 **	−1.86 **	−1.55	−3.00 ***	−4.82 ***	−1.16 ***	−2.58 **
	ADF first difference	−1.51	−2.05	−1.37 *	−2.95 **	−1.28 *	−2.27 ***	−2.36 *	−2.54 **	−2.83 **	−4.72 **	−2.17 **
	PP level	−1.23 *	−1.77 *	−1.01 **	−2.41 *	−0.74 ***	−1.73 **	−1.39 *	−3.08 ***	−3.27 **	−3.30 ***	−1.84 **
	PP first difference	−1.47 *	−2.22	−2.00	−1.09 **	−1.37 *	−2.92 ***	−1.05 **	−2.47 **	−2.65 **	−3.64 ***	−1.75 ***
Russia	ADF level	−2.99 **	−2.58 **	−2.45 **	−2.43 **	−2.83 ***	−4.19 *	−2.74 *	−4.25 ***	−4.18 ***	−2.09 **	−3.03 **
	ADF first difference	−2.70 **	−3.14 **	−3.58 **	−1.55 **	−2.06 **	−3.40 **	−1.16 **	−3.13 ***	−3.04 ***	−3.48 *	−2.64 **
	PP level	−3.58 **	−2.35 *	−2.10 *	−1.86 ***	−3.90 ***	−4.04 *	−2.38 *	−3.29 **	−4.29 ***	−2.26 **	−2.22 **
	PP first difference	−1.03 *	−2.73 **	−3.34 **	−2.01 **	−2.44 **	−3.29 **	−1.25 **	−4.21 **	−4.37 ***	−2.55 ***	−3.75 ***
South Korea	ADF level	−2.75 ***	−4.40 **	−4.22 **	−4.17 *	−1.92 *	−1.58 ***	−2.59 **	−0.80 *	−1.46 *	−4.00 *	−1.39 ***
	ADF first difference	−3.14 ***	−3.27 ***	−4.71 **	−3.33 *	−2.85 **	−2.25 **	−2.30 **	−0.75 **	−1.95 **	−3.59 *	−2.18 **
	PP level	−2.89 **	−2.05 ***	−3.18 ***	−2.80	−2.25 *	−1.71 ***	−3.67 *	−1.06	−1.57 **	−3.47 **	−1.42 ***
	PP first difference	−2.43 **	−3.49 **	−3.62 **	−2.74 *	−1.04 **	−2.53 **	−2.41 **	−1.77	−0.86 ***	−4.23 *	−2.30 **
Sweden	ADF level	−1.32 **	−1.98	−2.04 *	−2.05 **	−0.62 **	−1.34	−1.66 ***	−1.43 **	−1.00 **	−1.74 ***	−1.51 *
	ADF first difference	−1.13 ***	−0.46 *	−1.28 *	−1.48 **	−2.37 *	−3.00 *	−1.23 **	−2.59 **	−1.34 *	−0.88 ***	−1.45 ***
	PP level	−1.40 **	−1.13	−0.55 **	−1.51 ***	−1.50 **	−0.59 *	−1.50 ***	−1.40 **	−1.82 **	−1.51 **	−1.68 *
	PP first difference	−1.25 **	−0.80 *	−1.11 *	−2.16 ***	−1.33 *	−2.85	−2.28 **	−2.88	−2.40 *	−1.65 **	−2.11 **

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Appendix C

Table A4. ARDL short-run estimates, ports, 2015–2019.

Port	Parameter	ΔX₃	ΔX₄	ΔX₅	ΔX₆	ΔX₇	ΔX₈	ΔX₉	ΔX₁₀	ECM
China: Dalian	Coefficient	0.0994	0.2093	0.2187	0.2045	0.0594	−0.1238	−0.0457	−0.1309	0.1566
	t-stat	1.0298	−3.1550	−1.4885	−2.0882	4.6982	−2.0997	1.4409	2.1170	2.0297
	Prob	0.0827 ***	0.4146 ***	0.7209 **	0.5009 **	0.1597 *	0.5505 **	0.1287 ***	0.4691 ***	0.1502 **
China: Lianyungang	Coefficient	0.1725	0.2007	0.1044	0.1236	0.1809	−0.0562	0.0662	−0.0987	0.1419
	t-stat	−2.6009	3.4482	−2.0841	−2.9503	−3.8751	1.7793	2.4091	−3.6092	−2.5446
	Prob	0.1388 **	0.3091 **	0.0529 *	0.0987 *	0.3350 *	0.6720 *	0.6348 **	0.0505 **	0.4091 *
China: Qingdao	Coefficient	0.2476	0.2453	0.3112	0.3598	0.0983	−0.0186	−0.3007	−0.1559	−0.3008
	t-stat	1.5098	2.4458	−4.2678	−1.9942	2.0759	1.5631	3.6298	−1.5774	1.7832
	Prob	0.4033 **	0.7346 **	0.0039 ***	0.9387 ***	0.3391 *	0.8599 **	0.1127 ***	0.2386 ***	0.2557 **
China: Qinhuangdao	Coefficient	0.2092	0.1900	0.1251	0.1409	0.0985	0.0134	0.0263	−0.0112	0.0103
	t-stat	2.6071	3.1462	1.0093	2.0000	−2.5983	1.6673	2.6995	5.0064	3.6084
	Prob	0.2395 **	0.5884 **	0.0076 *	0.7503 *	0.4774 *	0.5887 *	0.2409 **	0.3081 **	0.1536 *
China: Rizhao	Coefficient	0.3993	0.3588	0.1092	0.1725	0.0070	0.1490	0.0135	0.0146	0.1597
	t-stat	4.0075	2.4902	−2.5557	−1.4647	3.5371	−2.5556	−2.6734	2.7795	1.2285
	Prob	0.5982 **	0.5395 **	0.4998 *	0.9098 *	0.5893 *	0.6729 *	0.8995 *	0.9806 **	0.2456 *
China: Shanghai	Coefficient	0.7300	0.7936	0.5781	0.6045	0.1400	0.2304	0.2289	−0.2037	−0.1877
	t-stat	5.1486	−1.2980	1.0008	2.6551	−3.7735	2.6780	−1.3485	2.1285	−3.5832
	Prob	0.4995 ***	0.0075 ***	0.4790 ***	0.8840 ***	0.3809 **	0.7713 **	0.6737 ***	0.7900 ***	0.1709 ***
China: Weihai	Coefficient	0.3215	0.4098	0.1452	0.1793	0.0673	0.1694	0.1891	0.0476	0.1558
	t-stat	4.6617	1.8403	−4.7937	−2.0041	3.7098	2.4843	2.1594	−1.5285	3.3790
	Prob	0.4592 **	0.3704 **	0.1364 **	0.2055 **	0.7149 *	0.7091 *	0.0005 **	0.9287 **	0.4421 *
China: Yantai	Coefficient	0.2498	0.2591	0.1990	0.2286	0.1303	0.2002	0.0309	−0.1098	0.0547
	t-stat	3.6895	−2.8390	2.5558	1.8930	−2.5681	3.4673	2.1587	−1.5556	2.0965
	Prob	0.0982 ***	0.3498 ***	0.4091 **	0.0089 **	0.3899 **	0.5508 **	0.3985 **	0.2018 **	0.2490 **
Denmark: Aarhus	Coefficient	0.1506	0.1183	0.0552	0.0344	0.0710	−0.0305	0.1335	0.0784	−0.1257
	t-stat	3.1377	2.2407	1.1147	−2.0728	1.2745	−3.4122	1.1784	2.1995	1.1346
	Prob	0.0793 ***	0.9874 ***	0.0005 *	0.1482 *	0.2993 *	0.4355 *	0.3985 **	0.3993 *	0.2066 *
Denmark: Copenhagen	Coefficient	0.1285	0.1596	0.0134	0.0637	0.0226	0.0490	0.0621	0.1006	−0.0557
	t-stat	−1.2759	2.8837	−2.2861	−4.0053	2.6298	4.8794	3.1784	−1.5975	−1.0086
	Prob	0.4102 ***	0.5884 ***	0.6390 *	0.0394 *	0.5094 *	0.2609 *	0.7985 *	0.8585 *	0.7723 *
Denmark, Greenland: Nuuk	Coefficient	0.7512	0.7056	0.1258	0.0115	0.5035	−0.1223	−0.0556	−0.0144	0.1609
	t-stat	3.5008	4.2224	−1.0677	2.3379	−1.7772	2.4000	−1.4700	−1.1863	2.2866
	Prob	0.5954 ***	0.3983 ***	0.2851 *	0.2807 *	0.3683 **	0.3875 *	0.3653 *	0.0005 *	0.4124 *
Iceland: Reydharfjordur	Coefficient	0.4872	0.4085	0.2338	0.2561	0.5506	−0.0206	0.0725	0.0236	0.0446
	t-stat	3.1676	2.1674	−1.0365	2.5974	−1.4287	2.0565	2.1277	1.6905	1.3378
	Prob	0.2805 ***	0.0875 ***	0.2870 *	0.3885 *	0.1209 ***	0.1274 *	0.1443 *	0.2553 *	0.2785 **
Iceland: Reykjavik	Coefficient	0.6609	0.6077	0.4924	0.2567	0.1558	−0.0258	0.1408	0.0784	0.1309
	t-stat	1.8642	−2.4365	−2.7385	2.3798	−2.4097	1.4596	2.2895	−2.0055	2.0554
	Prob	0.4900 ***	0.5836 ***	0.2294 **	0.5275 **	0.0050 **	0.4927 *	0.2093 **	0.7053 **	0.2378 **

Table A4. *Cont.*

Port	Parameter	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
Japan: Akita	Coefficient	0.5064	0.6235	0.2346	0.1999	0.1667	0.0238	−0.0606	−0.0437	−0.1345
	t-stat	2.0832	1.8509	−3.1459	−2.4875	2.2245	−1.2977	2.5498	1.3865	−1.6299
	Prob	0.0385 **	0.1274 **	0.3240 **	0.5083 **	0.0000 *	0.2769 *	0.0627 *	0.2790 *	0.4904 **
Japan: Hakata	Coefficient	0.4226	0.4800	0.1665	0.2664	0.3239	0.0304	0.0524	0.0654	0.1297
	t-stat	1.3094	2.5821	1.9974	2.5093	1.6008	4.6831	2.5563	−2.6003	1.5556
	Prob	0.1317 **	0.2650 **	0.6339 **	0.3837 **	0.0236 *	0.5583 *	0.2741 *	0.5995 *	0.2804 **
Japan: Kitakyushu	Coefficient	0.3735	0.4407	0.1509	0.1880	0.2013	0.1579	0.0337	0.0597	−0.2579
	t-stat	1.6220	2.6883	−2.0096	−2.4985	4.1794	−1.6282	2.0084	1.4083	2.5458
	Prob	0.4087 **	0.0005 **	0.5584 **	0.3077 **	0.6231 **	0.4595 *	0.2863 *	0.2129 *	0.4267 *
Japan: Niigata	Coefficient	0.2336	0.2551	0.2335	0.3134	0.0349	0.1543	−0.1245	−0.0450	0.0605
	t-stat	−2.5543	−2.9835	3.9598	2.0075	1.8444	2.1886	1.3062	3.1582	1.3490
	Prob	0.0985 ***	0.2987 ***	0.7401 ***	0.4982 ***	0.3986 ***	0.2583 *	0.2750 **	0.2086 **	0.4558 **
Norway: Bergen	Coefficient	0.2308	0.1347	0.2134	0.2086	0.1674	0.2996	0.1124	0.2057	0.4007
	t-stat	2.1894	−1.9845	−2.6755	−1.1455	−2.6281	1.3285	−1.8655	−2.3348	−3.3285
	Prob	0.1307 **	0.4808 **	0.5897 *	0.8743 *	0.3309 *	0.5281 **	0.2349 **	0.0293 **	0.5380 **
Norway: Hammerfest	Coefficient	0.0565	0.0655	0.0775	0.0776	0.2496	0.2457	0.0985	0.3615	0.2236
	t-stat	2.0296	3.2941	−3.1709	−2.3589	2.5414	−2.3987	−2.1294	3.0006	−2.1137
	Prob	0.5991 **	0.9836 **	0.4386 *	0.3034 *	0.6083 *	0.4446 **	0.0013 **	0.1257 **	0.2768 *
Norway: Stavanger	Coefficient	0.2783	0.2997	0.0688	0.0676	0.2379	0.2008	0.3872	0.2027	0.3566
	t-stat	5.0046	2.0953	4.1763	1.5583	−2.5245	1.5125	2.3409	1.1498	1.7495
	Prob	0.2098 ***	0.4827 ***	0.5266 **	0.4127 **	0.0488 **	0.2309 **	0.3874 **	0.1874 **	0.5574 **
Norway: Tromso	Coefficient	0.2449	0.2690	0.1295	0.0985	0.1794	0.0738	0.0228	0.0500	0.2323
	t-stat	2.6928	−4.9007	1.5693	2.2187	1.8609	−1.7995	3.1264	1.2046	−2.8476
	Prob	0.3582 ***	0.0006 ***	0.3475 *	0.3126 *	0.3453 **	0.6297 *	0.0996 *	0.4529 *	0.2001 **
Norway: Trondheim	Coefficient	0.1308	0.2564	0.3290	0.2997	0.0775	0.1555	0.4003	0.1654	0.3829
	t-stat	−1.9387	1.5981	2.1138	1.3854	−2.5498	3.6694	2.6595	−3.5521	2.5444
	Prob	0.2006 ***	0.4800 ***	0.3685 **	0.1237 **	0.2846 **	0.3712 **	0.0054 **	0.4670 **	0.0657 ***
Russia: Anadyr	Coefficient	0.0745	0.0011	0.0054	0.0060	0.0664	−0.0074	−0.0011	0.0014	−0.0565
	t-stat	−1.0043	−2.8749	−1.4976	−2.2381	1.7539	−2.0386	2.1554	3.4299	2.0657
	Prob	0.0428 *	0.6066 *	0.3453 *	0.5199 *	0.5665 **	0.2525 *	0.6877 *	0.5434 *	0.6225 *
Russia: Arkhangelsk	Coefficient	0.0314	0.0258	0.0069	0.0234	0.1221	−0.0066	0.2023	0.1285	0.0778
	t-stat	−2.5638	−2.3987	−2.9744	3.0445	2.8867	2.3854	−1.6684	−2.3254	2.0444
	Prob	0.5174 **	0.2216 **	0.0032 *	0.6256 *	0.4543 *	0.2850 *	0.0675 *	0.6193 *	0.3095 **
Russia: Dudinka	Coefficient	0.0067	0.0011	0.0050	0.0013	0.1138	0.0157	0.0098	0.0069	0.0352
	t-stat	−3.1286	1.6598	−2.4873	−2.4736	−1.4455	2.5180	1.5784	2.0575	−1.5476
	Prob	0.0000 *	0.4144 *	0.3864 *	0.5179 *	0.0098 **	0.1442 *	0.3591 *	0.3443 *	0.6564 *
Russia: Murmansk	Coefficient	0.1056	0.1316	0.0423	0.0122	0.1553	0.0205	0.1843	0.2114	0.2573
	t-stat	−2.5239	−1.5830	−1.6495	2.1540	−2.2376	−1.1222	2.1487	−2.4986	−2.0554
	Prob	0.6928 ***	0.7455 ***	0.2442 *	0.0085 *	0.4232 **	0.0000 **	0.6650 **	0.3000 **	0.1672 ***
Russia: Petropavlovsk	Coefficient	0.1392	0.1609	0.0219	0.0124	0.0664	0.0597	0.0045	0.0067	0.2012
	t-stat	−4.5667	−2.1423	1.1113	2.5548	−1.7459	2.6566	2.0027	−2.5068	3.1478
	Prob	0.6400 *	0.6998 *	0.1854 *	0.6512 *	0.0051 **	0.2875 *	0.1556 *	0.4366 *	0.5465 **

Table A4. *Cont.*

Port	Parameter	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
Russia: Pevek	Coefficient	0.1614	0.0087	0.0107	0.0053	0.0234	0.0124	0.0064	0.0078	0.1504
	t-stat	1.7958	1.3422	2.9876	1.4998	−3.1343	2.6579	−3.5538	−1.4657	−1.3227
	Prob	0.4123 *	0.5673 *	0.2333 *	0.0413 *	0.2265 **	0.4386 *	0.2656 *	0.5388 *	0.5980 *
Russia: Sabetta	Coefficient	0.0501	0.0015	0.1254	0.0015	0.0076	0.2235	0.0012	0.0043	0.3670
	t-stat	2.3472	−2.3762	1.2775	2.5234	2.1121	−4.2534	−2.7754	−3.0987	1.1231
	Prob	0.4653 **	0.6909 *	0.5634 **	0.6498 *	0.5398 *	0.5767 **	0.4486 *	0.6055 *	0.3875 **
Russia: Vladivostok	Coefficient	0.0638	0.2155	0.1552	0.2237	0.0423	0.0996	0.2667	0.2442	0.5234
	t-stat	4.7754	2.0007	−2.6578	3.3456	−2.1364	−2.3687	1.2355	1.0936	2.0669
	Prob	0.1906 ***	0.3908 **	0.5234 ***	0.3002 ***	0.3172 *	0.4522 **	0.2136 ***	0.2573 ***	0.4987 ***
South Korea: Gwangyang	Coefficient	0.4287	0.4065	0.3286	0.3314	−0.0965	−0.0940	−0.0025	−0.0074	0.4906
	t-stat	2.5005	1.1749	−2.0517	−1.5000	3.9187	−2.6053	1.8247	−2.6819	2.4022
	Prob	0.9276 ***	0.7378 **	0.4005 ***	0.6249 ***	0.0005 *	0.1547 *	0.1496 *	0.2760 **	0.3795 **
South Korea: Pusan	Coefficient	0.8340	0.8150	0.7349	0.6538	−0.1396	−0.1548	−0.0102	−0.0351	0.7007
	t-stat	−1.8733	−2.1244	−1.4380	−2.5356	1.1487	2.5952	−3.4783	−1.4958	−3.6541
	Prob	0.7612 ***	0.6626 ***	0.0095 ***	0.0298 ***	0.7395 *	0.3813 **	0.5849 **	0.0006 **	0.5328 ***
South Korea: Ulsan	Coefficient	0.6195	0.5892	0.5052	0.4872	0.0056	−0.0865	−0.0912	−0.0873	0.5045
	t-stat	4.0557	3.1505	−1.9347	−2.5360	−3.9841	−3.1260	−2.0375	−4.5941	−1.3968
	Prob	0.3941 ***	0.7984 ***	0.0498 ***	0.8375 ***	0.1203 *	0.4891 *	0.2096 *	0.7500 **	0.4093 **
Sweden: Gothenburg	Coefficient	0.6827	0.7023	0.1854	0.1733	0.1660	−0.0097	0.0150	0.0964	−0.3264
	t-stat	−2.1793	−1.0065	−2.0057	−3.4281	2.5377	−1.3761	2.5891	−1.3681	−2.7813
	Prob	0.5482 ***	0.6398 ***	0.2941 **	0.0054 **	0.2198 **	0.3405 *	0.0614 *	0.2592 *	0.8867 ***
Sweden: Halmstad	Coefficient	0.3864	0.4290	0.1519	0.1625	0.0634	−0.0143	0.0523	0.0775	0.0810
	t-stat	−1.0709	−3.5836	−3.4015	−1.3096	3.8765	2.0567	3.4175	1.8131	−1.3986
	Prob	0.5298 ***	0.4211 ***	0.2366 **	0.4231 **	0.3891 **	0.1831 *	0.0022 *	0.4973 *	0.5715 **

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table A5. ARDL short-run estimates, ports, 2020.

Port	Parameter	ΔX_1	ΔX_2	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
China: Dalian	Coefficient	−0.0108	−0.0182	0.1113	0.1290	0.1528	0.1670	0.0342	−0.1061	−0.0100	−0.1544	0.1305
	t-stat	2.0817	3.1175	2.1865	−4.4598	2.0483	−3.2391	2.5378	1.3728	2.3597	3.0580	2.5988
	Prob	0.1982 **	0.0255 **	0.3034 **	0.3600 **	0.3015 *	0.0045 **	0.3066 *	0.3762 **	0.0198 ***	0.1853 ***	0.1264 **
China: Lianyungang	Coefficient	−0.0271	−0.0390	0.0298	0.0357	0.0466	0.0322	0.1485	−0.0394	0.0514	−0.1098	0.1692
	t-stat	−3.4918	−2.8776	3.1765	2.6873	−1.7671	−2.5094	−2.0039	4.6380	2.5010	−1.4511	−3.9830
	Prob	0.3870 **	0.2871 **	0.0387 *	0.0294 *	0.0529 *	0.1298 *	0.2450 *	0.0045 *	0.4902 **	0.0387 **	0.2506 *
China: Qingdao	Coefficient	0.0189	0.0040	0.1011	0.1245	0.2067	0.2217	0.0551	−0.0041	−0.2697	−0.1673	−0.3567
	t-stat	2.9876	2.0586	3.0284	3.1257	−2.5083	−3.0083	4.6348	3.5026	2.5553	3.0856	2.0854
	Prob	0.0281 *	0.2877 *	0.2975 *	0.1654 *	0.0005 **	0.0491 **	0.0000 *	0.4817 **	0.0976 ***	0.1299 ***	0.2078 **
China: Qinhuangdao	Coefficient	−0.0677	−0.0562	0.1876	0.1522	0.0742	0.0504	0.0723	0.0038	0.0144	−0.0030	0.0035
	t-stat	−2.4980	−3.5991	1.9550	3.0973	4.3311	3.6566	−2.4475	1.5411	3.5095	4.7109	2.6419
	Prob	0.0485 *	0.0593 *	0.1183 **	0.3070 **	0.0760 *	0.0872 *	0.2559 *	0.3904 *	0.1567 **	0.2054 **	0.0754 *

Table A5. *Cont.*

Port	Parameter	ΔX_1	ΔX_2	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
China: Rizhao	Coefficient	−0.1096	−0.0987	0.1542	0.1276	0.0493	0.0910	0.0046	0.1053	0.0059	0.0102	0.1200
	t-stat	−4.8561	−3.4982	2.7091	3.0188	2.0452	2.6413	1.9550	−3.5085	−2.4832	1.6598	3.1675
	Prob	0.5875 **	0.1824 **	0.2587 **	0.4900 **	0.0500 *	0.1287 *	0.1677 *	0.0044 *	0.6910 *	0.0371 **	0.0444 *
China: Shanghai	Coefficient	0.1203	0.1186	0.3876	0.3497	0.2988	0.2462	0.1011	0.1876	0.1954	−0.2459	−0.2037
	t-stat	2.8762	2.0590	4.6003	3.6065	1.5974	1.8005	−4.7492	5.3009	3.0766	2.0076	−4.1002
	Prob	0.3094 *	0.5871 *	0.3760 ***	0.4012 ***	0.2867 ***	0.3041 ***	0.0083 **	0.0487 **	0.2598 ***	0.0834 ***	0.1885 ***
China: Weihai	Coefficient	−0.0087	−0.0124	0.1165	0.1411	0.0313	0.0456	0.0544	0.1250	0.1608	0.0325	0.1341
	t-stat	−1.3905	−2.4870	3.9841	3.0676	−4.0606	−3.3407	2.6715	3.5734	1.0075	−3.4472	2.1765
	Prob	0.0094 **	0.0288 **	0.3690 **	0.4059 **	0.0512 **	0.2888 **	0.0817 *	0.2986 *	0.1842 **	0.0000 **	0.9874 *
China: Yantai	Coefficient	−0.0582	−0.0444	0.1033	0.0962	0.1003	0.1516	0.1249	0.1378	0.0411	−0.1126	0.0368
	t-stat	3.8654	2.5109	4.0845	3.7764	2.5764	3.0693	−2.7308	4.1540	3.0697	−1.6093	2.1677
	Prob	0.3751 **	0.4225 **	0.2870 **	0.0061 **	0.3986 **	0.2100 **	0.0031 **	0.3991 **	0.2134 **	0.0421 **	0.1295 **
Denmark: Aarhus	Coefficient	−0.0125	−0.0056	0.3286	0.3064	0.0275	0.0186	0.0518	−0.0186	0.1046	0.0587	−0.1079
	t-stat	−4.3890	−3.8271	5.0400	3.1286	1.3884	−2.6931	1.4553	−2.5583	3.0035	3.0683	2.5872
	Prob	0.2362 *	0.3053 *	0.5156 **	0.2791 **	0.2380 *	0.3815 *	0.1609 *	0.3990 *	0.2377 **	0.2609 *	0.1884 *
Denmark: Copenhagen	Coefficient	−0.1274	−0.1040	0.2467	0.2075	0.0052	0.0457	0.0071	0.0155	0.0391	0.0846	−0.0385
	t-stat	2.0071	4.8638	−1.1865	2.9666	−3.1409	−4.9062	2.3645	1.6984	2.5986	−2.6122	−1.4096
	Prob	0.0385 **	0.1787 **	0.4003 **	0.3781 **	0.8726 *	0.0498 *	0.3096 *	0.0682 *	0.3352 *	0.4823 *	0.3193 *
Denmark, Greenland: Nuuk	Coefficient	0.0383	0.0446	0.7199	0.6483	0.0954	0.0073	0.4338	−0.0870	−0.0275	−0.0081	0.1487
	t-stat	−1.4984	−2.0095	4.2311	3.9750	2.8600	3.9846	−2.6094	3.5941	−1.5900	−3.1977	4.1550
	Prob	0.8780 *	0.3967 *	0.7820 ***	0.5301 ***	0.0016 *	0.6019 *	0.4487 **	0.1110 *	0.4692 *	0.5239 *	0.3819 *
Iceland: Reydharfjordur	Coefficient	0.0298	0.0202	0.5083	0.3716	0.2609	0.2317	0.5790	−0.0142	0.0613	0.0103	0.0204
	t-stat	−2.9334	−2.0651	4.5800	3.0825	−2.4485	4.0883	−2.0554	1.4496	2.8088	1.3585	2.5985
	Prob	0.5912 *	0.3894 *	0.3109 ***	0.2904 ***	0.5886 *	0.2076 *	0.1195 ***	0.0065 *	0.0301 *	0.2780 *	0.1920 **
Iceland: Reykjavik	Coefficient	−0.0155	−0.0097	0.6214	0.5575	0.3173	0.2800	0.1677	−0.0097	0.1005	0.0497	0.1106
	t-stat	−3.5506	4.6090	3.1798	−2.4900	−1.6960	1.9964	−3.1385	2.2853	3.8974	−2.6982	3.6899
	Prob	0.1483 *	0.3698 *	0.7926 ***	0.0187 ***	0.1678 **	0.4209 **	0.2509 **	0.3880 *	0.1296 **	0.3485 **	0.3871 **
Japan: Akita	Coefficient	−0.1047	−0.0964	0.5388	0.6011	0.1855	0.2076	0.1240	0.0047	−0.0371	−0.0222	−0.1102
	t-stat	−2.0739	−1.3009	2.4150	3.0653	−2.3920	−3.5391	4.7921	−2.1494	1.1986	2.1043	−2.7198
	Prob	0.3017 **	0.4755 **	0.5237 **	0.0517 **	0.1904 **	0.4864 **	0.3417 *	0.1000 *	0.0412 *	0.1498 *	0.5931 **
Japan: Hakata	Coefficient	−0.0341	−0.0865	0.4021	0.3500	0.1472	0.1558	0.3572	0.0155	0.0394	0.0417	0.1034
	t-stat	4.2880	3.6901	1.9733	2.8499	3.0593	2.6312	1.5996	2.9709	1.4980	−1.4020	1.8765
	Prob	0.4494 **	0.0007 **	0.0598 **	0.1784 **	0.5700 **	0.2909 **	0.0038 *	0.4882 *	0.2653 *	0.4883 *	0.0029 **
Japan: Kitakyushu	Coefficient	−0.2082	−0.2136	0.3424	0.4065	0.1975	0.1607	0.2005	0.1003	0.0167	0.0269	−0.2690
	t-stat	3.5685	−2.0071	1.5076	4.7702	−1.4767	−2.0041	3.5877	−1.5987	3.2992	2.8840	3.3851
	Prob	0.1376 **	0.2500 **	0.8927 **	0.8534 **	0.3092 **	0.2868 **	0.4982 *	0.0781 *	0.1558 *	0.2641 *	0.5980 *
Japan: Niigata	Coefficient	0.1595	0.1243	0.1980	0.2371	0.2206	0.2547	0.0523	0.1204	−0.0861	−0.0293	0.0416
	t-stat	4.1284	2.0009	−1.2956	−2.0046	4.1475	1.5083	2.9084	4.0880	3.1822	4.1000	2.1950
	Prob	0.3002 **	0.2764 **	0.0045 ***	0.0498 ***	0.0016 ***	0.1696 ***	0.5081 ***	0.3905 *	0.0015 **	0.1729 **	0.2407 **
Norway: Bergen	Coefficient	−0.0103	−0.0225	0.1286	0.1085	0.1690	0.1773	0.1503	0.2566	0.1408	0.1774	0.3718
	t-stat	−4.1852	−3.0741	2.0954	3.1264	−1.5821	−2.2045	−1.5938	2.0548	−1.3056	−2.0063	−2.2595
	Prob	0.1084 **	0.4827 **	0.1008 **	0.3851 **	0.4593 *	0.3841 *	0.2855 **	0.7109 **	0.1297 **	0.5028 **	0.2091 **

Table A5. *Cont.*

Port	Parameter	ΔX_1	ΔX_2	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
Norway: Hammerfest	Coefficient	−0.0287	−0.0113	0.0392	0.0506	0.0452	0.0587	0.2014	0.2065	0.0495	0.3125	0.2046
	t-stat	−3.7918	−1.0584	2.9805	3.8562	−4.0127	−2.1084	1.5039	−1.5003	−3.0882	1.4995	−3.0067
	Prob	0.3866 **	0.2095 **	0.6733 *	0.3500 *	0.2986 *	0.3762 *	0.5877 *	0.4201 **	0.0000 **	0.0982 **	0.0038 *
Norway: Stavanger	Coefficient	0.0110	0.0273	0.2409	0.2307	0.0175	0.0385	0.1805	0.1699	0.3019	0.2543	0.3102
	t-stat	2.1084	1.9820	4.9864	1.3986	3.0386	2.4761	−1.4082	2.4056	4.2066	3.0051	2.9047
	Prob	0.3872 *	0.2574 *	0.5001 **	0.3403 **	0.4501 **	0.5720 **	0.0060 **	0.1785 **	0.3874 **	0.5052 **	0.3855 **
Norway: Tromso	Coefficient	−0.0490	−0.0502	0.2288	0.1954	0.0787	0.0644	0.1513	0.0284	0.0135	0.0498	0.1984
	t-stat	1.8723	3.0001	2.6505	3.0843	2.0004	4.3965	3.8601	−2.6097	1.0741	3.1110	−2.4091
	Prob	0.0986 **	0.4985 **	0.0041 **	0.2671 **	0.3096 *	0.4861 *	0.2312 **	0.3550 *	0.2864 *	0.3509 *	0.4986 **
Norway: Trondheim	Coefficient	0.0564	0.0632	0.1152	0.1605	0.2851	0.2550	0.0397	0.1296	0.3750	0.2076	0.4097
	t-stat	3.2951	2.4077	3.4096	2.2472	3.0448	2.1977	−1.5085	4.5402	1.8563	−2.0985	3.0950
	Prob	0.0007 **	0.0134 **	0.2509 ***	0.4854 ***	0.2099 **	0.3296 **	0.4994 **	0.3347 **	0.5097 **	0.1209 **	0.0036 ***
Russia: Anadyr	Coefficient	0.0015	0.0019	0.0553	0.0002	0.0038	0.0005	0.0408	−0.0003	−0.0002	0.0005	−0.0481
	t-stat	3.1408	2.4801	−2.1984	−1.8508	−2.0045	−1.0672	3.7055	−4.1834	3.8591	2.5281	1.0833
	Prob	0.2981 *	0.0975 *	0.3061 *	0.4009 *	0.3072 *	0.6820 *	0.3097 **	0.2751 *	0.6953 *	0.6509 *	0.5802 *
Russia: Arkhangelsk	Coefficient	−0.0196	−0.0207	0.0187	0.0206	0.0054	0.0098	0.0829	−0.0040	0.1497	0.1025	0.0496
	t-stat	2.0507	3.8502	−1.3955	−2.0412	−4.9287	5.0945	2.7756	3.9852	−1.5054	−2.0064	3.1247
	Prob	0.0829 **	0.3813 **	0.4409 **	0.0389 **	0.5845 *	0.5699 *	0.7281 *	0.8555 *	0.0582 *	0.7177 *	0.2986 **
Russia: Dudinka	Coefficient	0.0062	0.0108	0.0052	0.0005	0.0059	0.0002	0.0665	0.0104	0.0051	0.0040	0.0182
	t-stat	−1.4078	−2.5095	4.0581	2.9770	3.9006	−4.5281	−1.9664	3.8911	2.6096	4.9873	−1.9503
	Prob	0.3769 *	0.4401 *	0.7200 *	0.3086 *	0.4071 *	0.5069 *	0.0052 **	0.0837 *	0.2223 *	0.5019 *	0.0849 *
Russia: Murmansk	Coefficient	−0.0295	−0.0180	0.1149	0.1509	0.0297	0.0104	0.1147	0.0124	0.1614	0.1808	0.2580
	t-stat	4.5096	2.5985	−1.4085	−3.0955	−1.0583	2.0588	1.0095	2.0985	3.0009	−2.4621	−4.9076
	Prob	0.4507 **	0.3811 **	0.3222 ***	0.4086 ***	0.5929 *	0.0061 *	0.3376 **	0.5902 *	0.6871 **	0.2984 **	0.0791 ***
Russia: Petropavlovsk	Coefficient	0.0663	0.0504	0.1146	0.1532	0.0135	0.0067	0.0508	0.0396	0.0023	0.0040	0.1573
	t-stat	2.0000	2.3856	−3.5041	−2.0698	1.0532	4.9433	−2.9870	1.6084	2.6830	−3.8045	2.0005
	Prob	0.5288 *	0.6902 *	0.0057 *	0.1904 *	0.0994 *	0.7502 *	0.3099 **	0.0087 *	0.1481 *	0.5409 *	0.4873 **
Russia: Pevek	Coefficient	0.0075	0.0104	0.2094	0.0066	0.0061	0.0013	0.0114	0.0058	0.0014	0.0023	0.1106
	t-stat	−1.9409	−3.8700	2.8895	1.0587	3.0855	2.9555	−2.0065	3.1335	−4.9722	−2.5561	−3.6091
	Prob	0.0663 *	0.4426 *	0.5873 *	0.4200 *	0.0000 *	0.0000 *	0.1982 **	0.5987 *	0.0003 *	0.4093 *	0.3863 *
Russia: Sabetta	Coefficient	0.0207	0.0195	0.0396	0.0008	0.0897	0.0002	0.0058	0.1804	0.0004	0.0002	0.3472
	t-stat	−2.2060	−1.4809	2.9487	4.0596	3.1774	2.1247	3.0871	−5.0822	−3.8961	−4.2247	3.6053
	Prob	0.4791 *	0.2853 *	0.0035 **	0.7091 *	0.6908 **	0.7883 *	0.0039 *	0.9431 **	0.2907 *	0.6148 *	0.5686 **
Russia: Vladivostok	Coefficient	−0.0593	−0.0355	0.0340	0.1985	0.1345	0.1590	0.0292	0.0853	0.2480	0.2175	0.4112
	t-stat	3.1134	1.4094	2.0556	3.5444	1.9800	4.9801	−2.0440	−3.5104	4.1564	3.9962	2.2275
	Prob	0.0988 **	0.0527 **	0.0974 ***	0.1307 **	0.4877 ***	0.2874 ***	0.0598 **	0.1365 *	0.3902 ***	0.8271 ***	0.3609 ***
South Korea: Gwangyang	Coefficient	−0.0570	−0.0651	0.3406	0.3053	0.3415	0.3076	−0.0817	−0.0993	−0.0036	−0.0036	0.2808
	t-stat	−3.5442	−2.2309	4.1158	3.4724	−1.5982	−2.7951	2.0041	−1.5081	2.5814	3.4140	1.7377
	Prob	0.8691 **	0.4255 **	0.3754 **	0.5160 **	0.4773 ***	0.5870 ***	0.0482 *	0.5802 *	0.1263 *	0.0006 **	0.1283 **
South Korea: Pusan	Coefficient	0.0814	0.0642	0.8115	0.8359	0.6776	0.6015	−0.1405	−0.1620	−0.0057	−0.0114	0.6217
	t-stat	1.8693	2.7993	4.6346	3.0045	−3.6871	−1.9865	2.0481	3.6111	−1.5548	−2.6932	−4.8994
	Prob	0.0809 **	0.5581 **	0.9500 ***	0.8198 ***	0.6900 ***	0.5824 ***	0.3870 **	0.4816 **	0.8347 **	0.5918 **	0.6000 ***

Table A5. *Cont.*

Port	Parameter	ΔX_1	ΔX_2	ΔX_3	ΔX_4	ΔX_5	ΔX_6	ΔX_7	ΔX_8	ΔX_9	ΔX_{10}	ECM
South Korea: Ulsan	Coefficient	−0.0474	−0.0576	0.5209	0.5573	0.5116	0.4370	0.0045	−0.0954	−0.0664	−0.0407	0.5836
	t-stat	3.5500	1.4732	3.5664	4.0560	−2.8095	−1.4567	−3.9582	−2.0585	−3.4493	−2.3763	−3.1371
	Prob	0.3571 **	0.5918 **	0.6816 ***	0.4176 ***	0.5983 ***	0.4442 ***	0.9185 *	0.7203 *	0.0037 *	0.0448 **	0.2795 **
Sweden: Gothenburg	Coefficient	0.0045	0.0037	0.7054	0.7650	0.1619	0.1890	0.1581	−0.0018	0.0136	0.0744	−0.3028
	t-stat	1.5828	2.5336	−4.9007	−3.1974	−1.8592	−2.2971	1.8429	−3.0284	1.7083	2.1286	−3.1401
	Prob	0.3752 *	0.4975 *	0.8162 ***	0.7005 ***	0.6866 **	0.2309 **	0.4105 **	0.1562 *	0.0000 *	0.0287 *	0.5982 ***
Sweden: Halmstad	Coefficient	0.0006	0.0004	0.3569	0.4021	0.1047	0.1456	0.0368	−0.0035	0.0275	0.0805	0.0485
	t-stat	3.7099	2.8671	−3.0988	−2.6810	−4.6438	−2.0974	2.0815	4.4911	2.6092	3.8881	−2.7002
	Prob	0.3812 *	0.4502 *	0.4713 ***	0.5658 ***	0.1870 **	0.2619 **	0.5092 **	0.2976 *	0.4983 *	0.2550 *	0.2976 **

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Appendix D

Table A6. ARDL long-run estimates, ports, 2015–2019.

Port	Parameter	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
China: Dalian	Coefficient	0.1235	0.2248	0.2035	0.1944	0.0720	−0.1424	−0.0565	−0.1527	3.2765
	t-stat	1.2741 ***	−3.4297 ***	−1.9264 **	−2.3273 **	3.8319 *	−1.8300 **	1.7347 ***	2.3091 ***	2.2281
China: Lianyungang	Coefficient	0.1638	0.2134	0.1386	0.1307	0.2015	−0.0748	0.0548	−0.1132	2.4523
	t-stat	−2.4371 **	2.9999 **	−2.3982 *	−3.2591 *	−3.4778 *	1.9756 *	2.7232 **	−3.4544 **	3.1742
China: Qingdao	Coefficient	0.2655	0.2318	0.3445	0.3616	0.1232	−0.0375	−0.3111	−0.1459	−4.1376
	t-stat	1.4967 **	2.6805 **	−4.5940 ***	−1.8367 ***	2.3719 *	1.7622 **	3.4780 ***	−1.3254 ***	−1.5005
China: Qinhuangdao	Coefficient	0.2352	0.2002	0.1453	0.1542	0.0863	0.0283	0.0387	−0.0371	5.1893
	t-stat	2.8307 **	3.1531 **	1.2763 *	2.5395 *	−2.1279 *	1.4721 *	1.0724 **	4.3864 **	3.4722
China: Rizhao	Coefficient	0.4176	0.3726	0.1280	0.1666	0.0084	0.1637	0.0255	0.0169	4.8531
	t-stat	4.3809 **	2.0827 **	−2.3195 *	−2.0874 *	3.4807 *	−2.1489 *	−2.2987 *	2.3206 **	3.3678 *
China: Shanghai	Coefficient	0.7254	0.7742	0.5683	0.5967	0.1798	0.2483	0.2659	−0.3215	−5.2730
	t-stat	4.9512 ***	−2.3945 ***	1.1700 ***	2.4843 ***	−3.4615 **	2.3311 **	−1.0315 ***	3.8843 ***	−3.1662
China: Weihai	Coefficient	0.3017	0.4276	0.1635	0.1955	0.0564	0.1829	0.1946	0.0636	2.2113
	t-stat	4.5200 **	1.6991 **	−4.2046 **	−2.2316 **	3.2851 *	2.1272 *	3.0271 **	−1.8200 **	3.6585
China: Yantai	Coefficient	0.2784	0.2465	0.1739	0.2341	0.1529	0.2585	0.0555	−0.1478	4.3971
	t-stat	3.0773 ***	−2.5710 ***	3.2285 **	1.7275 **	−2.3004 **	3.1964 **	2.7232 **	−2.7193 **	2.2276
Denmark: Aarhus	Coefficient	0.1845	0.1344	0.0722	0.0624	0.0965	−0.0421	0.1617	0.0995	−3.5323
	t-stat	2.3808 ***	2.5956 ***	1.5310 *	−2.2937 *	1.5312 *	−3.1375 *	1.2534 **	2.3852 *	1.5905
Denmark: Copenhagen	Coefficient	0.1402	0.1732	0.0255	0.0813	0.0400	0.0667	0.0511	0.1267	−4.6628
	t-stat	−1.5213 ***	3.1648 ***	−2.0176 *	−4.2565 *	2.1406 *	4.5489 *	2.7042 *	−1.8553 *	−2.7390
Denmark, Greenland: Nuuk	Coefficient	0.7235	0.6857	0.1523	0.0246	0.5275	−0.1382	−0.0756	−0.0250	5.2034
	t-stat	3.0804 ***	4.1621 ***	−1.4592 *	2.4521 *	−1.9221 **	2.3176 *	−1.3413 *	−1.5126 *	3.5615
Iceland: Reydharfjordur	Coefficient	0.5156	0.4275	0.2551	0.2472	0.5384	−0.0347	0.0614	0.0411	2.3587
	t-stat	2.7443 ***	2.6310 ***	−1.2964 *	2.8333 *	−1.6565 ***	2.4251 *	2.7256 *	1.8324 *	2.0671

Table A6. *Cont.*

Port	Parameter	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
Iceland: Reykjavik	Coefficient	0.6842	0.6198	0.4823	0.2755	0.1716	−0.0423	0.1399	0.0638	4.2592
	t-stat	2.1763 ***	−2.5334 ***	−2.5562 **	2.6216 **	−2.6288 **	1.7262 *	3.1762 **	−1.8230 **	3.7460
Japan: Akita	Coefficient	0.5111	0.6087	0.2431	0.2284	0.1803	0.0479	−0.0843	−0.0655	−4.5829
	t-stat	2.2875 **	2.7918 **	−3.3827 **	−2.5197 **	2.6951 *	−1.6035 *	2.4114 *	1.5314 *	−2.7044
Japan: Hakata	Coefficient	0.4584	0.4975	0.1963	0.2512	0.3560	0.0671	0.0782	0.0821	4.8276
	t-stat	1.7721 **	2.8512 **	3.0008 **	2.4908 **	1.9542 *	3.2556 *	2.3907 *	−2.6630 *	2.7921
Japan: Kitakyushu	Coefficient	0.3927	0.4584	0.1746	0.2165	0.2294	0.1777	0.0653	0.0882	−5.6415
	t-stat	1.8409 **	2.9116 **	−2.3875 **	−2.1840 **	4.5517 **	−1.8623 *	2.7621 *	1.7313 *	−4.5526
Japan: Niigata	Coefficient	0.2752	0.2460	0.2861	0.3485	0.0514	0.1405	−0.1584	−0.0621	3.3840
	t-stat	−2.8150 ***	−2.3854 ***	3.3705 ***	2.6832 ***	1.7280 ***	2.7334 *	1.7335 **	3.5992 **	2.0052
Norway: Bergen	Coefficient	0.2516	0.1563	0.2440	0.2186	0.1843	0.3247	0.1360	0.2239	3.5287
	t-stat	2.3543 **	−2.1885 **	−2.2598 *	−1.4934 *	−3.7609 **	1.6111 **	−2.3952 **	−2.5251 **	2.1645
Norway: Hammerfest	Coefficient	0.0744	0.0800	0.0961	0.0709	0.2665	0.2330	0.0941	0.3883	5.3054
	t-stat	2.3187 **	3.5816 **	−3.0335 *	−2.5882 *	2.9174 *	−3.5792 **	−2.5304 **	3.4737 **	3.5287
Norway: Stavanger	Coefficient	0.2995	0.3447	0.0927	0.0731	0.2652	0.1755	0.4265	0.2385	4.2556
	t-stat	4.1850 ***	2.5643 ***	4.4436 **	1.8520 **	−3.0186 **	1.7234 **	2.8667 **	1.7114 **	2.0081
Norway: Tromso	Coefficient	0.2713	0.2862	0.1543	0.1256	0.1913	0.0996	0.0309	0.0622	3.4619
	t-stat	2.2246 ***	−4.5505 ***	2.6285 *	2.7095 *	1.7200 **	−2.2838 *	3.5176 *	2.3787 *	2.0387
Norway: Trondheim	Coefficient	0.1637	0.2739	0.3612	0.3330	0.0908	0.1831	0.4274	0.1916	5.1862
	t-stat	−2.3062 ***	1.8174 ***	2.7556 **	1.8621 **	−3.1634 **	4.2559 **	2.2965 **	−3.0001 **	4.6559
Russia: Anadyr	Coefficient	0.0706	0.0032	0.00109	0.0075	0.0837	−0.0112	−0.0030	0.0028	−3.1780
	t-stat	−2.5873 *	−3.5985 *	−1.3917 *	−2.6173 *	1.4095 **	−2.3887 *	2.6774 *	2.1795 *	−2.5545
Russia: Arkhangelsk	Coefficient	0.0581	0.0374	0.0095	0.0457	0.1520	−0.0135	0.2487	0.1553	5.2761
	t-stat	−2.3995 **	−2.0456 **	−3.5286 *	3.6812 *	3.2293 *	2.7697 *	−1.9990 *	−2.0046 *	4.6882
Russia: Dudinka	Coefficient	0.0089	0.0037	0.0077	0.0065	0.1671	0.0202	0.00116	0.0122	3.4550
	t-stat	−3.3553 *	1.8820 *	−2.8148 *	−2.9153 *	−1.8729 **	2.8151 *	1.5370 *	2.7609 *	2.7166
Russia: Murmansk	Coefficient	0.1417	0.1815	0.0621	0.0120	0.1773	0.0266	0.11744	0.2751	6.3375
	t-stat	−3.0815 ***	−2.0058 ***	−1.8130 *	2.4839 *	−2.0194 **	−1.7810 **	2.7151 **	−2.0365 **	5.0949
Russia: Petropavlovsk	Coefficient	0.1550	0.1732	0.0445	0.0278	0.0709	0.0628	0.0076	0.0090	3.5812
	t-stat	−4.2656 *	−2.8954 *	1.8182 *	3.3365 *	−1.6845 **	3.1475 *	2.6187 *	−2.1154 *	3.2980
Russia: Pevek	Coefficient	0.1822	0.00135	0.0163	0.0189	0.0200	0.0447	0.0103	0.0067	4.3167
	t-stat	1.9457 *	1.6089 *	3.8265 *	1.7704 *	−3.5287 **	2.1860 *	−3.1498 *	−1.5980 *	2.0095
Russia: Sabetta	Coefficient	0.0663	0.0043	0.1664	0.0091	0.0084	0.2788	0.0060	0.0069	3.7599
	t-stat	2.5055 **	−2.0787 *	1.9875 **	2.4980 *	2.5112 *	−4.5909 **	−3.1693 *	−3.4897 *	2.4631
Russia: Vladivostok	Coefficient	0.0884	0.2352	0.1713	0.2054	0.0535	0.1275	0.2926	0.2112	6.2680
	t-stat	4.4591 ***	2.3716 **	−2.5361 ***	3.8276 ***	−2.6289 *	−2.5804 **	1.2017 ***	1.7975 ***	5.3799
South Korea: Gwangyang	Coefficient	0.4516	0.4285	0.3590	0.3082	−0.0904	−0.1126	−0.0132	−0.0089	3.2795
	t-stat	2.8029 ***	1.5296 **	−2.3983 ***	−1.6396 ***	4.8275 *	−2.8227 *	1.5541 *	−2.4002 **	2.7891
South Korea: Pusan	Coefficient	0.8217	0.7814	0.7093	0.6619	−0.1541	−0.1773	−0.0158	−0.0594	5.3987
	t-stat	−2.0039 ***	−2.5870 ***	−1.4069 ***	−2.9276 ***	1.8266 **	2.0095 **	−4.5203 **	−1.8886 **	3.1963

Table A6. *Cont.*

Port	Parameter	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
South Korea: Ulsan	Coefficient	0.6573	0.5718	0.5608	0.4767	0.0134	−0.0874	−0.1227	−0.0995	4.0440
	t-stat	4.1280 ***	3.0052 ***	−2.4816 ***	−2.0086 ***	−4.5598 *	−3.2790 *	−2.4986 *	−4.2644 **	3.8215
Sweden: Gothenburg	Coefficient	0.7031	0.7394	0.2001	0.1670	0.1783	−0.0144	0.0169	0.0931	6.4778
	t-stat	−2.3827 ***	−1.6590 ***	−2.3857 **	−3.5281 **	3.5990 **	−1.8976 *	2.1024 *	−1.5509 *	4.6380
Sweden: Halmstad	Coefficient	0.4136	0.4322	0.1760	0.1574	0.0775	−0.0353	0.0665	0.0963	5.1385
	t-stat	−1.4789 ***	−3.2971 ***	−3.9178 **	−1.6660 **	4.9836 **	2.4812 *	3.0009 *	1.5987 *	3.0041

Note: *, **, *** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

Table A7. ARDL long-run estimates, ports, 2020.

Port	Parameter	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Constant
China: Dalian	Coefficient	−0.0157	−0.0245	0.1470	0.1568	0.1773	0.1982	0.0561	−0.1450	−0.0239	−0.1725	3.7612
	t-stat	2.2249 **	3.0019 **	2.9387 **	−4.0012 **	2.6981 *	−3.5099 **	2.8512 *	1.9563 **	2.0045 ***	3.2986 ***	2.6546
China: Lianyungang	Coefficient	−0.0358	−0.0442	0.0528	0.0647	0.0425	0.0513	0.1630	−0.0672	0.0730	−0.1379	6.3715
	t-stat	−3.2905 **	−2.5990 **	3.6111 *	2.1295 *	−1.6056 *	−2.6276 *	−2.4389 *	4.1508 *	2.6884 **	−1.5203 **	4.2100
China: Qingdao	Coefficient	0.0312	0.0054	0.1452	0.1555	0.2234	0.2521	0.0618	−0.0083	−0.2953	−0.1476	−5.8761
	t-stat	3.1649 *	2.5189 *	3.3765 *	3.6186 *	−2.6701 **	−3.3478 **	4.7165 *	3.4514 **	2.6197 ***	3.2421 ***	−3.3409
China: Qinhuangdao	Coefficient	−0.0754	−0.0548	0.2387	0.1752	0.0733	0.0567	0.0831	0.0097	0.0205	−0.0044	5.1285
	t-stat	−2.6285 *	−3.7153 *	1.7440 **	3.1508 **	4.5172 *	3.3196 *	−2.2590 *	1.3896 *	4.0089 **	3.5217 **	4.0006
China: Rizhao	Coefficient	−0.1340	−0.1195	0.1297	0.1201	0.0376	0.0935	0.0097	0.1582	0.0094	0.0190	4.1138
	t-stat	−4.2759 **	−3.0164 **	2.2256 **	3.2378 **	2.1390 *	2.8527 *	1.8361 *	−3.4800 *	−2.7182 *	1.3114 **	3.5706
China: Shanghai	Coefficient	0.1304	0.1256	0.4150	0.3628	0.4209	0.2514	0.1523	0.2195	0.2156	−0.2230	−6.1713
	t-stat	2.5981 *	2.1294 *	3.7598 ***	3.4519 ***	1.3871 ***	1.5662 ***	−4.5299 **	5.3298 **	3.1590 ***	2.1308 ***	−4.2992
China: Weihai	Coefficient	−0.0122	−0.0237	0.1442	0.1753	0.0674	0.0751	0.0640	0.1483	0.1815	0.0427	5.7634
	t-stat	−1.5380 **	−2.6908 **	4.5700 **	3.4729 **	−4.2568 **	−3.6225 **	2.8321 *	3.2648 *	1.2930 **	−3.5113 **	2.5310
China: Yantai	Coefficient	−0.0503	−0.0531	0.1256	0.0950	0.1241	0.1553	0.1452	0.1527	0.0505	−0.1486	4.4456
	t-stat	3.6125 **	2.7142 **	4.4003 **	3.6128 **	2.3987 **	3.1786 **	−2.5009 **	4.7996 **	3.2913 **	−2.7962 **	3.5897
Denmark: Aarhus	Coefficient	−0.0246	−0.0097	0.3419	0.2915	0.0347	0.0224	0.0575	−0.0192	0.1164	0.0740	−5.1362
	t-stat	−4.4085 *	−3.7736 *	5.3600 **	3.6262 **	1.5503 *	−2.2843 *	1.6448 *	−2.4861 *	3.7080 **	3.5123 *	−4.6251
Denmark: Copenhagen	Coefficient	−0.1566	−0.1454	0.2503	0.2264	0.0060	0.0554	0.0083	0.0164	0.0435	0.0777	−3.2587
	t-stat	2.3051 **	4.7238 **	−1.4967 **	2.7481 **	−3.3714 *	−4.7006 *	2.5091 *	1.5226 *	2.6172 *	−2.4553 *	−2.3521
Denmark, Greenland: Nuuk	Coefficient	0.0366	0.0473	0.7351	0.6775	0.0921	0.0070	0.4516	−0.0832	−0.0299	−0.0134	4.5600
	t-stat	−1.5827 *	−2.2518 *	4.2879 ***	3.8163 ***	2.7265 *	3.6198 *	−2.6315 **	3.4440 *	−1.7451 *	−3.5819 *	4.2187
Iceland: Reydharfjordur	Coefficient	0.0342	0.0215	0.5274	0.3969	0.2830	0.2697	0.5930	−0.0156	0.0715	0.0147	5.0232
	t-stat	−2.4054 *	−2.7916 *	4.2613 ***	3.3514 ***	−2.5326 *	4.4625 *	−2.4811 ***	1.6822 *	2.6380 *	1.0000 *	3.5714
Iceland: Reykjavik	Coefficient	−0.0236	−0.0174	0.6532	0.5731	0.3003	0.2954	0.1850	−0.0123	0.1486	0.0638	6.3522
	t-stat	−3.7198 *	4.5261 *	3.3899 ***	−2.5247 ***	−1.8345 **	1.9685 **	−3.2747 **	2.4981 *	3.5344 **	−2.8625 **	5.4910
Japan: Akita	Coefficient	−0.1123	−0.0909	0.5563	0.6215	0.1964	0.2240	0.1498	0.0086	−0.0465	−0.0341	−3.5213
	t-stat	−2.5934 **	−1.5487 **	2.5712 **	3.3408 **	−2.5370 **	−3.0567 **	4.4665 *	−2.4565 *	1.3173 *	2.4226 *	−2.3999
Japan: Hakata	Coefficient	−0.0405	−0.0864	0.4340	0.3422	0.1635	0.1754	0.3613	0.0170	0.0381	0.0654	3.6280
	t-stat	4.2984 **	3.7282 **	1.8651 **	2.8537 **	3.2049 **	2.6210 **	1.7506 *	2.8418 *	1.7399 *	−1.5980 *	2.1341

Table A7. *Cont.*

Port	Parameter	X₁	X₂	X₃	X₄	X₅	X₆	X₇	X₈	X₉	X₁₀	Constant
Japan: Kitakyushu	Coefficient	−0.2316	−0.2300	0.3145	0.4928	0.2250	0.1549	0.2407	0.1255	0.0182	0.0333	−5.3826
	t-stat	3.7388 **	−2.2738 **	1.7507 **	4.5755 **	−1.6131 **	−2.1213 **	2.6628 **	−1.5673 *	3.1996 *	2.0276 *	−3.0024
Japan: Niigata	Coefficient	0.1775	0.1104	0.2158	0.2470	0.2015	0.2824	0.0600	0.1364	−0.0975	−0.0409	6.2345
	t-stat	3.5172 **	1.7396 **	−2.5573 ***	−3.6369 ***	4.3862 ***	2.5731 ***	1.5382 ***	4.7211 *	2.7523 **	3.3278 **	4.6117
Norway: Bergen	Coefficient	−0.0164	−0.0331	0.1485	0.1001	0.1884	0.1569	0.1754	0.2362	0.1565	0.1831	3.5220
	t-stat	−3.8526 **	−3.5920 **	2.1567 **	2.8332 **	−1.7210 **	−2.4352 *	−2.3709 **	2.5863 **	−2.4207 **	−2.7456 **	2.3476
Norway: Hammerfest	Coefficient	−0.0265	−0.0326	0.0472	0.0743	0.0399	0.0545	0.2356	0.2134	0.0612	0.3007	5.9992
	t-stat	−3.4387 **	−2.4187 **	3.4206 *	2.6938 *	−3.4251 *	−2.5710 *	2.4884 *	−1.6307 **	−3.2655 **	1.6284 **	3.5475
Norway: Stavanger	Coefficient	0.0153	0.0242	0.2580	0.2421	0.0166	0.0532	0.1775	0.1863	0.3350	0.2675	6.6820
	t-stat	3.2854 *	2.4966 *	4.7364 **	1.6408 **	3.2489 **	2.3005 **	−1.5113 **	2.5981 **	4.1673 **	3.2151 **	4.7532
Norway: Tromso	Coefficient	−0.0483	−0.0574	0.2341	0.1752	0.0785	0.0519	0.1670	0.0445	0.0256	0.0662	5.5311
	t-stat	2.5800 **	3.2856 **	2.7209 **	3.1954 **	2.3661 *	3.5998 *	3.4839 **	−2.9113 *	1.2749 *	3.4806 *	3.8006
Norway: Trondheim	Coefficient	0.0677	0.0585	0.1217	0.1751	0.2630	0.2652	0.0523	0.1400	0.3675	0.2138	4.3717
	t-stat	2.3692 **	3.6401 **	2.5962 ***	2.3760 ***	3.2624 **	2.2471 **	−1.6296 **	4.1625 **	2.8841 **	−2.1532 **	3.9552
Russia: Anadyr	Coefficient	0.0018	0.0023	0.0562	0.0009	0.0065	0.0012	0.0550	−0.0031	−0.0042	0.0013	−5.3276
	t-stat	2.1535 *	2.5184 *	−1.2396 *	−1.2536 *	−2.1427 *	−1.3074 *	2.6186 **	−3.5283 *	4.0635 *	2.1467 *	−4.4884
Russia: Arkhangelsk	Coefficient	−0.0332	−0.0411	0.0357	0.0448	0.0125	0.0231	0.0824	−0.0057	0.1621	0.1274	4.1235
	t-stat	2.1574 **	3.6275 **	−2.5583 **	−3.5751 **	−4.8266 *	5.2408 *	1.6200 *	4.8652 *	−2.6333 *	−3.6755 *	3.0053
Russia: Dudinka	Coefficient	0.0095	0.0127	0.0234	0.0032	0.0070	0.0035	0.0844	0.0159	0.0167	0.0281	3.2344
	t-stat	−2.3746 *	−2.4993 *	4.3857 *	2.6350 *	3.5416 *	−4.3683 *	−1.7268 **	3.7004 *	2.5758 *	4.5006 *	2.1206
Russia: Murmansk	Coefficient	−0.0443	−0.0325	0.1342	0.1781	0.0453	0.0328	0.1367	0.0335	0.1862	0.1775	6.1731
	t-stat	4.1986 **	3.6174 **	−2.6315 ***	−3.4277 ***	−2.2200 *	2.3990 *	1.2708 **	2.2847 *	3.4721 **	−2.2740 **	4.5255
Russia: Petropavlovsk	Coefficient	0.0857	0.0546	0.1473	0.1624	0.0366	0.0247	0.0612	0.0554	0.0135	0.0076	3.2346
	t-stat	2.2249 *	2.3358 *	−3.8821 *	−2.5290 *	1.2987 *	4.5224 *	−2.2775 **	1.7189 *	2.5000 *	−3.5227 *	2.9672
Russia: Pevek	Coefficient	0.0070	0.0122	0.2425	0.0258	0.0021	0.0046	0.0230	0.0337	0.0255	0.0088	5.3381
	t-stat	−1.8421 *	−3.4339 *	2.5190 *	1.3912 *	3.3059 *	2.4483 *	−2.3995 **	3.2694 *	−4.7141 *	−2.1945 *	4.0053
Russia: Sabetta	Coefficient	0.0243	0.0330	0.0527	0.0035	0.1232	0.0024	0.0113	0.2055	0.0013	0.0005	4.1225
	t-stat	−2.5992 *	−1.7268 *	2.3981 **	4.2664 *	3.0676 **	2.8495 *	3.4887 *	−5.1837 **	−3.4416 *	−4.3663 *	3.3406
Russia: Vladivostok	Coefficient	−0.0884	−0.0561	0.0402	0.2145	0.1567	0.1783	0.0285	0.0996	0.2743	0.2284	6.5893
	t-stat	3.2056 **	1.5725 **	2.6843 ***	3.3003 **	1.3280 ***	4.5871 ***	−2.1264 *	−3.4720 *	4.0065 ***	3.4071 ***	5.2444
South Korea: Gwangyang	Coefficient	−0.0664	−0.0852	0.3643	0.3315	0.3364	0.3142	−0.1398	−0.1145	−0.0020	−0.0074	4.3718
	t-stat	−3.2817 **	−2.5006 **	4.1509 ***	3.4782 **	−1.7016 ***	−3.5290 ***	2.2750 *	−2.4988 *	3.4285 *	3.5311 **	2.2269
South Korea: Pusan	Coefficient	0.0953	0.0714	0.8165	0.8554	0.6571	0.6794	−0.1562	−0.1724	−0.0055	−0.0247	6.1378
	t-stat	1.7136 **	2.2485 **	4.9127 ***	4.2942 ***	−3.2704 ***	−1.6228 ***	2.3007 **	3.7506 **	−1.4682 **	−2.8156 **	4.4093
South Korea: Ulsan	Coefficient	−0.0676	−0.0608	0.5153	0.5429	0.5620	0.4475	0.0063	−0.1164	−0.0725	−0.0637	5.7107
	t-stat	3.3175 **	1.2601 **	3.4274 ***	4.1212 ***	−2.0053 ***	−1.7312 ***	−3.9279 *	−2.1505 *	−3.1000 **	−2.4861 **	3.2123
Sweden: Gothenburg	Coefficient	0.0068	0.0052	0.6987	0.7425	0.1850	0.1874	0.1637	−0.0032	0.0145	0.0957	−4.1752
	t-stat	1.3791 *	2.4720 *	−4.2405 ***	−3.6029 ***	−1.7442 **	−2.4933 **	1.7446 **	−3.1268 *	1.5286 *	2.3864 *	−3.6973
Sweden: Halmstad	Coefficient	0.0005	0.0007	0.3316	0.4254	0.1261	0.1100	0.0432	−0.0047	0.0530	0.0813	2.2097
	t-stat	3.3796 *	2.4305 *	−3.2777 ***	−2.7315 ***	−4.5985 **	−2.6013 **	2.3615 **	4.5841 *	2.7998 *	3.7286 *	2.0585

Note: *, **,*** = significance at 10% level, 5% level, and 1% level, respectively. Source: Authors' calculation.

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