IMPACTS OF COVID-19 NON-PHARMACEUTICAL INTERVENTIONS ON TRADE FLOWS: A GLOBAL PANEL VECTOR AUTOREGRESSION ANALYSIS

Worawat Srisawasdi[1, *], Sylvia Szabo[2], Takuji W. Tsusaka[3]
Neil D. Burgess[4], James Vause[5]

Abstract

The COVID-19 outbreak has contributed to a tremendous global decline in international trade flows. The rapid spread of the disease and the control measures implemented by governments to contain the virus have led to serious consequences for the global economy. The pandemic has affected the international movement of people, goods, and services. Currently, the systematic quantitative research investigating the effects of specific non-pharmaceutical intervention policy clusters on country-level international trade flows, remains limited. In this study, the Panel Vector Autoregression (PVAR) method was conducted using country-level panel data collected from various international sources including the United Nations, World Bank, and University of Oxford. The results show that stringent COVID-19 closure, social distancing, and containment measures and health-related measures, had significant negative impacts on trade flows. In contrast, economic support measures showed significant positive effects on trade. In summary, the findings suggest that policymakers should maintain less stringent containment measures related to public closure and movement restrictions and stimulate economic activities through economic support policies in order to minimize losses in trade flows during the pandemic.

Keywords: international trade, COVID-19, SARS-CoV-2, non-pharmaceutical intervention, UKRI-GCRF Trade Hub, panel vector autoregression

JEL Codes: F10, C33, I00, F01

[1] Dr. Worawat Srisawasdi is currently the Academic Researcher at the Multicultural Studies and Social Innovation Center/The Multicultural Studies and Social Innovation Research Unit, Institute of Asian Studies, Chulalongkorn University. He obtained his PhD in Natural Resources Management from the Asian Institute of Technology. He received his master's degree in Management and Marketing from College of Management Mahidol University and bachelor's degree in International Business Management from Chulalongkorn University. Email: worawat2555@gmail.com

[2] Dr. Sylvia Szabo was a Research Professor at Dongguk University, South Korea at the time of writing this paper. She holds a doctoral degree from the University of Southampton and master's degrees from the London School of Economics and Political Science.

[3] Dr. Takuji W. Tsusaka is currently an Assistant Professor at the Department of Development and Sustainability, School of Environment, Resources and Development, the Asian Institute of Technology. He holds a PhD and master degree from the National Graduate Institute for Policy Studies and a bachelor degree from the University of Tokyo.

[4] Dr. Neil Burgess is currently the Head of the Science Programme at UNEP-WCMC and a Professor at the Center for Marcoecology, Evolution and Climate at the University of Copenhagen.

[5] James Vause is currently the Lead Economist of the UN Environment World Conservation Monitoring Centre (UNEP-WCMC).

1. INTRODUCTION

Since the outbreak of the COVID-19, countries around the world have experienced several 'pandemic waves' (Diaz 2020). While uncertainty remains as to how and when the pandemic will subside, the unprecedented economic impact caused by the global health emergency has sharply exposed the global economy's weaknesses in complex supply chains, severely slowing down the progress of development around the world (UNCTAD 2020). Statistics show that more people live in extreme poverty as the global economy experienced a sharp contraction in 2020 (UNCTAD 2020).

The COVID-19 non-pharmaceutical interventions (NPIs) implemented by governments had serious consequences for international trade flows (Hayakawa and Mukunoki, 2021a-c). In 2020, the world's economy experienced some of the largest reductions in international trade since World War II (WTO, 2021). The declines in both world industrial production and goods trade in the first half of 2020 were comparable to those during the Global Financial Crisis. International trade plunged in 2020 but recovered sharply in 2021 (WTO, 2021). While total trade flows are now comfortably above pre-pandemic levels, trade impacts across specific goods, services and trade partners are highly diverse, creating pressures on specific sectors and supply chains.

Recent literature documents that the COVID-19 pandemic has had multiple direct impacts on the global economy. Literature surveys by Goodell (2020) and Yarovaya et al. (2020) further show that the pandemic has had a negative impact on the financial sector. Bachman (2020) pointed out that the pandemic has negatively affected global production, disrupted supply chains, and unsettled financial markets globally. Ashraf (2020a) found that higher national-level uncertainty significantly aggravates negative stock markets' reaction to an increase in reported COVID-19 cases. The decline in purchasing power linked to lost income due to the pandemic has threatened food security, disrupted the global supply chain, and interrupted the movement of migrant workers (UNEP, 2020).

Some literature has explored the COVID-19 impact on globalization. Shrestha et al. (2020) found that the pandemic has affected the world economy, healthcare, and globalization through disturbances in travel, events, employment, food supply chains, academia, and healthcare capacity. Certain countries were more vulnerable than others. In Africa, more vulnerable countries included South Africa and Egypt; in Europe, Russia, Germany, and Italy; and in Asia, India, Iran, Pakistan, Saudi Arabia, and Turkey; for the Americas, Brazil, the United States of America (USA), Chile, Mexico, and Peru (Shrestha et al., 2020).

The COVID-19 first wave led to a contraction in the volume of international trade. The total 2020 trade volume was down 5.3% compared to 2019 (WTO, 2021). Particularly affected was export from large economies including the USA, Japan, and the European Union (EU). The economic contraction in China was smaller than the global average, as it managed to control the first wave and reopened its economy relatively quickly. Latin America and the Caribbean were the developing regions most affected by the pandemic. In terms of sectors, manufacturing activities were disrupted first in Asia and then in Europe, North America, and the rest of the world (UNECLEC, 2020). Widespread border closures resulted in a steep rise in unemployment, especially in the USA, which led to reduction in demand for goods and services. The global GDP in 2020 registered its sharpest contraction since the Second World War (UNECLAC 2020).

The rapid spread of COVID-19 and the public measures implemented by governments to contain it had serious consequences for the global economy and trade flows. Maliszewska (2020) conducted ex-ante assessment of the impact of the pandemic on GDP and trade using a standard global computable general equilibrium model, indicating a fall in the global GDP by 2% below the benchmark for the baseline

pandemic scenario and by 4% for the amplified pandemic scenario. The biggest negative shock was found in the following areas: reduction in the domestic services output, an increase in international trade costs, a decline in travel services, and reduction in activities that required proximity between people. The World Bank projects that as a result of the pandemic, the global output will fall by between 5.2 % and 8.0 % in 2020 and the World Trade Organization projects global merchandise trade to fall by between 13 % and 32 % in their optimistic and pessimistic scenarios (WB 2020; WTO 2020a). According to the report by UNCTAD, world merchandise trade decreased by 7.4% in 2020 during the COVID-19 pandemic. Furthermore, global exports fell by 1.4 trillion USD compared to the previous year (UNCTAD 2020). The first wave caused sharp declines in export, particularly from the EU and the USA.

The pandemic also sparked concerns regarding export restrictions imposed around the world. In an effort to control the pandemic, some governments decided to establish export control over certain medical products in the form of temporary export bans or additional requirements for licensing and authorization. Other governments, concerned with the sufficiency of food supplies, introduced export restrictions over agricultural products. These policies had implications for equitable food distribution in the global market (Nguyen 2020).

Some studies show that global trade flows were heavily impacted by the pandemic. Hayakawa and Mukunoki (2021a, b) examined the impact of the COVID-19 spread and lockdown policies on international trade, finding that stay-at-home policies did not have significant effects on overall trade, while negative effects were found in a few industries. Workplace closures had significant negative effects on trade, affecting most industries, except for intra-Asian trade. The same authors also investigated how these negative impacts on international trade changed over time, comparing the duration of the first wave (January to August) of the pandemic, with the same period in 2019, covering the export flow from 34 countries to 173 countries, and discovering significant negative effects of the pandemic on both exports and imports (Hayakawa and Mukunoki, 2021c).

While literature on the impacts of COVID-19 control measures on global trade begins to emerge, as exemplified by Hayakawa and Mukunoki (2021a-c), there is limited evidence of the impacts of a broader range of specific control measures on country-level trade values. Building upon Hayakawa and Mukunoki's (2020b) work, which examined stay-at-home orders and workplace closure, the present paper expands the scope by investigating multiple response measures. In other words, the main objective of this paper is to examine the effects of the three clusters of non-pharmaceutical interventions (NPIs) on international trade flows amid the first wave of the COVID-19 pandemic by using a panel vector autoregression (PVAR) approach. The PVAR approach allows for analysis of a large cross-country dataset consisting of 70 countries observed over the period from January 2020 to May 2021 amid the COVID-19 pandemic crisis. The PVAR approach also addresses the endogeneity problem by allowing endogenous interaction between the variables in the model. By undertaking this analysis, the paper will contribute not only to literature but also to the policy debate and respective choices of policy instruments aimed at controlling the spread of COVID-19 and other global pandemics while maintaining economic growth at the same time.

2. HYPOTHESES

This section presents three testable hypotheses regarding the direct and indirect impacts of the non-pharmaceutical interventions on international trade flows. Three policy clusters are adopted, namely, the containment and health cluster, stringency cluster, and economic support cluster. The containment and health cluster represents emergency policies and is constructed from

containment policies as well as three specific health-related policies: public awareness campaigns, COVID-19 testing, and use of facial coverings (Ashraf 2020b). The restrictions on domestic movement, and restrictions on international travel. The stringency cluster consists of social distancing measures including school closure, workplace closure, public event cancellations, gathering restrictions, public transport closure, stay-at-home requirements, and restrictions on domestic and international travel. The economic support cluster is composed of two policies, namely income support and household debt relief, which aim to provide financial support to citizens amid the economic crisis (Hale et al. 2020b). Accordingly, the three hypotheses are described as follows.

Hypothesis 1: Containment and health-related policies have a positive impact on trade flows.

According to the CDC (2020), intensive information campaigns provide awareness of the benefits of sanitation while frequent testing and contact tracing can help identify infected and suspected cases early on and contribute to reducing the number of infected cases. Reduced numbers can boost public confidence in dealing with the pandemic. Consequently, good management of the pandemic with saved lives and reduced overall impacts can provide economic support (Greenstone and Nigam, 2020; Thunström et al., 2020). Furthermore, several studies have showed that facial covering policies have a positive impact on trade and overall economic performance during the pandemic crisis (Ashraf, 2020b; Barbero et al., 2021; Hayakawa and Mukonoki (2020b). Therefore, it is hypothesized that containment and health-related policies lead to strengthening economic activities and increasing trade flows during the pandemic.

Hypothesis 2: Stringent closure and social distancing policies have negative impacts on trade flows.

Several studies have revealed the negative impacts of stringent closure and social distancing measures on the economy and trade activities. Hayakawa and Mukunoki (2020b) investigated the effects of stay-at-home and workplace closure on international trade, finding significant negative effects of workplace closure on exports. Stannard (2020) estimated the impact of stringent COVID-19 measures, finding that impacts ranged from an estimated 4 percent reduction in the GDP under Alert Level 1 to 37 percent reduction in the GDP under Alert Level 4. Eichenbaum, Rebelo and Trabandt (2020) suggested that, while cutting back on work and consumption during the COVID-19 pandemic can help reduce fatalities, they tend to also exacerbate economic recession at the same time. Existing research leans toward the negative effects of stringent measures on trade activities and overall economic performance (Deb, 2020; Hayakawa 2021a; Ashraf 2020). Therefore, this research hypothesizes that stringent policies have negative impacts on international trade.

Hypothesis 3: Economic support policies lead to an increase in trade flows.

Economic support policies are expected to increase economic capacity to produce greater surplus that can be traded both domestically and internationally. These policies include debt relief and income support. Small businesses are enabled to invest in productive capital when receiving economic support from the government (BOT, 2020), while burdens on households are eased when stringent measures suppress economic activities (BOT, 2020). It is thus hypothesized that income support and debt relief measures lead to a boost in trade activities.

3. MATERIALS AND METHODS

3.1 Data

Country-level panel data were collected in two major categories, namely, international trade flows and non-pharmaceutical interventions for 70 countries from January

2020 to May 2021, covering a 15-month period. The trade data for imports, exports, and total trade, were obtained from the UN Trade Statistics Database (UN Comtrade, 2021). The government response indices for the three non-pharmaceutical policy clusters were collected from the COVID-19 Government Response Tracker database of the Blavatnik School of Government, University of Oxford (Hale et al., 2020b). At the cluster level, three aggregate indices were adopted: the containment and health index (CH), stringency index (SI), and economic support index (ES). The containment and health index was aggregated from four sub-indicators for disease containment policies and health system policies, which were public information campaign, disease testing policy, contact tracing, and facial covering policy (Hale et al. 2020b). The stringency index records the information on closure and social distancing measures by aggregating eight

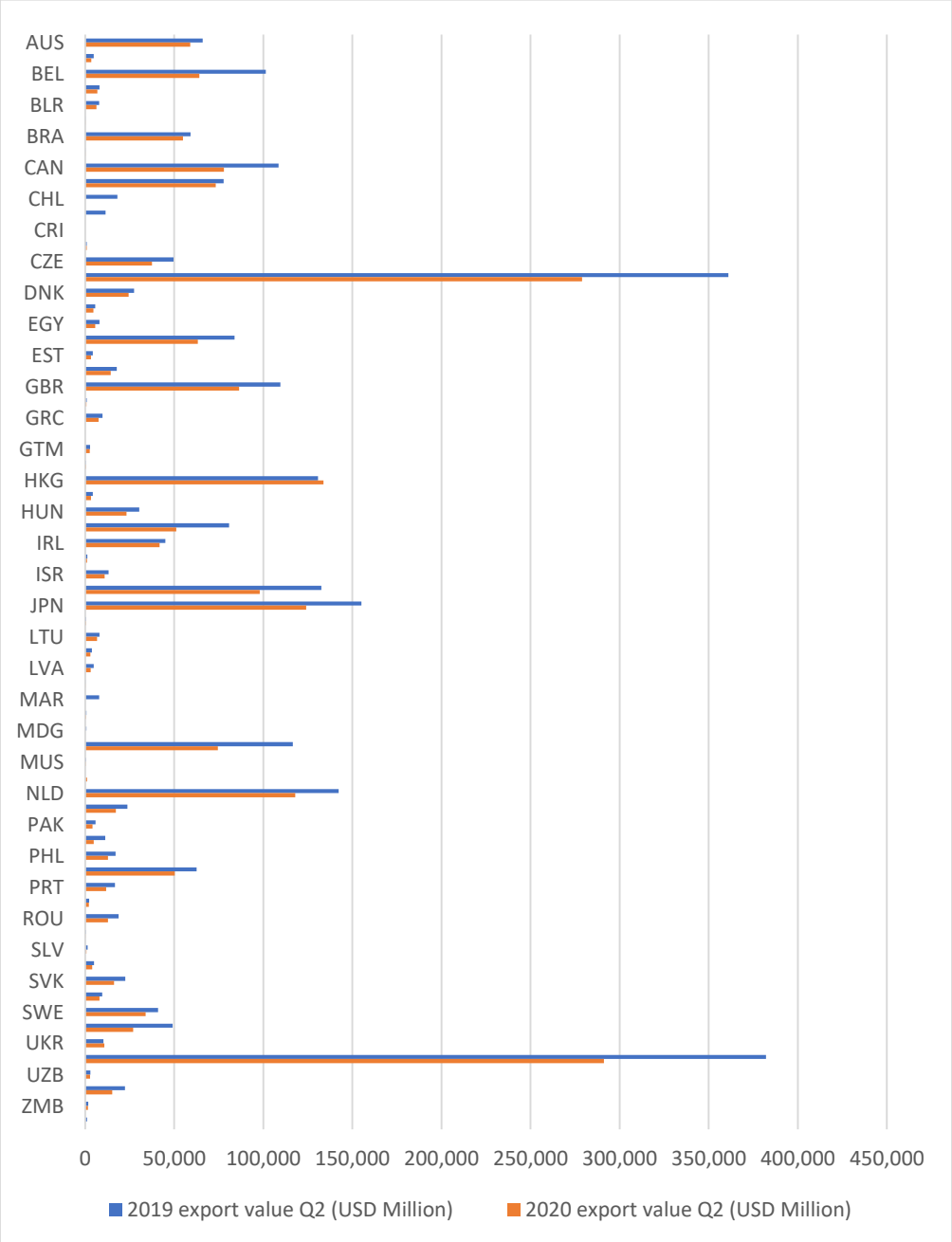

Figure 1 Export Value Comparison for The Second Quarter Between 2019 and 2020.

sub-indicators, namely, school closure, workplace closure, public transport closure, public events cancellation, gathering restrictions, stay-at-home requirements, restrictions on domestic movement, and restrictions on international travel. The economic support index was an aggregation of two policy sub-indicators, namely, income support and debt relief for households. The three indices were arithmetic means of the sub-indicators for specific nonpharmaceutical policies as measured on ordinal scales. The cluster indices were regarded as numerical variables as opposed to ordinal ones, and were rescaled to range from 0 to 100. In total, the collected panel data consisted of 70 countries and 17 time periods (monthly) from January 2020 to May 2021.

Table 1 (see Appendix) summarizes the variables analyzed in the statistical analysis. The variables include total export and import value (in million USD), total trade value (in million USD), the containment & health index, stringency index, economic support index, and the sub-indices representing the specific measures, which include school closure, workplace closure, public event cancellation, gathering restrictions, stay-at-home requirements, domestic travel restrictions, international travel restrictions, income support policy, public awareness campaigns, testing policy, debt relief, and facial covering policy.

Table 2 (see Appendix) lists the 70 countries included in the analysis, with export values for the second quarter of 2019 and 2020, cumulative COVID-19 cases as of 10th October 2021, and the Government Response Index (GRI) during 2020. The second quarter of 2020 is shown as the pandemic became a global threat at around the end of March 2020, resulting in a significant decline in global trade flows. In the second quarter of 2020, the effects of the pandemic began to manifest serious impacts on economic activities including international trade, except for some small-sized low-income countries.

3.2 Descriptive sketch of the data

Figure 1 compares exports in the second quarter of 2019 and 2020. The orange-colored bars and blue-colored bars represent 2019 and 2020 export values, respectively. According

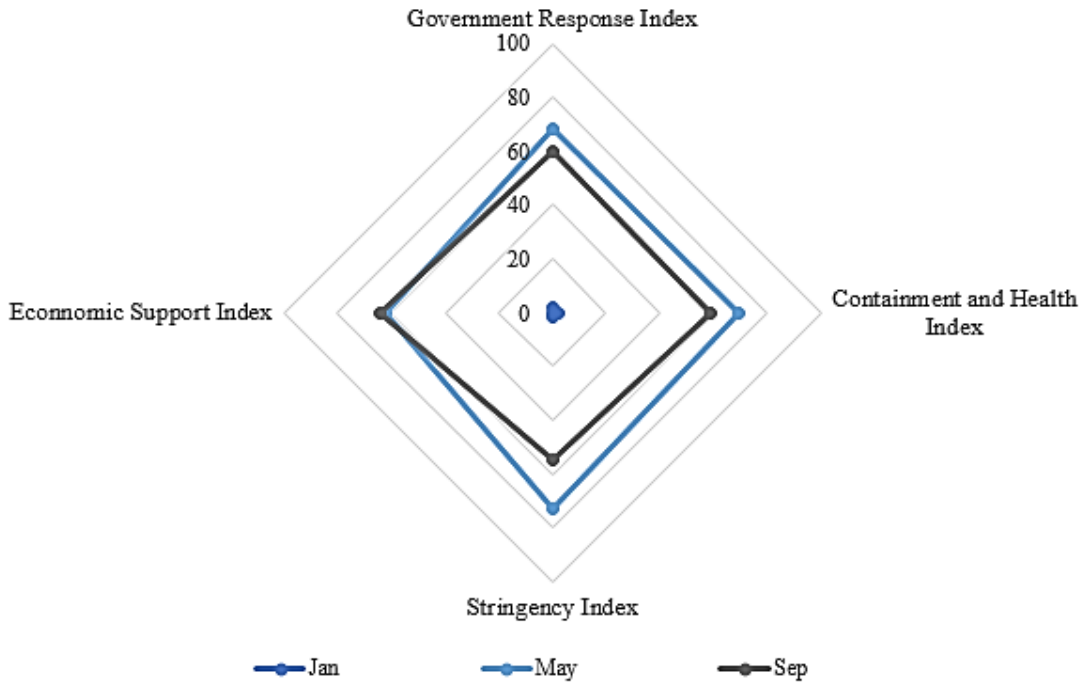

Figure 2 Total Government Response Index, Containment and Health Index, Stringency Index, and Economic Support Index in January, May, and September 2020

to Figure 1, it was clear that export values declined significantly in the second quarter of 2020 compared to the second quarter of 2019 Figure 2 and 3 show changes in non-pharmaceutical intervention indices at the policy cluster level and specific policy level, respectively, for January, May, and September 2020. For policy cluster indices (Figure 2), the values were lowest in January, increased significantly in May, and declined slightly in September. Figure 3 shows that there was a gradual increase in specific policy indices as well. Restrictions on traveling and public gatherings remained relatively high. Other specific measures also showed a sharp rise. The values of specific indices reached

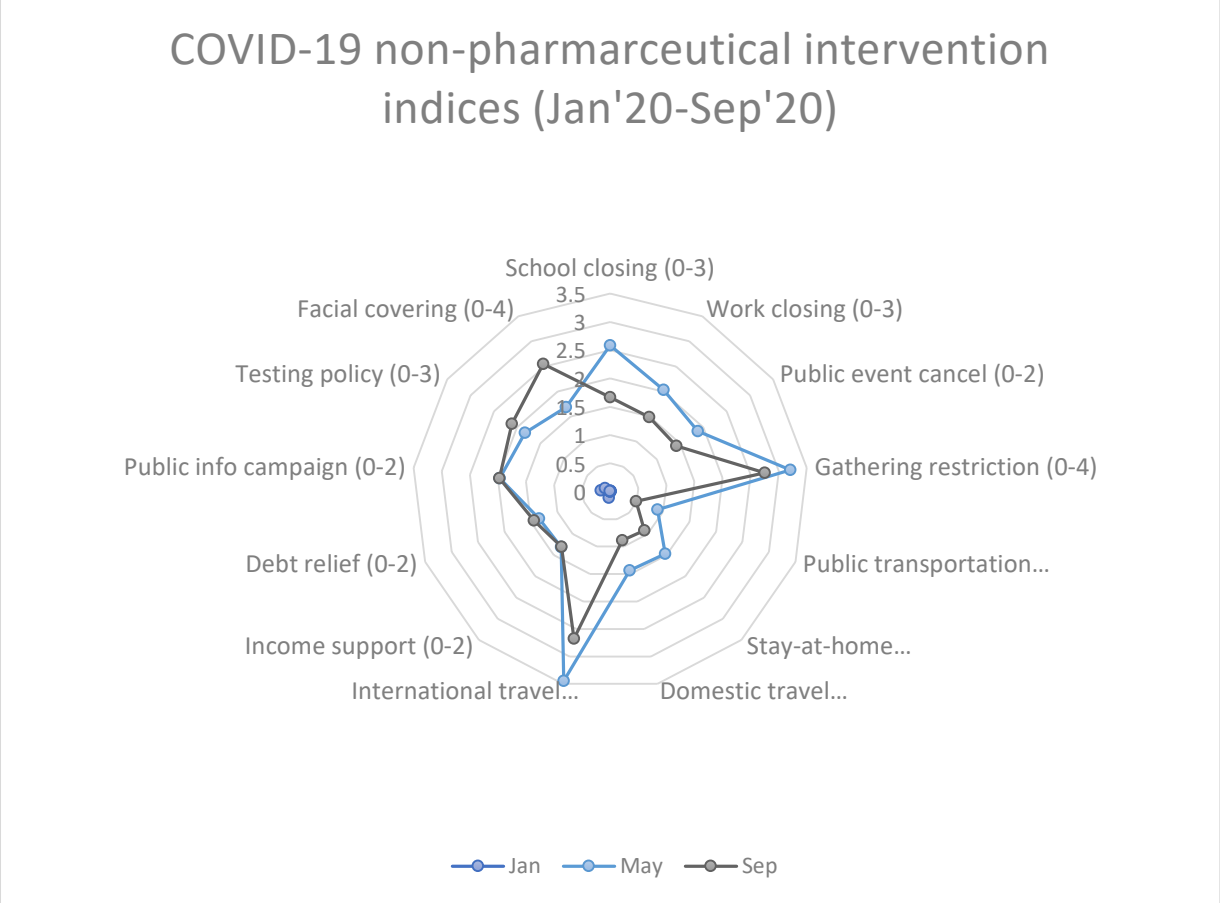

Figure 3 Gradual Changes in Specific COVID-19 Non-pharmaceutical Policy Indices in January, May, and September 2020.

Notes: School closure: 0 – No closure, 1 – Recommend closing, or all schools open with alterations resulting in significant differences compared to usual, non-COVID-19 operations, 2 – Require closing some levels or categories, 3 – Require closing all levels; Workplace closure: 0 – No closure: 1 – Recommend closing, 2 – Require closing for some sectors or categories of workers, 3 – Require closing all-but-essential workplaces; Public event cancellation: 0 – No cancellation, 1 – Recommend cancellation, 2 – Require cancellation; Public transport closure: 0 – No closure, 1 – Recommended closure, 2 – Require closure; Stay-at-home: 0 – No requirement, 1 – Recommend not leaving house, 2 – Require not leaving house with exceptions for grocery and essential trips, 3 – Require not leaving house with minimal exceptions; Domestic travel: 0 – No restriction, 1 – Recommend not traveling between regions/cities, 2 – Internal movement restrictions in place; International travel: 0 – No restriction, 1 – Screening, 2 – Quarantine for arrivals from high-risk regions, 3 – Ban on arrivals from some regions, 4 – Ban on arrivals from all regions or total border closure; Income support: 0 – No income support, 1 – Government is replacing less than 50% of lost salary, 2 – Government is replacing 50% or more of lost salary; Debt relief: 0 – No, 1 – Narrow relief, specific to one kind of contract, 2 – Broad debt/contract relief; Testing policy: 0 – No testing policy: 1 – Only those who have symptoms and meet specific criteria, 2 – testing of anyone showing COVID-19 symptoms; Facial covering: 0 – No policy, 1 – Recommended, 2 – Required in specified shared/public spaces outside the home; 3 – Required in all shared/public spaces outside the home.

their highest values around May. The chart suggests that since the advent of the pandemic in March 2020, the stringency of intervention measures remained high.

Figures 4 and 5 show the gradual increase in the number of daily reported new test-positive cases and deaths from COVID-19 in six main regions of the world (Africa, Asia, Europe, Oceania, North America, and South America) from January to September 2020. Numbers started to rise in March 2020 onward (Figure 4). In April 2020, Europe and North America in particular, experienced a sharp increase in daily cases. From May 2020 onward, other regions including Asia and South America faced significant increases. Africa and Oceania appeared to be the least affected regions. Daily new deaths (Figure 5) show similar trends to daily new cases. South Africa appeared to experience large fluctuation in death cases, reaching over 5,000 daily deaths in certain periods, which could be due to failure in management of healthcare systems, relative to other regions. Europe, on the other hand, tended to experience a gradual decline in death cases. The reported daily death toll in Oceania and Africa remained lower compared to other regions. Death cases in Asia and North America remained relatively high through

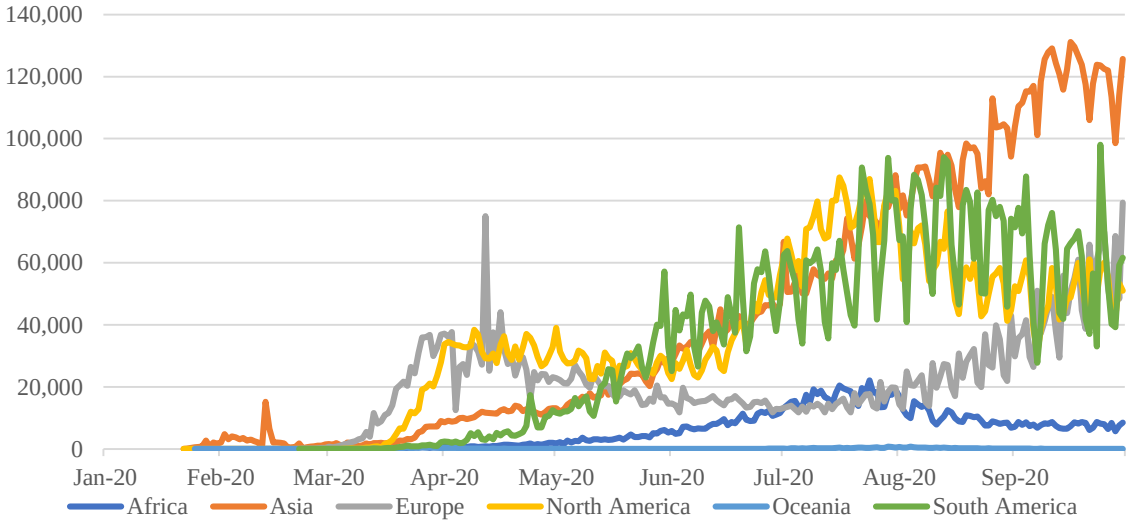

Figure 4 COVID-19 Daily Reported New Tested-Positive Cases by Region from January to September 2020.

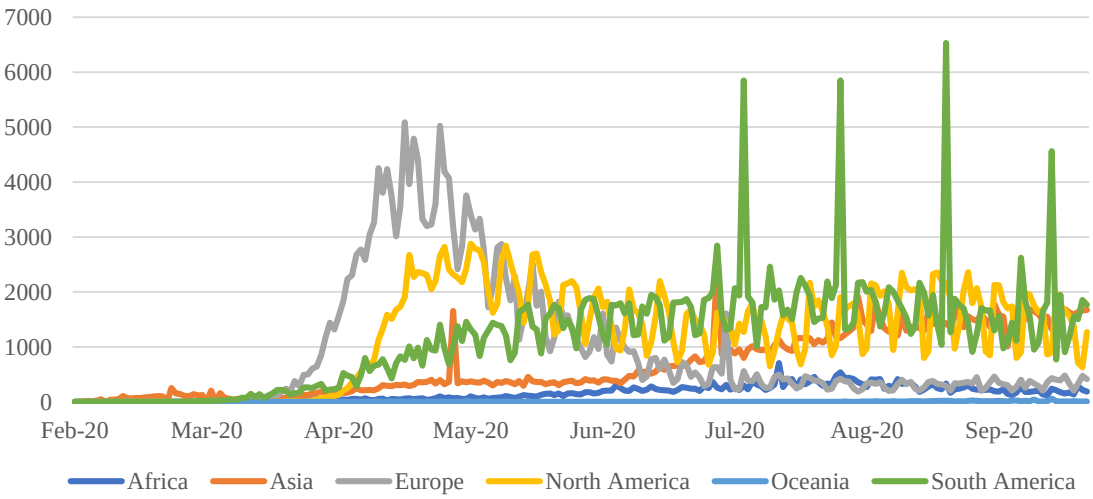

Figure 5 COVID-19 Daily New Deaths by Region from January to September 2020.

September 2020.

Figure 6 illustrates the effective reproduction rate (*R*) in the six regions from January to September 2020. The effective reproduction rate is defined as the average number of secondary cases produced by a primary case (Arrryo-Marioli et al. 2021). The number of infected individuals keeps increasing as long as $R > 1$. The effective reproduction number remained high in February to March 2020 and gradually declined to around 1.0-1.5 in April 2020 onward. In the Oceania region, the effective reproduction rate remained relatively low. On average, the effective reproduction rate for other regions was above 1.0. Therefore, other regions apart from Oceania continued faced rising numbers of test-positive individuals in 2020.

3.3 Unit Root Test

For PVAR analysis, it is essential to conduct a unit root test prior to the implementation of the time series analysis. There are several methods to conduct the first-generation panel unit root tests. The Harris and Tzavalis (HT) unit root test was first developed by Harris and Tzavalis (Harris and Tzavalis 1999). Levin et al. (2002) also developed the Levin-Lin-Chu test for panel data unit root testing. The Harris-Tzavalis (1999), Levin–Lin–Chu (2002) and Im-Pesaran-Shin (2003) tests all have a null hypothesis stating that the panels have a unit root. The Pesaran (2004) test for cross-sectional dependence is commonly used when testing a dynamic panel dataset.

In this study, the Im–Pesaran–Shin (2003) test (IPS test) was chosen for testing the presence of unit roots. All series were tested to investigate the presence of the unit root. The tests were conducted on a demeaned data series to eliminate the concern of cross-sectional dependence. The IPS test was conducted on balanced panel data consisting of 70 countries across 17 monthly periods. The null hypothesis states that the series contains a unit root. Thus, rejecting the null hypothesis indicates that there is no presence of a unit root in the cross sections. The first difference of all series in the model ensures that all cross sections are stationary. The results of the IPS test on the first differenced series points to rejection of the null hypothesis of a unit root in all differenced series.

3.4 Panel Vector Autoregression Analysis

The PVAR approach treats all variables as endogenous to one another, and explicitly models the time dimension of the series

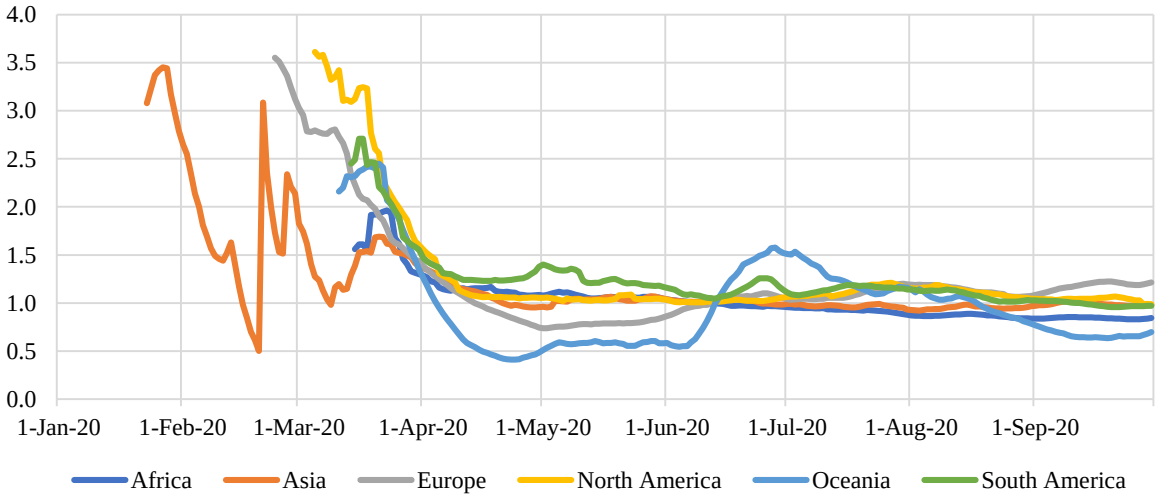

Figure 6 COVID-19 effective reproduction rate by region from January to September 2020.

(Holtz-Eakin et al. 1988). The advantage of the PVAR approach over the traditional VAR estimation is that it greatly increases the sample size by combining the time dimension with the cross-sectional dimension. This method has been implemented to study research topics related to finance and economics including financial markets (Love and Zicchino 2006). Equation 2 describes the variables in the PVAR model,

$$X_{it}^{\Delta} = \alpha_0 + \alpha_0 X_{it-1}^{\Delta} + f_i + \tau_t + \varepsilon_{it}^{\Delta} \quad \text{Eq. (2)}$$

where X_{it}^{Δ} is

$$X_{it}^{\Delta} = \begin{Bmatrix} \Delta IM_{it} \\ \Delta CH_{it} \\ \Delta SI_{it} \\ \Delta ES_{it} \end{Bmatrix}, \begin{Bmatrix} \Delta EX_{it} \\ \Delta CH_{it} \\ \Delta SI_{it} \\ \Delta ES_{it} \end{Bmatrix}, \begin{Bmatrix} \Delta TR_{it} \\ \Delta CH_{it} \\ \Delta SI_{it} \\ \Delta ES_{it} \end{Bmatrix}$$

The vector X_{it}^{Δ} contains the first difference of IM_{it}, EX_{it}, TR_{it}, CH_{it}, SI_{it}, and ES_{it}; where IM_{it} represents the import value, EX_{it} represents the export value and TR_{it} represents the total trade value. CH_{it}, SI_{it}, and ES_{it} represent the three policy indices. CH_{it} represents the containment & health index, SI_{it} represents the stringency index and ES_{it} represents the economic support index, i is an index of each of the N countries, while t represents the time period from 1 to T. The error term, $\varepsilon_{it}^{\Delta}$, is identically and independently distributed. The variable f_i is included for each country and τ_t is included to account for common time effects.

The impulse response functions (IRF) are constructed following the PVAR analysis. The impulse response function of the PVAR model measures changes in the future responses of all variables in the system when a variable is shocked by an impulse. The constructed IRF in this study covers 5 periods following the initial shock, representing the relationships between the trade flows (i.e., exports, imports, and total trade) and the COVID-19 non-pharmaceutical intervention indices (i.e., containment and health, stringency, and economic support). In this study, one period represents a 1-month interval. Therefore, an impulse response function of 5 periods is equivalent to a 5-month interval. Furthermore, the bootstrapped error bands from 500 Monte Carlo simulations were applied with a corresponding 95% confidence interval in each impulse response function.

4. RESULTS

4.1 Descriptive Statistics Summary

Table 3 summarizes the descriptive statistics for the variables included in the analysis. The mean values of imports, exports, and total trade were 14,504, 13,012, and 27,515 million USD, respectively. The standard deviations for imports, exports, and total trade were 29,732, 23,183 and 52,191 million USD, respectively. The mean indices for the three policy clusters were 48.3, 48.4, and 44.3 for the CH, SI, and ES, respectively. The standard deviations for the three policy clusters were 27.1, 29.4 and 34.3 for the CH, SI, and ES, respectively. The specific measurement indices had different ranges of values. The average indices and standard deviations for specific measures were 1.31 and 1.29 (school closure), 1.27 and 0.99 (workplace closure), 1.20 and 0.83 (public event cancellation), 2.09 and 1.56 (gathering restrictions), 0.88 and 0.87 (stay-at-home requirements), 0.86 and 0.84 (domestic travel restrictions), 2.39 and 1.39 (international travel restrictions), 0.93 and 0.80 (income support policy), 1.63 and 0.70 (public awareness campaign), 1.48 and 0.95 (testing policy), 0.97 and 0.83 (debt relief), and 1.34 and 1.41 (facial covering policy).

4.2 Unit Root Test Results

Using the Pesaran (2004) test, the results of testing the series for cross-sectional dependence are shown in Table 4. According to the results, the null hypothesis of cross-sectional independence was not rejected. This means that the assumptions of the first-generation panel data unit root tests still hold.

Table 3 Summary of Descriptive Statistics for The Variables Included in This Study

Variable	Scale	Mean	Std. Dev.	Min	Max
Imports (million USD)	Ratio	14,504	29,732	51	212,437
Exports (million USD)	Ratio	13,012	23,183	11	134,401
Total trade (million USD)	Ratio	27,515	52,191	71	333,953
Containment and health index (CH) (0-100)	Interval	48.3	27.1	0	94.5
Stringency index (SI) (0-100)	Interval	48.4	29.4	0	100
Economic support index (ES) (0-100)	Interval	44.3	34.3	0	100
School closure (0-3)	Interval*	1.31	1.26	0	3
Workplace closure (0-3)	Interval*	1.27	0.99	0	3
Public event cancellation (0-2)	Interval*	1.20	0.83	0	2
Gathering restrictions (0-4)	Interval*	2.09	1.56	0	4
Stay-at-home requirements (0-3)	Interval*	0.88	0.87	0	3
Domestic travel restrictions (0-2)	Interval*	0.86	0.84	0	2
International travel restrictions (0-4)	Interval*	2.39	1.39	0	4
Income support policy (0-2)	Interval*	0.93	0.80	0	2
Public awareness campaign (0-2)	Interval*	1.63	0.70	0	2
Testing policy (0-3)	Interval*	1.48	0.95	0	3
Debt relief (0-2)	Interval*	0.97	0.83	0	2
Facial covering policy (0-4)	Interval*	1.34	1.41	0	4

* The monthly average was calculated from daily ordinal-scale data. Therefore, effectively these are interval-scale variables.

Table 4 Pesaran (2004) Cross-sectional Dependence Test

Variable	CD-test	*p*-value	Corr.
Imports	89.38	0.00	0.44
Exports	74.10	0.00	0.36
Total trade	93.56	0.00	0.46
Containment & health index	164.36	0.00	0.81
Stringency index	151.47	0.00	0.75
Econ. support index	132.64	0.00	0.71

Notes: Under the null hypothesis of cross-sectional independence CD ~ N(0,1)

Table 5 The Im–Pesaran–Shin (2003) Unit Root Test

	IPS			
	Level		1st difference	
Variables	Stat	p-value	Stat	p-value
Imports	-1.883	0.03	-10.686	0.00
Exports	-1.632	0.05	-13.397	0.00
Total trade	-1.737	0.04	-11.81	0.00
Containment & health index	-6.218	0.00	-15.671	0.00
Stringency index	-5.619	0.00	-14.077	0.00
Economic support index	-10.076	0.00	-23.162	0.00

Table 5 shows the results of the Im-Pesaran-Shin (2003) unit root test. The IPS unit root test suggests rejection of the null hypotheses for all series, at their levels. Thus, it is concluded that all series in the model are stationary at their respective levels. The first difference was also taken for all of the five series and retested for stability and stationarity to ensure that all cross sections were stationary at the first difference. The results suggested rejection of the null hypothesis at the first differenced level across all series.

4.3 PVAR-IRF Results

The impulse response functions were reported for five periods following the initial shock, which represented the relationships between the trade flows (exports, imports, and total trade) and the COVID-19 public measures indices (containment & health index, stringency index and economic support index). In this study, one period represents a one-month interval. Therefore, the impulse response function for five periods is equivalent to a 5-month interval. Figures 7 and 8 provide the complete cumulative impulse response functions representing the relationships between exports, the containment & health index, stringency index, and economic support index.

In Figure 7, the three NPI indices are ordered before total exports, while in Figure 8, export value is ordered before the three public measures indices. In each impulse response function, bootstrapped error bands from 500 Monte Carlo simulations were applied with a corresponding 95% confidence. In both figures, the same pattern representing significant relationships between the exports and COVID-19 non-pharmaceutical interventions emerged. Shocks to the economic support index (ES) have a statistically significant positive effect on exports. Furthermore, shocks to the stringency index (SI) have a significant negative effect on exports. Similarly, shocks

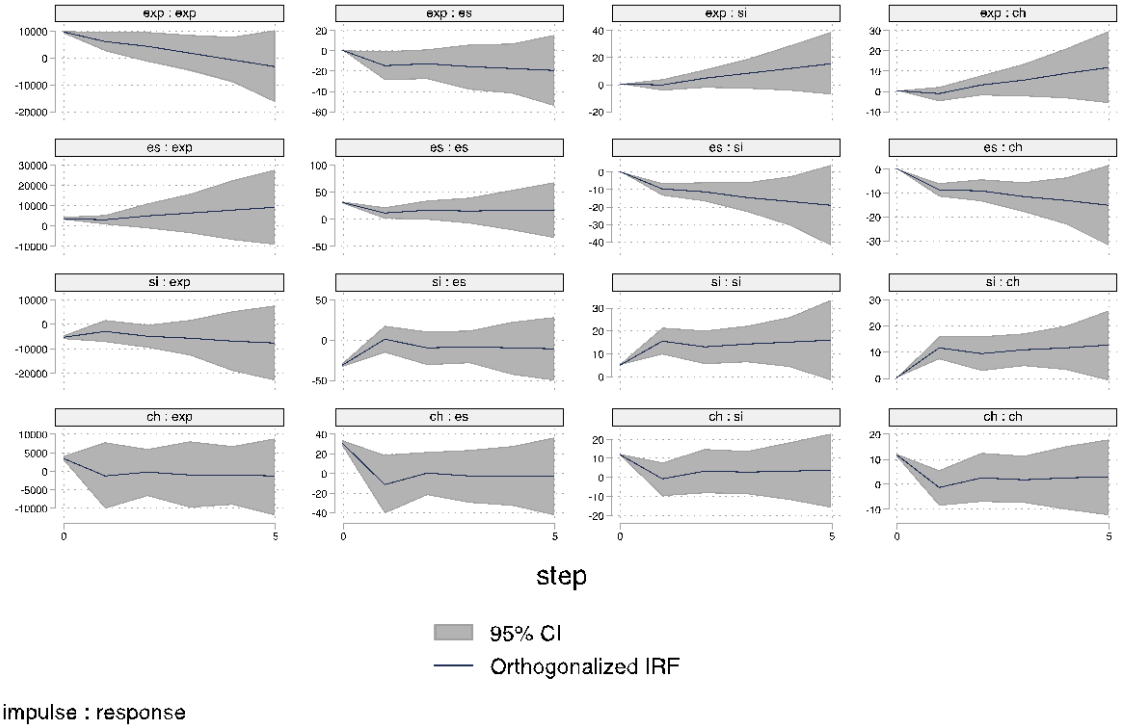

Figure 7: Orthogonalized Impulse Response Function Bootstrapped Error Bands from 500 Monte Carlo Simulations with A Corresponding 95% Confidence Interval. Ordering: 1. Containment & Health index (CH) 2. Stringency index (SI) 3. Economic Support index (ES) 4. Exports (EXP)

*exp = export, ch = containment & health index, si = stringency index, es = economic support index.

to the containment and health index (CH) have a borderline significant negative effect on exports. Therefore, it can be concluded from the impulse response functions in Figures 7 and 8 that stringency and containment and health related measures have significant negative impacts on exports, while economic support measures have significant positive impacts on exports.

Figures 9 and 10 show the impulse response function between the imports value and the three COVID-19 policy indices. In Figure 9, the ordering is containment & health index, stringency index, economic support index and lastly imports. In figure 10, imports is placed in the first order, followed by the containment & health index, stringency index and economic support index. Despite the difference in ordering, a significant pattern emerges showing the effects of the COVID-19 NPIs on imports. The IRF results revealed that shocks to the economic support index have a statistically significant positive effect on imports. In contrast, shocks to the stringency index and containment & health index have borderline significant negative effects on imports. The patterns of the effects on both imports and exports are very similar. Therefore, it can be concluded that stringency measures and containment and health measures have significant negative effects on imports, while economic support measures have significant positive effects on imports.

Figures 11 and 12 apply the IRF ordering in a similar way to the initial orderings found in Figure 9 and 10, but with the imports variable being replaced with the total trade value. In Figure 11, the three COVID-19 policy indices were placed in the first order with total trade in the last order. Figure 12 puts total trade in the first order, followed by the containment & health index, stringency index, and economic support index. The IRF patterns for both Figure 11 and 12 show significant relationships between the COVID-19 NPIs and trade flows. Shocks to the economic support index had statistically significant positive effects on the total trade

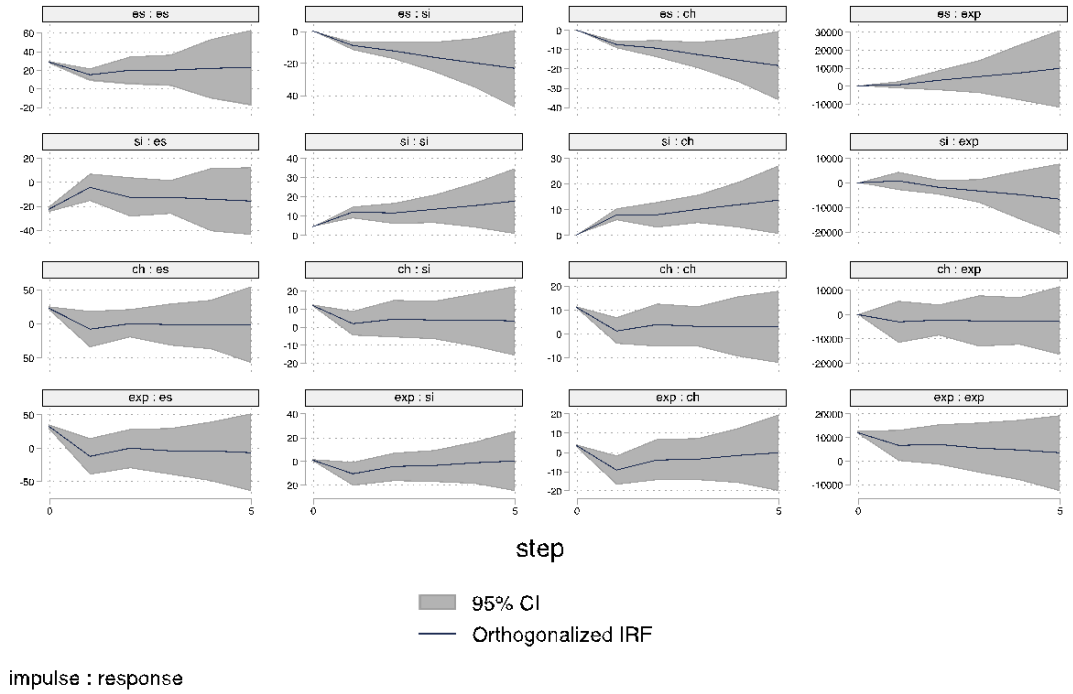

Figure 8: Orthogonalized Impulse Response Function Bootstrapped Error Bands from 500 Monte Carlo Simulations with A Corresponding 95% Confidence Interval. Ordering: 1. Exports (EXP) 2. Containment & Health Index (CH)3. Stringency Index (SI) 4. Economic Support Index (ES)

*exp = export, ch = containment & health index, si = stringency index, es = economic support index.

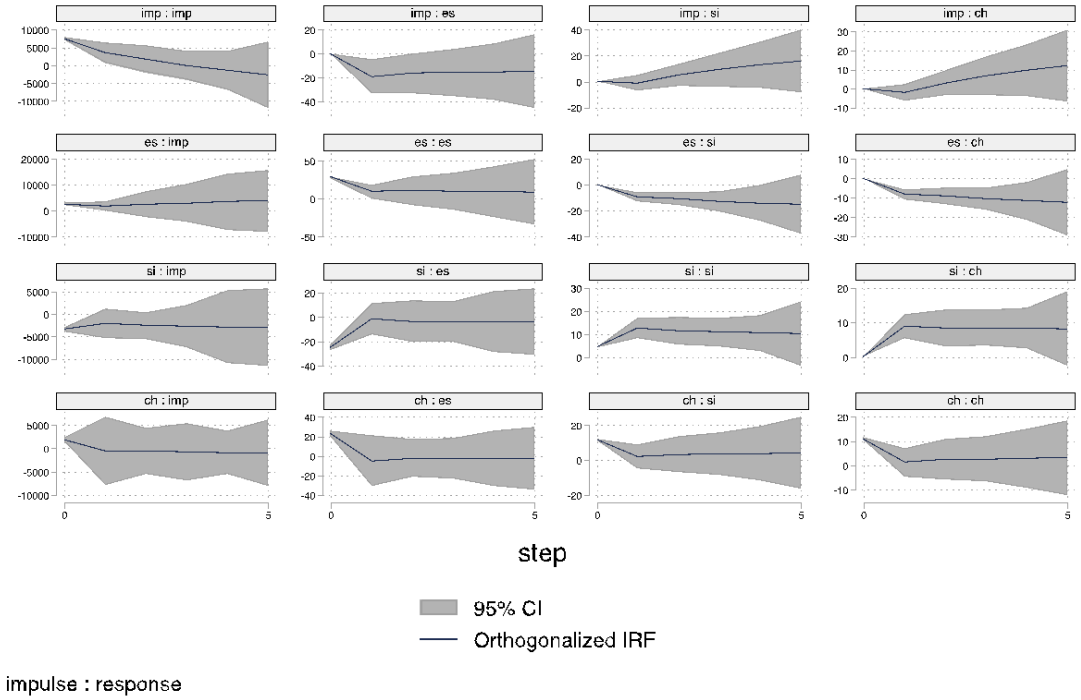

Figure 9: Orthogonalized Impulse Response Function bootstrapped error bands from 500 Monte Carlo simulations with a corresponding 95% confidence interval. Ordering: 1. Containment & Health index (CH) 2. Stringency index (SI) 3. Economic Support index (ES) 4. Imports (IMP)

*imp = import, ch = containment & health index, si = stringency index, es = economic support index.

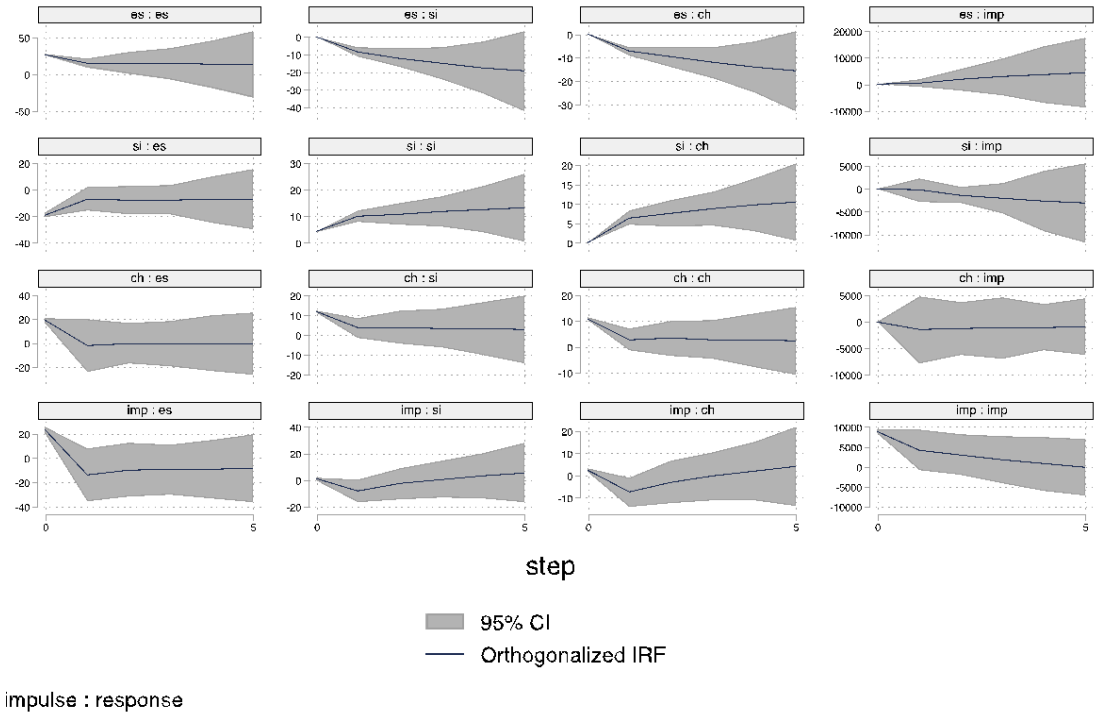

Figure 10: Orthogonalized Impulse Response Function Bootstrapped Error Bands from 500 Monte Carlo Simulations with A Corresponding 95% Confidence Interval. Ordering: 1. Imports (IMP) 2. Containment & Health index (CH) 3. Stringency index (SI) 4. Economic Support index (ES)

*imp = import, ch = containment & health index, si = stringency index, es = economic support index.

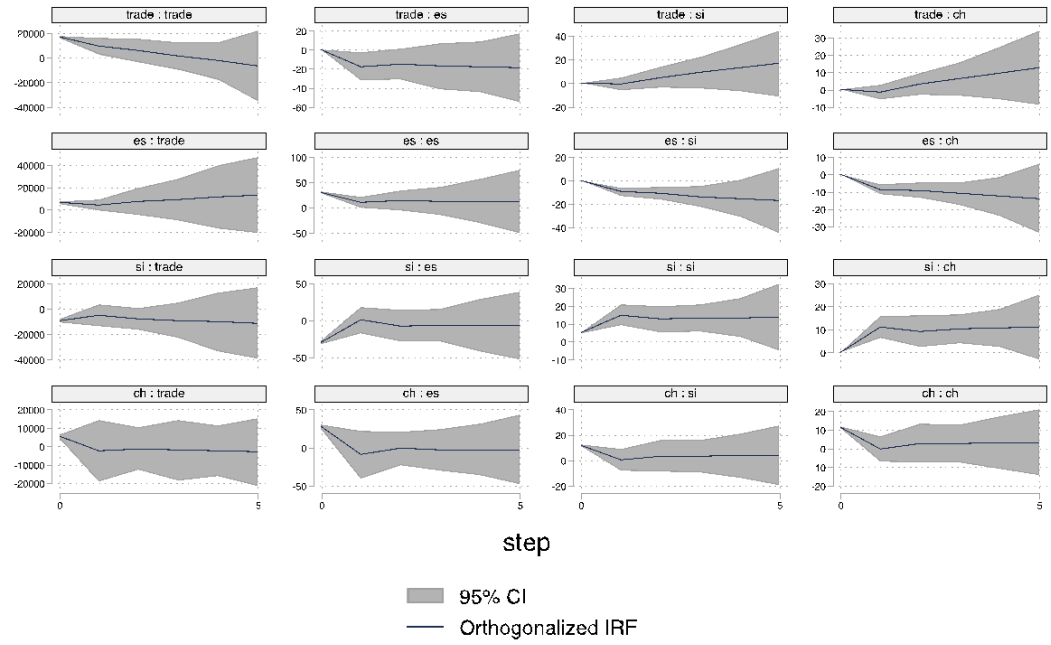

Figure 11: Orthogonalized Impulse Response Function Bootstrapped Error Bands from 500 Monte Carlo Simulations with a Corresponding 95% Confidence Interval. Ordering: 1. Containment & Health Index (CH) 2. Stringency Index (SI) 3. Economic Support Index (ES) 4. Total Trade

*trade = total trade, ch = containment & health index, si = stringency index, es = economic support index.

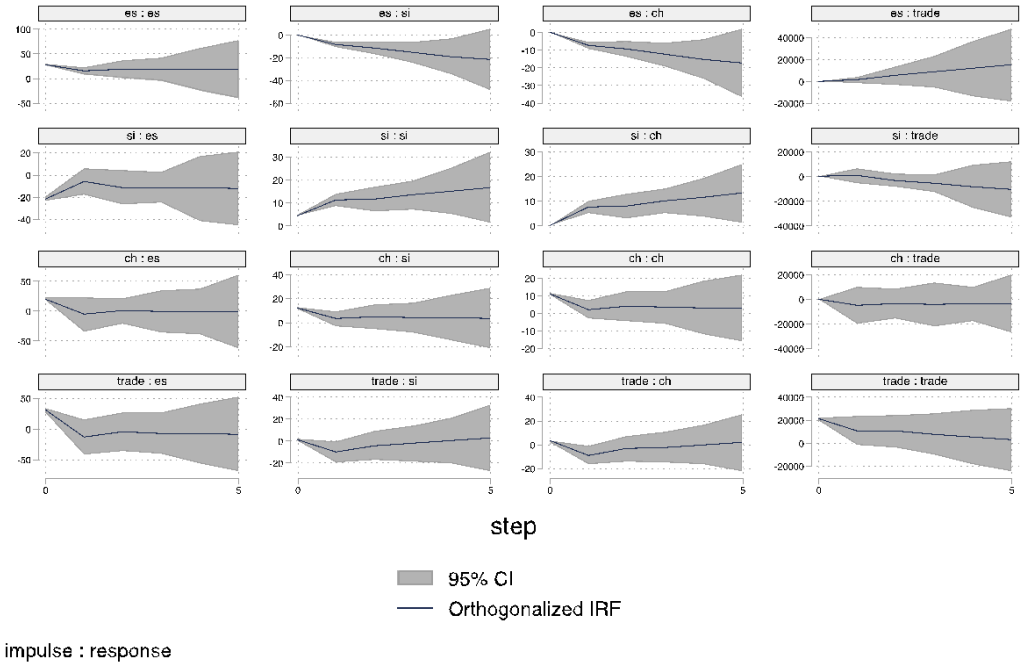

Figure 12: Orthogonalized Impulse Response Function Bootstrapped Error Bands from 500 Monte Carlo Simulations with a Corresponding 95% Confidence Interval. Ordering: 1. Total Trade 2. Containment & Health Index (CH) 3. Stringency Index (SI) 4. Economic Support Index (ES)

*trade = total trade, ch = containment & health index, si = stringency index, es = economic support index.

value. Additionally, shocks to the stringency index show statistically significant negative effect on total trade. Likewise, shocks to the containment & health index show a borderline negative effect on total trade. Thus, it is concluded that stringency measures and containment and health related measures have significant negative effects on imports, exports, and total trade, while economic support measures have significant positive effects on imports, exports, and total trade.

5. DISCUSSIONS

Tighter containment and health policies, as represented by the CH, showed negative impacts on trade flows. Some studies suggest that containment and healthcare policies produce benefits in terms of reducing new infections and death rates, which may lead to improved public confidence in executing economic activities (Greenstone and Nigam 2020; Thunström et al. 2020). Ashraf (2020b) studied stock markets, showing that government announcements regarding public awareness programs, testing, and quarantine policies largely resulted in positive market returns. In contrast, this study found negative impacts of containment and health policies on trade flows. Tightening the containment and health related policy tended to cause a reduction in economic activities. This can be explained by the fact that those who tested positive would not be allowed to work, thus decreasing overall productivity.

The SI had negative impacts on trade flows, largely consistent with literature such as Heyden and Heyden (2020), Shanaev et al. (2020), and Zaremba et al. (2020), which indicates that social distancing measures are unproductive in respect of economic activities. Deb (2020) shows that lockdown measures have huge negative impacts on economic activities. Deb (2020) concludes that stringent measures have, on average, large negative impacts on economic activities, equivalent to a loss of 15 % in industrial production over the 30-day period following their implementation. Hayakawa and Mukunoki (2020b) investigated how stay-at-home orders and workplace closure affected international trade, discovering negative effects of workplace closure on exports. Deb (2020) found that among the different types of stringency measures, workplace closure, stay-at-home orders, and cancellation of events, were the costliest due to their negative impacts on economic activities, albeit effective in flattening COVID-19 test-positive cases. This indicates that easing stringency measures can basically help maintain trade flows. Moreover, our results showed negative impacts of school closure and stay-at-home requirements on imports. While the detailed mechanism is unknown, the results suggest that consumption of some imported products was negatively affected as people stopped going to school and/or going out in general. Hayakawa and Mukunoki (2020b) argue that the demand-side effects are critical for some particular industries while the supply-side effects are more important for evaluating the effects of lockdown policies.

The economic support index (ES) showed a significant positive impact on trade flows. Thus, economic support measures during the pandemic should not be ignored as these policies help to alleviate the financial stress on households and individuals, which are the foundation of the demand side of the economy (Ashraf, 2020b; Hale et al., 2020b). Despite tremendous public spending and fiscal actions, it will take some time for the economy to return to a pre-COVID-19 level as the income shock may have a long-term impact on the private sector. In addition, businesses, especially the tourism sector, may take time to alter their business models to respond to the new normal where people are more concerned regarding health and safety (BOT 2020).

6. CONCLUSION

To date, research on the impacts of specific non-pharmaceutical interventions to the spread of COVID-19 on global trade have been relatively limited. While evidence on the effects of COVID-19 policies is increasing, a

consensus has not been reached at specific policy levels. This study statistically assessed the impacts of non-pharmaceutical measures on international trade at the country level by using the PVAR method to analyze global panel data from January to March 2021. The PVAR results suggest that COVID-19 containment and health related measures as well as stringent closure and social distancing policies had significant negative effects on trade flows. On the other hand, COVID-19 economic support related policies had significant positive effects on trade flows. Different ordering allowed similar patterns regarding the impacts of COVID-19 NPIs on trade to be observed. Shocks to the stringency index and containment & health index had significant negative effects on imports, exports, and total trade, while shocks to the economic support index had significant positive effects on imports, exports and total trade.

This study has some limitations. First, it assessed the impacts of COVID-19 policies on a single economic activity, international trade, and did not include the potential impacts of the COVID-19 NPIs on other economic activities that appear to have been heavily affected by the pandemic, such as the tourism sector or domestic trade. In order to assess the broader economic impacts, future research should explore other major activities as well. Secondly, accuracy of the data for the policy indices may not be high. The policy-related data were obtained from a single source, not from individual countries. Third, there may be other relevant time-varying covariates or unobservable policy variables that were not included within the estimation models. One of the important key variables that was not considered is the number of COVID-19 infection cases and the number of deaths from COVID-19. Finally, the study depended on macroeconomic data, which was not conducive to deriving household and individual level insights.

Based on the findings, it is recommended that policy makers should consider easing of stringent closure and containment measures such as public closures and movement restrictions. Furthermore, policy makers should consider the potential positive impacts of economic support measures such as debt relief and income support as one of the effective countermeasures to boost trade flows during pandemic situations. It is recommended that future research should examine other aspects of COVID-19 policies, such as pharmaceutical interventions including various types of vaccines and medicines. Furthermore, other key variables that can potentially affect the trade flows, such as the number of COVID-19 infections and deaths, should be incorporated into the analytical model in future research. In addition, as the public awareness of different sustainability issues rises, future research should explore the pandemic's impacts on BioTrade as defined by UNCTAD (2021). Furthermore, as more data become available, further research may be undertaken with expanded coverage of countries, or within countries and regions, which would help provide an assessment of the impacts of intervention measures on international, regional, and domestic trade.

ACKNOWLEDGMENTS

The authors acknowledge the valuable comments received from Lisen Runsten, Camilla Blasi Foglietti, and Julia Wentworth of the UN Environment Programme World Conservation Monitoring Centre.

FUNDING

This research was funded by the UK Research and Innovation's Global Challenges Research Fund (UKRI GCRF) through the Trade, Environment and Development Hub project (project number ES/S008160/1) led by the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Anitha, S., Muzanila, Y., Tsusaka, T.W., Kachulu, L., Kumwenda, N., Musoke, M., Swai, E., Shija, J., Siambi, M., Monyo, E.S., Bekunda, M., Okori, P. (2020). Reducing Child Undernutrition through Dietary Diversification, Reduced Aflatoxin Exposure, and Improved Hygiene Practices: The Immediate Impacts in Central Tanzania. *Ecology of Food and Nutrition*, 59:3, 243-262, doi: 10.1080/03670244.2019 .1691000

Arellano M. (1993). On the testing of correlated effects with panel data. *Journal of Econometrics* 59, 87-97.

Arroyo-Marioli F, Bullano F, Kucinskas S, Rondón-Moreno C. (2021). Tracking $\mathcal{R}$ of COVID-19: A new real-time estimation using the Kalman filter. PLoS ONE. 16(1): e0244474.

Ashraf, B.N. (2020a). Stock markets' reaction to COVID-19: cases or fatalities? *Res. Int. Bus. Finance.* 54, 101249.

Ashraf, B.N., Zheng, C., Jiang, C., Qian, N. (2020b). Capital regulation, deposit insurance and bank risk: International evidence from normal and crisis periods. *Res. Int. Bus. Finance.* 52.

Bank of Thailand. (2020). Roles of public policies in restoring the Thai economy amid the highly uncertain COVID-19 outbreak. Monetary Policy Report, June 2020.

Battistini, N., and Stoevsky, G. (2021). The impacts of containment measures across sectors and countries during the COVID-19 pandemic. ECB Economic Bulletin, Issue 2.

Barbero, J., de Lucio, J. J., & Rodríguez-Crespo, E. (2021). Effects of COVID-19 on trade flows: Measuring their impact through government policy responses. *PloS one*, *16*(10), e0258356.

Berlinguer G. (1999). Globalization and global health. Int J Health Serv. 29(3):579-95.

Deb P., Furceri D., Ostry J., and Tawk N. (2020). The Effects of Containment Measures on the COVID-19 Pandemic. Covid Economics: Vetted and Real-Time Papers. 2020(19), pp.53- 86.

Diaz RS, Vergara TRC. (2021). The COVID-19 second wave: A perspective to be explored. Braz J Infect Dis. Jan-Feb;25(1):101537.

Greene, W.H., 2011. Econometric Analysis, 7th ed., Prentice Hall.

Hale, T., Petherick, A., Phillips, T., Webster, S. (2020a). Variation in Government Responses to COVID-19. Blavatnik School of Government Working Paper 2020a, 31.

Hale, T., Webster, S., Petherick, A., Phillips, T., Kira, B. (2020b). Oxford Covid-19 government response tracker. Blavatnik School of Government 2020b, 25.

Harris RDF, Tzavalis E. (1999). Inference for unit roots in dynamic panels where the time dimension is fixed. J Econometrics 91:201–226. https://doi.org/10.1016/S0304-4076(98) 00076-1

Holtz-Eakin, D., Newey, W., Rosen, H. (1988). Estimating Vector Autoregressions with Panel Data, Econometrica, 56, (6), 1371-95.

Hayakawa, K., and H. Mukunoki. (2021a). Impacts of COVID-19 on Global Value Chains. *The Developing Economies* 2021a, 59(2): 154-177.

Hayakawa, K., and H. Mukunoki. (2021b). Impacts of Lockdown Policies on International Trade. *Asian Economic Papers* 2021b, 20(2): 73–91.

Hayakawa, K., and H. Mukunoki. (2021c). The Impacts of COVID-19 on International Trade: Evidence from the First Shock. *Journal of the Japanese and International Economies* 2021c, 60: 101135.

Heyden KJ, Heyden T. (2021). Market reactions to the arrival and containment of COVID-19: An event study. *Financ Res Lett*. Jan; 38:101745.

Hsiao, Cheng. (2003). Analysis of Panel Data (2nd ed.). New York, NY: Cambridge University Press 2003. pp. 73.

Huang, C., Y. Wang, X. Li, et al. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China." *Lancet* 395 (10223).

Im, K.S., Pesaran. M.H., Shin, Y. (2003). Testing for unit roots in heterogeneous panels. J Econ. 115:53–74.

International Monetary Fund (IMF). (2020). A Crisis Like No Other, An Uncertain Recovery: A Crisis Like No Other, An Uncertain Recovery. June 2020.

Khorana, S., Martínez-Zarzoso, I., and Ali, S. (2021). The Impact of COVID-19 on the Global and Intra-Commonwealth Trade in Goods. International Trade Working Paper 2021/08, Commonwealth Secretariat, London.

Levin, A., Lin, C.F, Chu, C.S.J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. J Econometrics 108:1–24. https://doi.org/10.1016/S0304-4076(01)00098-7.

Love, I., Zicchino, L. (2006). Financial development and dynamic investment behavior: evidence from panel VAR. Q Rev Econ Fin 46:190–210. https://doi.org/10.1016/j.qref.2005.11.007

Minondo, A. (2021). Impact of COVID-19 on the trade of goods and services in Spain. Applied Economic Analysis. Vol. 29, No. 85, pp.55-76.

Murphy, R.H., O'Reilly, C. (2019). Applying panel vector autoregression to institutions, human capital, and output. *Empir. Econ* 57, 1633–1652). https://doi.org/10.1007/s00181-018-1562-0

Maliszewska, Maryla; Mattoo, Aaditya; van der Mensbrugghe, Dominique. (2020). The Potential Impact of COVID-19 on GDP and Trade: A Preliminary Assessment. Policy Research Working Paper 2020; No. 9211. World Bank, Washington, DC.

Mitze, T., Kosfeld, R., Rode, J., Wälde, K. (2020). Face masks considerably reduce COVID-19 cases in Germany. Proc Natl Acad Sci U S A. Dec 22;117(51):32293-32301. doi: 10.1073/pnas.2015954117. Epub 2020 Dec 3. PMID: 33273115; PMCID: PMC7768737.

Nguyen, S. (2020). Coronavirus: Vietnam Stockpiles Rice as Outbreak Spreads and Food Security Concerns Grow. South China Morning Post, Accessed 28 March 2020.

Osterrieder, A., Cuman, G., Pan-Ngum, W., et al. (2021). Economic and social impacts of COVID-19 and public health measures: results from an anonymous online survey in Thailand, Malaysia, the UK, Italy and Slovenia. *BMJ Open.* 11:e046863.

Prem, K., Liu Y., Russell, T.W. et al. (2020). "The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study." *Lancet Public Health* 5 (5).

Ramsey, F., Schafer, D. (2002). The Statistical Sleuth: A Course in Methods of Data Analysis, 2nd ed. Duxbury Press.

Shrestha, N., Shad, M. Y., Ulvi, O., Khan, M. H., Karamehic-Muratovic, A., Nguyen, U. S. D., Haque, U. (2020). "The impact of COVID-19 on globalization.", One Health, 11, 100180.

Shanaev, S., Shuraeva, A., Ghimire, B. (2020). The financial pandemic: COVID-19 and policy interventions on rational and irrational markets. SSRN Electronic Journal 2020. Available at SSRN: http://dx.doi.org/10.2139/ssrn.3589557.

Spelta, A., Flori, A., Pierri, F., Bonaccorsi, G., Pammolli, F. (2020). After the lockdown: simulating mobility, public health, and economic recovery scenarios. Scientific rep. 2020, 10(1), pp.1-13.

Srisawasdi, W. et al. (2022). Impacts of COVID-19 public policy measures on global trade flows: Initial findings and future research avenues. Trade, Development & The Environment Hub blog. https://tradehub.earth/2022/01/24/impacts-of-covid-19-public-policy-measures-on-global-trade-flows-initial-findings-

and-future-research-avenues/

Srisawasdi, W., Tsusaka, T.W., Szabo, S., Kadigi, R.M.J., Vause, J., Burgess, N.D. (2021). Impacts of COVID-19 public measures on country-level trade flows: Global panel regression analysis. MedRxiv. doi: 10.1101/2021.07.09.21260294.

Stannard, T., Steven, G., McDonald, C. (2020). "Economic impacts of COVID-19 containment measures," Reserve Bank of New Zealand Analytical Notes series AN2020/04, Reserve Bank of New Zealand.

Thunström, L., Newbold, S.C., Finnoff, D., Ashworth, M., Shogren, J.F. (2020). The benefits and costs of using social distancing to flatten the curve for COVID-19. J. Benefit-Cost Anal. 2020, 1–27.

Tsusaka, T., Otsuka, K. (2013a). Chapter 4: The declining impacts of climate on crop yields during the green revolution in India: 1972 to 2002. In: K. Otsuka, D. F. Larson (eds.) An African Green Revolution: Finding Ways to Boost Productivity on Small Farms. Dordrecht, Springer, 71-94. doi: 10.1007/978-94-007-5760-8_4.

Tsusaka, T., Otsuka, K. (2013b). Chapter 5: The impact of technological change on crop yields in Sub-Saharan Africa, 1967 to 2004. In: K. Otsuka, D. F. Larson (eds.) An African Green Revolution: Finding Ways to Boost Productivity on Small Farms. Dordrecht, Springer, 95-120. doi: 10.1007/978-94-007-5760-8_5.

UN Comtrade. (2021). Available at http://comtrade.un.org/, Accessed 24 April, 2021.

UNCTAD. (2021). Global merchandise trade exceeds pre-COVID-19 level, but services recovery falls short, December 2021.

UNCTAD. (2020). Impact of the Coronavirus Outbreak on Global FDI, March 2020.

UNCTAD. (2021). Online workshop on trade and biodiversity for the post-2020 global biodiversity framework, March 2021.

UNECLAC. (2020). The effects of the coronavirus disease (COVID-19) pandemic on international trade and logistics, August 2020.

UNEP. (2020). COVID-19, the Environment, and Food Systems: Contain, Cope and Rebuild Better, December 2020.

UN Statistics Division. (2021). Available at https://unstats.un.org/, Accessed 24 April, 2021.

Verschuur, J., Koks, E.E., Hall, J.W. (2021). Global economic impacts of COVID-19 lockdown measures stand out in high-frequency shipping data. PLoS ONE 16(4): e0248818.

Wang, C., P.W. Horby, F.G. Hayden, G.F. Gao. (2020). A novel coronavirus outbreak of global health concern. *Lancet*. 395 (10223).

World Health Organization (WHO). (2020). COVID-19: Trade and Trade-Related Measures, March 2020.

World Health Organization (WHO). (2021). COVID-19 shows why united action is needed for more robust international health architecture, March 2021.

World Health Organization (WHO). (2021). WHO Coronavirus Disease (COVID-19) Dashboard. Available at https://covid19.who.int/, accessed 22 April 2021.

Wooldridge, J. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). Cambridge, Mass.: MIT Press 2010. p. 252.

Worldometer. Coronavirus Update (Live) – Worldometer, (2021). Available at. https:// www.worldometers.info/coronavirus/#countries, accessed 12 May 2021.

World Bank. (2020). Projected poverty impacts of COVID-19 (coronavirus), June 2020.

World Trade Organization. (2020). WTO report on G20 trade measures, June 2020.

WTO. (2021). World trade primed for strong but uneven recovery after COVID-19 pandemic shock, March 2021.

Zhang, Y., Jiang, B., Yuan, J., Tao, Y. (2020).

The Impact of Social Distancing and Epicenter Lockdown on the COVID-19 Epidemic in Mainland China: A Data-Driven SEIQR Model Study. Available at [https://www.medrxiv.org/content/10.1101/ 2020.03.04.20031187v1.full.pdf], accessed 15 May 2021.

Zaremba, A., Kizys, R., Aharon, D.Y., Demir, E. (2020). Infected markets: Novel coronavirus, government interventions, and stock return volatility around the globe. Finance Res. Lett. 2020. 101597.

APPENDIX

Table 1 Summary of the Collected Variables, Their Definitions, and Sources

Variable	Scale	Description	Data source
Export	Ratio	Monthly export value (Million USD)	UN Trade Statistics (2021)
Import	Ratio	Monthly import value (Million USD)	UN Trade Statistics (2021)
Trade value	Ratio	Total monthly trade value (import + export) (Million USD)	UN Trade Statistics (2021)
Containment and Health Index (CH)	Interval	A containment and health index scaled from 0 to 100, which combines lockdown restrictions and closures with measures such as testing policy and contact tracing, short term investment in healthcare, as well investment in vaccines.	OxCGRT database (2020)
Stringency Index (SI)	Interval	The composite measure of stringency policies, rescaled to vary from 0 to 100	OxCGRT database (2020)
Economic Support Index (ES)	Interval	The composite measure of economic support policies, rescaled to vary from 0 to 100	OxCGRT database (2020)
Testing policy	Ordinal	Record of the level of COVID-19 testing strictness 0 – No testing policy 1 – Only those who both (a) have symptoms AND (b) meet specific criteria (e.g., key workers, admitted to hospital, came into contact with a confirmed case, returned from overseas) 2 – Testing of anyone showing COVID-19-like symptoms	OxCGRT database (2020)
Facial covering policy	Ordinal	Record of policies on the use of facial coverings outside the home. 0 – No policy 1 – Recommended 2 – Required in **some** specified shared /public spaces outside the home with other people present 3 – Required in **all** shared/public spaces outside the home with other people present	OxCGRT database (2020)
Public awareness campaign	Ordinal	Recorded presence of public information campaigns. 0 -No COVID-19 public information campaign 1 - public officials urging caution about COVID-19 2 - coordinated public information campaign (e.g., across traditional and social media)	OxCGRT database (2020)
School closure	Ordinal	Record of closing of schools and universities. 0 – No closure 1 – Recommend closing, or all schools open with alterations resulting in significant differences compared to usual, non-COVID-19 operations 2 – Required closing at some levels or categories 3 – Required closing at all levels	OxCGRT database (2020)
School closure	Ordinal	Record of closing of schools and universities. 0 – No closure 1 – Recommend closing, or all schools open with alterations resulting in significant differences compared to usual, non-COVID-19 operations 2 – Required closing at some levels or categories 3 – Required closing at all levels	OxCGRT database (2020)

Table 1 (Continued)

Variable	Scale	Description	Data source
Workplace closure	Ordinal	Record of closing of workplaces. 0 – No closure 1 – Recommend closing 2 – Required closing for some sectors or categories of workers 3 – Required closing of all-but-essential workplaces	OxCGRT database (2020)
Public event cancelling	Ordinal	Record of cancellation of public events. 0 – No cancellation 1 – Recommended cancellation 2 – Required cancellation	OxCGRT database (2020)
Gathering restrictions	Ordinal	Record of the cut-off size for bans on private gatherings 0 – No restriction 1 – Restrictions on very large gatherings above 1000 2 – Restrictions on gatherings between 101-1000 people 3 – Restrictions on gatherings between 11-100 people 4 – Restrictions on all gatherings	OxCGRT database (2020)
Public transportation closure	Ordinal	Record of closure of public transport 0 – No closure 1 – Recommended closing 2 – Required closing	OxCGRT database (2020)
Stay-at-home requirements	Ordinal	Record of orders to "shelter -in- place" and be otherwise confined to the home 0 – No requirement 1 – Recommend not leaving house 2 – Requirement on not leaving the house with exceptions for grocery shopping and 'essential' trips 3 – Requirement on not leaving the house with minimal exceptions	OxCGRT database (2020)
Demestic travel restrictions	Ordinal	Record of restrictions on internal movement 0 – No restriction 1 – Recommendations not to travel between regions or cities 2 – Internal movement restrictions in place	OxCGRT database (2020)
International travel restrictions	Ordinal	Record of restrictions on international travel 0 – No restriction 1 – Screening 2 – Quarantine of arrivals from high-risk regions 3 – Ban on arrivals from some regions 4 – Ban on all regions or total border closure	OxCGRT database (2020)
Income support	Ordinal	Record of government support for salary or direct cash payments, universal basic income, or similar, of people who lose their jobs or cannot work. 0 - No income support 1 - Government is replacing less than 50% of lost salary 2 - Government is replacing 50% or more of lost salary	OxCGRT database (2020)
Debt relief Support	Ordinal	Record of freezing of financial obligations to citizens. 0 – No 1 – Narrow relief, specific to one kind of contract 2 – Broad debt/contract relief	OxCGRT database (2020)

Table 1 (Continued)

Variable	Scale	Description	Data source
		1 – Only those who both (a) have symptoms AND (b) meet specific criteria (e.g., key workers, admitted to hospital, came into contact with a confirmed case, returned from overseas) 2 – Testing of anyone showing COVID-19-like symptoms	
Facial covering policy	Ordinal	Record of policies on the use of facial coverings outside the home. 0 – No policy 1 – Recommended 2 – Required in **some** specified shared/public spaces outside the home with other people present 3 – Required in **all** shared/public spaces outside the home with other people present	OxCGRT database (2020)
Unemployment rate (%)	Ratio	The percentage of unemployed workers in the total labor force.	World Bank (2020)
Population	Ratio	The total number of people or inhabitants in a country or region.	UNSD (2021)
Population density	Ratio	The number of people per square kilometer.	UNSD (2021)
Poverty rate (%)	Ratio	Poverty headcount ratio at USD 1.90 a day (% of population).	World Bank (2020)
Average life expectancy	Ratio	Average number of years that a person can expect to live.	UNSD (2021)
Surface area	Ratio	The total area of the country, comprising land area and inland waters (Km^2).	UNSD (2021)

Table 2 List of 70 Countries Included in the Analysis, with the Second Quarter Export Value in 2019 and 2020, Cumulative COVID-19 Reported Cases, and the Government Response Index

Country	**Code**	**Q2 export value (USD million)***		**Cumulative COVID-19 cases, thousand (Oct 10, 2021)****	**2020 Government Response Index (GRI)*****
		2019	**2020**		
Australia	AUS	65,973	58,951	127.4	79.28
Azerbaijan	AZE	4,845	3,480	491.1	74.03
Belgium	BEL	101,341	64,048	1,261.1	58.75
Bulgaria	BGR	7,930	6,809	520.2	45.75
Belarus	BLR	7,770	6,230	555.7	23.21
Belize	BLZ	71	68	22.1	72.57
Brazil	BRA	59,156	54,935	21,567.1	70.66
Barbados	BRB	109	74	10.6	47.81
Canada	CAN	108,561	77,917	1,657.2	69.01
Switzerland	CHE	77,660	73,282	854.5	47.42
Chile	CHL	18,113	N/A	1,661.3	83.63
Colombia	COL	11,359	N/A	4,970.7	61.31
Costa Rica	CRI	N/A	N/A	544.0	56.62
Cyprus	CYP	914	888	119.5	66.83
Czech Republic	CZE	49,623	37,516	1,699.0	50.24
Germany	DEU	360,987	278,981	4,323.4	55.68
Denmark	DNK	27,467	24,375	363.3	62.40
Ecuador	ECU	5,617	4,533	511.6	61.84

Table 2 (Continued)

Country	Code	Q2 export value (USD million)*		Cumulative COVID-19 cases, thousand (Oct 10, 2021)**	2020 Government Response Index (GRI)***
		2019	2020		
Egypt	EGY	7,952	5,666	311.5	66.67
Spain	ESP	83,786	63,171	4,987.3	65.42
Estonia	EST	4,195	3,256	163.8	31.78
Finland	FIN	17,772	14,326	145.6	41.67
United Kingdom	GBR	109,640	86,335	8,448.7	67.31
Georgia	GEO	910	724	631.5	61.65
Greece	GRC	9,680	7,544	675.4	67.23
Greenland	GRL	N/A	N/A	623	42.38
Guatemala	GTM	2,690	2,536	578.8	73.15
Guyana	GUY	418	541	33.5	68.90
Hong Kong, PRC	HKG	130,716	133,800	12.2	72.62
Croatia	HRV	4,287	3,196	416.9	44.17
Hungary	HUN	30,351	23,135	827.4	46.73
India	IND	80,777	51,194	33,952.2	76.15
Ireland	IRL	44,998	41,742	401.7	70.85
Iceland	ISL	1,274	1,038	12.1	57.62
Israel	ISR	13,153	10,930	1,304.3	63.63
Italy	ITA	132,549	98,004	4,698.0	61.62
Japan	JPN	155,047	123,973	1,709.6	42.56
Kyrgyz Republic	KGZ	461	480	179.1	62.86
Lithuania	LTU	8,018	6,710	350.0	51.79
Luxembourg	LUX	3,794	2,934	79.0	59.34
Latvia	LVA	4,752	3,103	169.9	47.42
Macao, PRC	MAC	222	172	77	41.07
Morocco	MAR	7,782	N/A	938.8	71.88
Moldova	MDA	616	495	305.9	53.57
Madagascar	MDG	736	N/A	42.8	56.05
Mexico	MEX	116,575	74,528	3,720.5	58.43
Mauritius	MUS	587	375	16.1	44.64
Namibia	NAM	N/A	1,006	128.0	58.87
Netherlands	NLD	142,305	117,951	2,021.4	54.70
Norway	NOR	23,622	17,130	193.2	47.02
Pakistan	PAK	5,865	4,099	1,257.1	56.49
Peru	PER	11,229	4,836	2,183.5	82.74
Philippines	PHL	17,072	12,749	2,654.4	69.54
Poland	POL	62,460	50,309	2,920.8	43.29
Portugal	PRT	16,652	11,704	1,074.8	63.25
Paraguay	PRY	2,145	2,040	460.1	77.98
Romania	ROU	18,690	12,711	1,346.2	52.78
Rwanda	RWA	281	250	98.5	78.10
El Salvador	SLV	1,318	743	110.1	73.39
Serbia	SRB	4,932	3,959	1.000.3	58.75

Table 2 (Continued)

Country	Code	Q2 export value (USD million)*		Cumulative COVID-19 cases, thousand (Oct 10, 2021)**	2020 Government Response Index (GRI)***
		2019	2020		
Slovak Republic	SVK	22464	16,170	424.4	51.04
Slovenia	SVN	9,579	7,971	300.9	52.38
Sweden	SWE	40,863	33,972	1,157.8	41.07
Turkey	TUR	49,051	26,969	7,416.1	72.30
Ukraine	UKR	10,151	10,661	2,529.9	64.40
United States	USA	382,198	291,236	45,179.2	67.40
Uzbekistan	UZB	2,859	2,649	177.8	65.66
South Africa	ZAF	22330	15,188	2,911.4	70.24
Zambia	ZMB	1,688	1,593	209.3	49.70
Zimbabwe	ZWE	963	N/A	131.7	65.26

* Obtained from the UN Comtrade Database.
** Obtained from the World Health Organization.
*** Obtained from Blavatnik School of Government, University of Oxford.
N/A means data are not available.

Table 6 GMM Estimation coefficients results for PVAR models

Variables	Model 1 CH>SI>ES>EX Coefficients (SE)	Model 2 EX>CH>SI>ES Coefficients (SE)	Model 3 CH>SI>ES>IM Coefficients (SE)	Model 4 IM>CH>SI>ES Coefficients (SE)	Model 5 CH>SI>ES>TR Coefficients (SE)	Model 6 TR>CH>SI>ES Coefficients (SE)
Containment & Health						
CH	0.207	0.207	0.379	0.379	0.282	0.282
	(0.467)	(0.467)	(0.376)	(0.376)	(0.427)	(0.427)
SI	0.418	0.418	0.321	0.321	0.378	0.378
	(0.213)	(0.214)	(0.180)	(0.180)	(0.195)	(0.195)
ES	-0.272	-0.272	-0.267	-0.267	-0.270	-0.270
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
EX/IM/TR	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Stringency						
CH	-0.241	-0.241	-0.147	-0.147	-0.189	-0.189
	(0.555)	(0.555)	(0.381)	(0.381)	(0.480)	(0.480)
SI	1.001	1.001	0.946	0.946	0.976	0.976
	(0.248)	(0.248)	(0.176)	(0.176)	0.210)	0.210)
ES	-0.322	-0.322	-0.319	-0.319	-0.321	-0.321
	(0.046)	(0.046)	(0.045)	(0.045)	(0.046)	(0.046)
EX/IM/TR	-0.000	-0.000	0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Economic Support						
CH	-3.674	-3.674	-2.203	-2.203	-3.096	-3.096
	(2.124)	(2.124)	(2.197)	(2.197)	(2.255)	(2.255)

Table 6 (Continued)

Variables	Model 1 CH>SI>ES>EX Coefficients (SE)	Model 2 EX>CH>SI>ES Coefficients (SE)	Model 3 CH>SI>ES>IM Coefficients (SE)	Model 4 IM>CH>SI>ES Coefficients (SE)	Model 5 CH>SI>ES>TR Coefficients (SE)	Model 6 TR>CH>SI>ES Coefficients (SE)
SI	1.731	1.731	0.928	0.928	1.395	1.395
	(1.029)	(1.029)	(1.091)	(1.091)	(1.099)	(1.099)
ES	0.533	0.533	0.568	0.568	0.545	0.545
	(0.125)	(0.125)	(0.108)	(0.108)	(0.120)	(0.120)
EX/IM/TR	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Export/ Import/ Trade						
CH	-574.345	-574.345	-173.396	-173.396	-821.976	-821.976
	(782.975)	(782.975)	(607.570)	(607.570)	(1408.9)	(1408.9)
SI	220.216	220.216	0.058	0.058	256.263	256.263
	(401.368)	(401.368)	(293.440)	(293.440)	(696.160)	(696.160)
ES	18.982	18.982	17.177	17.177	33.381	33.381
	(33.797)	(33.797)	(24.894)	(24.894)	(58.794)	(58.794)
EX/IM/TR	0.625	0.625	0.479	0.479	0.560	0.560
	(0.215)	(0.215)	(0.203)	(0.203)	(0.201)	(0.201)