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ORIGINAL ARTICLE

Did economic cooperation encourage trade in essential medical goods? Empirical evidence from the Asia–Pacific during COVID-19

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Abstract

Our paper empirically investigates the role of economic cooperation involving trade in coronavirus disease (COVID-19)-related essential medical goods—vaccines and their value chains, personal protective equipment, and diagnostic test kits—across 29 Asia and the Pacific economies. The paper incorporates vaccines and their global value chain products trade for the first time in the empirical literature. We further investigate whether trade facilitation, proxied by membership in regional trade agreements (RTAs), can help mitigate any adverse impact on trade in essential medical goods, applying a structural gravity framework. The results confirm that while trade is critical for Asian economies, its nature differs. Low-income economies are largely dependent on imports, whereas selected middle- and high-income economies are part of two-way trade and engaged in the low end of the vaccine value chain. We find that the onset of the pandemic has hurt exports of these goods. This adverse effect is found to be lowered for economies engaged in RTAs. This emphasizes the role of governments in committing to RTAs and implementing trade facilitation measures.

KEYWORDS
Asia–Pacific, COVID-19, essential medical goods, RTAs, vaccine supply chain

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1 | INTRODUCTION

The COVID-19 pandemic created global havoc during 2020–2022. Starting as a major health crisis, the adverse impact of the virus was soon felt in larger parts of economies. International trade came under pressure in 2020 and the pain was felt differently in different regions and commodity groups (Arriola et al., 2021). The pandemic brought to the fore vulnerabilities and challenges in sourcing products or parts and components from other countries. While in some cases, inventories built up due to a fall in demand, in others, the concept of lean manufacturing and just-in-time inventory systems backfired due to supply shortages. Nonetheless, for selected product categories such as essential medical goods and food supplies, cross-border trade continued. Thus, global trade fell much less than earlier expected as aggregate demand increased in certain categories of goods (WTO, 2020, 2021a).

While the coronavirus disease (COVID-19) was ongoing, the vaccine rollout in early 2021 brought some relief. This remains uneven across countries, however. For example, as of the end of March 2022, vaccine doses administered per 100 people in Asia were high (more than 200) for countries such as China, South Korea, Malaysia, and Singapore. It is relatively low for Bangladesh, Laos, Nepal, and Indonesia (below 140). Availability of other COVID-19-related medical goods was also uneven across countries.

Several reasons explain the disparity in the availability of COVID-19 essential medical goods. While not all countries were self-sufficient in producing them (OECD, 2020a), production and export capacity were concentrated in a handful of countries (WTO, 2021b). Most countries imported these goods, thus providing a strong case for international trade.

However, trade had encountered its own limitations, leading to supply shortages. Major suppliers of medical goods had imposed export bans during the high COVID-19 burden (Hayakawa & Imai, 2022). This had implications for importing countries as well as manufacturers that rely on ingredients from other countries, affecting part of the global value chain (GVC) for producing medical goods. Supplies of COVID-19 medical goods also suffered, as countries such as China, Malaysia, and Thailand—which accounted for the major share of medical goods production (face masks, gloves)—experienced local shocks, like worker illness, strict lockdowns, and manufacturing shutdowns. International trade also suffered due to transport and shipping constraints or port congestion due to workers' illness or social distancing measures, leading to supply chain disruptions (ESCAP & ADB, 2021).

The impact of COVID-19 on medical goods trade is an under-researched area, with virtually no empirical analysis of the vaccine value chain trade and the role of regional cooperation, particularly trade facilitation and agreements. Against this backdrop, the aim of our paper is to understand the importance of regional cooperation and trade facilitation for the cross-border supply chain of

the same. Many of the countries discussed in the paper are part of many trade agreements and hence are party to implement trade facilitation measures in terms of lowering trade barriers, improving customs efficiency, and enhancing other "hard" and "soft" cooperation. All these are generally expected to promote the smooth operation of supply chains for these goods.

We extend the analysis of OECD (2020a) and Hayakawa and Imai (2022), covering Asia, Europe, and North America. Our study deploys the trade value of medical products globally and follows the World Trade Organization (WTO)'s three of the four categorizations of medical goods. These include medical supplies, including test kits; medicines, including vaccines for human medicine; and personal protective products, which include hand soap, hand sanitizer, face masks, protective eyewear/spectacles, and other cleaning products (WTO, 2021b). For vaccines, we examine the GVC of vaccine manufacturing and distribution and analyze three other categories, called ingredients, primary packaging, and secondary packaging (storage, distribution, and administration) based on the Organization for Economic Co-operation and Development (OECD, 2021) compilation of vaccine-related inputs. A list of six-digit level codes in the Harmonized System (HS) 2017 for these seven product categories is presented in Table A1.

The original data set thus comprises 29 countries and 29 medical goods products sourced from the United Nations Commodity Trade Database. The analyses are carried out over two-time points, that is, 2019 (pre-COVID-19) and 2020 (during COVID-19). We employ bilateral monthly data to analyze the role of trade agreements, that cover trade facilitation measures, at the onset of the pandemic. Thus, having a trade agreement between two or more countries symbolizes not only their like-minded nature for cooperation but also promotes the smooth flow of goods across borders.

It should be noted that almost all trade agreements since early 2000 cover trade facilitation measures either implicitly (such as general principles or as a chapter on simplifying customs procedures) or explicitly (such as a chapter covering both customs measures and other regulatory and administrative processes). Trade facilitation is considered nondiscriminatory in nature and has evolved over time from being narrowly focused provisions on customs to a wider discussion on areas of transparency, simplification, harmonization, coordination among border agencies, digitalization, and others. Provisions around customs also expanded to cover measures like risk management, advance rulings, express shipments, release of goods, and others.

Our paper adds value to the analysis of trade interdependency by extending the OECD (2020a) discussion to developing Asia. It contributes to the existing literature on trade in medical goods by Hayakawa and Imai (2022) in the following manner. First, we focus the discussion on developing Asia. Second, as opposed to four broad medical goods trade categories in Hayakawa and Imai (2022), we disaggregate COVID-19-related essential medical goods into seven

categories, specifically focusing on vaccine production and value chain. The value chain discussion has not been attempted in the empirical literature and hence is a key contribution of our paper. We contribute to understanding of ways regional cooperation around improving facilitation, may or may not have mitigated adverse impact on GVC of vaccines.

The remainder of the paper is organized as follows. Following the introduction, Section 2 reviews the existing literature and gaps therein. Section 3 summarizes the trade data trends for the top 20 exporters and importers of COVID-19-related essential medical goods with an emphasis on the role of Asian economies following Das and Sen (2022) and discusses the methodology used in the paper. An empirical analysis estimating the impact of COVID-19 on bilateral trade involving these countries and the role of economic cooperation, measured in terms of regional trade agreements (RTAs), is undertaken in Section 4. The paper concludes with policy recommendations in the final section.

2 | LITERATURE REVIEW

The section reviews the existing literature, broadly categorizing them into (i) the importance of international trade, (ii) the geographic concentration in production, and (iii) the GVC of production and distribution. The studies allude to supply chain breakdowns by including discussion on spikes in demand for essential medical goods in producing economies, trade restricting policy measures, shortages in vital ingredients, and transport and shipping bottlenecks.

2.1 | Importance of international trade for supply of medical goods

In the first year of the pandemic in 2019, the OECD (2020a) revealed that no country was able to efficiently produce all the goods needed to fight the virus, highlighting a high degree of trade interdependency between economies. For example, OECD (2020b) reports that China's medical, transport, and manufacturing workers alone would have required 240 million face masks per day, much higher than the 20 million it produced daily in January 2020. It categorically noted that "no country can meet increased demand for face masks alone" (OECD, 2020b, p, 9), implying that cross-border supply would be necessary to curb the adversity of the pandemic.

In a subsequent study, the OECD (2021, p. 2) emphasized that "all countries need vaccines, but not all are able to produce them." While 208 economies were said to be importing vaccines, 90 were exporting them, making international trade an integral part of vaccine supply. Strong trade interdependencies also exist for vaccine production and distribution. This is because the vaccine supply chain comprises four stages, including drug discovery, production, distribution,

and administration. Each of these stages can be located across different economies. Even if vaccine production is concentrated in a few, the ingredients are procured from many economies. Production of packaging material for vaccine transportation, storage, and administration is also spread across several economies. Das and Sen (2022) estimate trade interdependencies using product-level intra-industry trade estimates and confirm the same.

2.2 | Geographic concentration of medical goods production

The location of COVID-19 vaccine manufacturers and distributors is highly concentrated in high-income and emerging economies (ADB, 2020a, 2020b). Few firms are registered as vaccine distributors in South America or Southeast Asia. This geographic concentration of production and distribution capacities again emphasizes the importance of trade and cross-border logistics efficiency for vaccine delivery globally.

Brown (2020) notes that China—the largest supplier of face masks, medical goggles, and protective gowns in 2019—directed these for its own use in 2020, lowering exports. The country also started importing many of these goods from other economies in early 2020 and, on a net basis, China's exports of face masks to the world economy fell 24% in January–February 2020 compared to the same period in 2019. Given the growing demand for these goods globally, the prices of facemasks skyrocketed, meaning that, primarily, only the rich economies such as Japan or the United States could afford it at that time. This highlights the ill-effect of geographic concentration of production of COVID-19 medical goods, where trade itself could not resolve supply shortages.

2.3 | GVC or supply chain disruption

Evenett (2020), taking a supply chain perspective, mentions that as of September 4, 2020 medical goods and medicine sectors were subject to around 459 trade policy interventions, though only half were trade-restricting measures. In 2020, several economies introduced export controls and other restrictive measures that disrupted operations. Yet, other economies undertook trade policy reforms to ease imports of medical goods in their jurisdictions.

Evenett et al. (2022) make similar observations. The incidence of trade policy measures, a combination of export controls and import liberalization-cum-facilitation, increased during the first quarter of 2020, in line with the rise in COVID-19 cases. While some of them seem to be temporary in nature, some are left open-ended, depending on the economy or region. Around two-thirds of trade policy measures during the pandemic were targeted towards medical goods and personal protection equipment (PPE), as compared to agriculture and food products.

Gopalakrishnan et al. (2020), analyzing economies from the Commonwealth grouping, find that while the production of high-end medical goods, such as ventilators and oxygen therapy equipment, is concentrated in the European Union and the United States, China dominates the manufacturing of PPE. Within the Commonwealth, developed economies are the leading exporters, and large developing economies are the importers. The prevalence of export restrictions and high tariffs weakens the resilience of supply chains from shocks like COVID-19.

Gereffi (2020) describes the value chain of producing N95 face masks, which requires at least three layers of nonwoven specialized fabric, which in turn is manufactured from polypropylene (derived from petroleum oil and plastic) after being "melt-blown" to obtain fibers that can trap small particles. Despite a relatively simple value chain, the melt-blown, nonwoven fabric is only made by a limited number of companies globally, and hence, scaling up production is time-consuming.

Park et al. (2020), discussing supply chain issues in PPE goods (e.g., N95 face masks), identifies five sources of disruption. Apart from a shortage of raw materials, geographic concentration of manufacturers, and export bans, it also highlights challenges in transport and shipping due to lockdown and quarantine measures, limited availability of freight containers, and low capacity of workforce due to illness or social distancing measures. This led to supply chain disruptions, causing delays and shortages of goods in importing economies.

Hayakawa and Imai (2022) acknowledge that several economies adhered to export bans to match domestic demand for medical goods such as face masks during the peak pandemic when they faced large numbers of COVID-19 confirmed cases. Using bilateral trade values of medical products for 35 reporting and 250 partner economies, they conclude that even though the burden of COVID-19 cases led to lower exports, the decrease was smaller when exporting to partner economies with political or economic ties. Demographic ties played a role only for specific medical goods, that is, PPE. The study did not focus on vaccine products global value chain trade.

Notwithstanding the above observations, these studies reiterate the importance of international trade in the production and supply of medical goods and demonstrate the potential of policy measures, often governed by economies' own priorities and driven by the burden of the COVID-19 pandemic, to cause disruption in existing supply chains. Several economies attempts to control trade or to relocate supply chains was not efficient and it creates high cost in the global supply chain activities. Retaliatory actions by economies can destroy the manufacturing productive capacity of these essential goods, hampering economic recovery and prolonging the pandemic (Baldwin & Freeman, 2020). Alternatively, economies need to pay attention to trade facilitation and cooperation measures to see how fast and efficiently COVID-related medical goods could be transported and distributed to all economies to manage risks in global production value chains.

3 | DATA AND METHODOLOGY

Examining the global trends identifying the top 20 countries involved in exports and imports of our chosen category of essential medical goods in 2019 and 2020, summarizing Das and Sen (2022), it is observed that the international trade of COVID-19-related essential medical goods has been concentrated among a few developed countries and selected developing countries in Asia, well before the onset of the pandemic. Asia is primarily dominated by China for most of the categories for both exports and imports. However, other countries, such as India, Japan, Korea, and Singapore, feature well in the top 20 list for some of these goods where these are either high- or middle-income economies in Asia. Other Southeast Asian countries do not have a significant presence for most of these goods, highlighting their vulnerability to COVID-19.

To analyze the impact of RTAs as a form of trade facilitation to encourage seamless goods flow, we apply Hayakawa and Imai (2022) to the chosen category of essential medical goods. We only focus on bilateral import and export statistics for 26 pairs of economies in the data set based on the United Nations Commodity Trade Database.[1] These economies feature at least once among the top 20 exporters or importers of the seven medical goods categories as analyzed in Das and Sen (2022). The aggregated values at the HS six-digit level, according to the seven categories of medical products, form our baseline model that is specified as follows:

$$\text{Trade}_{ijy} = \exp\left[\alpha_1 \text{COVID}_{iy} + \beta_1 \text{COVID}_{jy} + \delta_{ij} + \delta_{yf}\right] \times \varepsilon_{ijy}, \tag{1}$$

where Trade_{ijy} is the sum of export values from economies i to j during January–December in year y. COVID_{jy} and COVID_{iy} are the COVID-19 incidence variables in exporting economies and importing economies, respectively. Our model controls for two fixed effects, δ_{ij} and δ_{yf} refer to the pair of economies and the trade flow-year fixed effects. Our model controls for two fixed effects, δ_{ij} and δ_{yf} refer to the pair of economies and the trade flow-year fixed effects. The subscript "f" indicates the trade flow (i.e., exporter or importer year fixed effects). We estimate this equation for each of the seven categories of essential medical products.[2] Such a modeling structure allows us to account for the effects of inward and outward multilateral resistance and account for endogeneity issues, as per the structural gravity model estimation procedures detailed in Yotov et al. (2016). In particular, the key gravity equation variable of

[1]From the original dataset of 29 economies, Das and Sen (2022) found that three economies—Brunei, Cambodia, and Laos—are completely import dependent, and hence, we exclude them in our regression model.

[2]We also estimated separated a similar model based on monthly trade data using country pair month and year month fixed effects following Hayakawa and Imai (2022), but the results are not discussed here due to reasons of brevity. They are available from the authors on request.

bilateral distance, being time-invariant, is absorbed by the country-pair fixed effects δ_{ij}.

A Poisson pseudo-maximum likelihood (PPML) method is applied as per the empirical trade literature, following Santos Silva and Tenreyro (2006, 2011) and Yotov et al. (2016). This is consistent with the fact that there are zero trade flow data observations we need to include in our model among pairs of economies. As an example, the PRC's hand sanitizer exports to Malaysia are recorded as zero from February to December 2019, while there are positive export values observed from January to December 2020.

We use two COVID-19 incidence variables in the model to check for robustness. One is the sum of a number of confirmed cases, and the other is a number of deaths from January to December. Given no COVID-19 incidence in 2019, we set those values to zero. However, for estimation, we add a value of one to them, incorporating their log specifications in our model.[3] The coefficients for these variables demonstrate the effect of COVID-19 on trade in these essential medical goods, including those in the vaccine value chain.

To analyze the impact of trade facilitation measures, which are part of RTAs, we extend our model by introducing the interaction terms of COVID-19 variables with an RTA dummy as follows:

$$\begin{aligned} \text{Trade}_{ijy} = \exp\Big[&\alpha_1 \text{COVID}_{iy} + \alpha_2 \text{COVID}_{iy} \times \text{RTA}_{ij} + \beta_1 \text{COVID}_{jy} \\ &+ \beta_2 \text{COVID}_{jy} \times \text{RTA}_{ij} + \delta_{ij} + \delta_{yf}\Big] \times \varepsilon_{ijy}, \end{aligned} \tag{2}$$

wherein RTA_{ij} specifies a dummy variable that takes the value 1 if both the exporting and importing economy are part of an enforced RTA for that period and 0 otherwise. As an example, in our model, bilateral trade values for vaccine exports between the PRC and Singapore take a value of 1 due to an enforced RTA between them, but the same between Belgium and India takes a value of 0. The information on the presence of an RTA or not are obtained from the WTO RTA database[4] and updated for 2020 using the information available on the WTO website.

In the above model, coefficients α_2 and β_2 estimate the effect of an RTA during the COVID-19 pandemic for an exporting and importing country, respectively, when cases and deaths were on the rise in 2020, compared to none in

[3]As analyzed in Hayakawa and Imai (2022), these incidence variables are a reasonably good measure of the economic impact of COVID-19, although other measures such as the government stringency index calculated daily by the Oxford University research exist. The stringency index was not employed in our estimation as its time series characteristics are likely to be different than case or death numbers with a stable trend reflecting same level of restrictions (higher or lower) over a given period.

[4]See World Trade Organization. Regional Trade Agreements Database. https://rtais.wto.org/UI/PublicMaintainRTAHome.aspx (accessed March 31, 2022).

2019. A positive value of both α_2 and β_2 would suggest that, on average, RTA membership would have a direct impact on increasing bilateral trade in essential medical goods even as COVID-19 cases and deaths rise in both exporting and importing countries.

The RTA effects are important to analyze as Das and Sen (2022) observe varying degrees of trade interdependence in the trade of essential medical goods. While Southeast Asian economies, particularly Brunei, Cambodia, and Laos, were involved in one-way trade for these goods, that is, major importers of these products, the other countries in the region, that is, Thailand, Philippines, Vietnam, Singapore (2020 only), and Malaysia (2019 only) show one-way trade in vaccine manufacturing as well as COVID-19 diagnostic testing and kits (imports), while being involved in two-way trade of vaccine GVC products. Notably, while China moved from one-way trade for vaccines to two-way trade between 2019 and 2020, Singapore engaged in one-way trade in 2020. Among Australia and New Zealand, the former is involved in one-way trade (i.e., imports) for almost all the essential medical goods.

It is noteworthy that all European and North American countries (with the exception of Mexico), which received the brunt of COVID-19 cases globally in its initial stages, demonstrated the presence of two-way trade in these medical goods, suggesting that they have been interdependent on the rest of the world for manufacturing and supply of these COVID-19 related critical medical goods (Table 1).

In our study, the observed trade interdependencies are higher for Asian countries in PPE and lower end of the value chain in the vaccine GVC through primary and secondary packaging and vaccine administration. Developed countries in the West tend to dominate the Test kits and upper end of the value chain (ingredients) as well as final production in vaccines.[5] This implies there is mutual complementarity in the vaccine GVC and both developed and developing countries would benefit from closer economic cooperation in facilitating access to this, crucial for a quick recovery from COVID-19.[6]

The above findings highlight the potential role of RTAs among these countries. Particularly for the countries in Asia where trade dependency is high, signing RTAs and committing to trade facilitation initiatives do provide insurance for access to these essential medical goods. Being part of RTAs strengthens Southeast Asian countries participation in vaccine GVCs. RTAs among the Asian countries or among the developed and developing countries bodes well. This emphasizes the role of existing RTAs, that is, the ASEAN Economic Community, Asia–Pacific Economic Cooperation (APEC); and some of the future

[5]See Das and Sen (2022) for a detailed data analysis of trade interdependencies involving these essential medical goods.

[6]An important caveat here is that current vaccine production and GVC trade data is only available up to 2020. This does not include COVID-19-specific vaccine trade information, and with both India and PRC developing and exporting these vaccines in 2021, the nature of these interdependencies may have changed as of 2022.

ones, including the Regional Cooperation Economic Partnership (RCEP) and Comprehensive and Progressive Trans-Pacific Partnership (CPTPP).[7]

We, therefore, need to attempt to empirically prove whether RTAs mattered, particularly when there was a rise in infection of COVID-19 and countries were looking inward to protect their own populations.

4 | ROLE OF RTAS AND TRADE BARRIERS TO MITIGATE SLOWING TRADE

We present the empirical estimation results of the impact of the COVID-19 pandemic, linking it next with the observed trends in tariff barriers or the extent of implementation of trade facilitation measures to understand what has been and can be the potential role of RTAs in mitigating any adverse effects of the pandemic. Do RTAs help to mitigate the adverse impact of lower trade during times of crisis?

4.1 | Empirical estimation results

Based on the specifications of Equations (1) and (2) in Section 3, we estimate four sets of regressions for seven categories of COVID-19-related essential medical goods as specified in Table A1, using cases and deaths, respectively, as the COVID incidence variables, which allows us to check whether the results are robust with respect to more than one COVID incidence variable. For all estimations, we cluster the standard errors by country pairs as per the PPML modeling exercise norms.[8] Estimation results for Equation (1) are shown in Tables 2 and 3 for cases and deaths as the incidence variable, respectively.

Results are reported for five vaccines and their GVC product categories, and PPE and COVID-19 test kits separately. The coefficient for exporting partner COVID impact is negative and significant for PPE products, and for vaccine ingredients, and storage and distribution products within its value chain, confirming that those top 20 economies hurt more by COVID-19 in cases and deaths reduced their exports of these critical and essential medical goods. The adverse impact is most severe for PPE products by magnitude and weakest for vaccine ingredients. This explains the possible observed decline in overall trade interdependence with the advent of COVID-19 in 2020, led by a decline in

[7]Most of the countries whose trade interdependencies were analyzed in Das and Sen (2022) were part of one or more of these important RTAs in the region. One notable exception is India, which though features significantly in vaccine GVC and PPE trade, is not part of APEC, RCEP, or CPTPP. India has bilateral FTAs with selected East Asian countries, including Singapore, Malaysia, Thailand, Japan, and Korea, and a regional agreement with ASEAN.

[8]See Yotov et al. (2016) for details regarding gravity model and application of PPML models.

TABLE 1 Countries that involved one-way trade in COVID-19-related essential medical goods.

	2019	2020
Vaccine	Brunei, Cambodia, Laos, Vietnam, Philippines, Thailand, Malaysia, China, NZ, and Mexico	Brunei, Cambodia, Laos, Vietnam, Philippines, Thailand, Malaysia, Singapore, Japan, and Mexico
Vaccine GVC: Ingredients	Brunei, Cambodia, Laos, Philippines, Vietnam, Australia, Canada, and Germany	Brunei, Cambodia, Laos, Philippines, Australia, and Mexico
Vaccine GVC: Primary Packaging	Brunei, Cambodia, Laos, Australia	Brunei, Cambodia, Laos, Australia
Vaccine GVC: Secondary packaging (distribution/ storage)	Brunei, Cambodia, Laos	Brunei, Cambodia, Laos
Vaccine GVC: Secondary packaging (administration)	Brunei, Cambodia, Laos, Australia	Brunei, Cambodia, Laos, Australia
PPE		Brunei, Cambodia, Laos, Australia
COVID-19 test kits and instruments	Brunei, Cambodia, Laos, Vietnam, Philippines, Thailand, Australia	Brunei, Cambodia, Laos, Indonesia, Thailand, Vietnam, Philippines, Australia

Abbreviations: COVID-19, coronavirus disease; GVC, global value chain; PPE, personal protective equipment.
Source: Author's own calculations.

bilateral exports of PPE products as well as some products in the vaccine supply chain.

The coefficient for importer's COVID-19 incidence by cases was found to be significant and positive for trade in PPE, test kits, and vaccine storage and distribution, indicating that economies in our dataset with a larger number of cases increased their imports of these three categories of essential medical goods. This is expected given that economies with many COVID-19 cases required greater imports of both PPE and test kits to contain the spread of infection and "flatten the curve." The same coefficients by number of deaths report similar results for PPE and vaccine storage/distribution products, while for test kits, trade is positive but not significant. The positive impact of COVID-19 in the importing economy driving bilateral exports is strongest for PPE and weakest for vaccine secondary packaging (storage and distribution). Vaccine primary packaging exports seem to be undermined by COVID-19 cases and deaths in the importing partner, although the effect is stronger with respect to deaths. The impact of

COVID-19 is found to be insignificant for both trade in vaccine administration (syringes and needles) and vaccines. The latter is likely, since 2020 data does not capture trade involving COVID-19-specific vaccines. These results confirm Hayakawa and Mukunoki (2021) finding that the pandemic has had a heterogenous impact across industries, adversely affecting some but not all industries in a similar manner.[9]

Moving on to the role of regional economic cooperation or RTAs, specifically of both exporting and importing members in an RTA partnership, estimation of Equation (2) is undertaken. The results are reported in Tables 4 and 5 (COVID-19 cases and deaths, respectively). Before that, we include the RTA variable by itself to identify the overall and average impact of free trade agreements on essential medical products. We estimate that, on an average, a country with RTA membership was likely to increase bilateral trade in essential medical products by 59%.[10]

We observe that the RTA coefficient for the exporting economy is positive and significant for all essential medical goods categories in terms of deaths and all but vaccine administration products in terms of cases. Comparing the baseline and RTA results, it can be observed that, on average, countries that were members of RTAs were more likely to increase bilateral trade in these essential medical goods; and this also played a vital role in mitigating any initial adverse impact of the pandemic on the vaccine supply chain and test kits trade among these RTA member economies. Our study also finds that economies were more likely to import those essential medical products from RTA partners involved in the primary and secondary packaging and distribution stage of the vaccine value chain. Vaccine ingredients, a critical component of the vaccine development supply chain, increase their exports within RTA members, but the same has an insignificant impact if it is an importing economy.

4.2 | Role of tariff barriers

Some of the above results can be explained by the tariff structure that exists on these goods. The product level analysis presents a wide disparity between developed and developing countries when it comes to tariff barriers and their range of medical products. Summarizing the data, Figure 1 presents the share of COVID-

[9]The results are even stronger when using monthly trade data and monthly dummies, with exports of essential medical goods negatively affected for most of 2020 and in particular during April to September, which was the peak period of cases and deaths across most of the countries included in this study. For importing countries with COVID cases and deaths during this period, the effect was positive and strongly significant. The detailed results are not included here due to reasons of brevity and are available from the authors on request.

[10]The detailed results are not included here due to reasons of brevity and are available from the authors on request. As an example, the β coefficient for RTA dummy only (without interacting with COVID incidence), for PPE products was found to be 0.471 and statistically significant at 1% level. In a PPML estimation, this is interpreted as $e^{(0.4714-1)} \times 100 = 58.94\%$.

TABLE 2 Baseline model results of impact of COVID cases on trade in critical and essential medical goods.

Variables	Personal protective products	Test kits	Vaccines	Vaccine ingredients	Vaccine primary packaging	Vaccine storage and distribution	Vaccine admin
Export partner COVID	−0.059*** [0.012]	0.001 [0.012]	0.029 [0.021]	−0.023* [0.014]	0.009** [0.003]	−0.01** [0.005]	0.003 [0.004]
Import partner COVID	0.059*** [0.008]	0.024** [0.012]	0.005 [0.020]	0.004 [0.006]	−0.007* [0.003]	0.013** [0.005]	0.001 [0.003]
Pseudo log likelihood	−3.34E+11	−2.34E+11	−2.56E+10	−3.72E+10	−2.14E+10	−1.99E+11	−4.08E+10
Psuedo R^2	0.494	0.600	0.786	0.404	0.57	0.434	0.613
Observations	115 473	57 327	14 400	86 400	28 800	86 400	28 800

Note: Estimation results reported by the PPML method. ***, **, and * denote 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are those clustered by country pairs. In all specifications, we control for country-pair fixed effects and trade flow-year fixed effects. "COVID" indicates the number of confirmed cases (cases).

TABLE 3 Baseline model results of impact of COVID deaths on trade in critical and essential medical goods.

Variables	PPE	Test kits	Vaccines	Vaccine ingredients	Vaccine primary packaging	Vaccine storage and distribution	Vaccine admin
Export partner COVID	−0.044*** [0.009]	0.006 [0.012]	0.032 [0.023]	−0.015* [0.009]	0.002 [0.003]	−0.014** [0.006]	0.0004 [0.004]
Import partner COVID	0.065*** [0.010]	0.018 [0.012]	0.003 [0.024]	0.004 [0.008]	−0.01*** [0.003]	0.01* [0.005]	−0.001 [0.004]
Pseudo Log likelihood	−3.34E+11	−2.34E+11	−2.57E+10	−3.72E+10	−2.14E+10	−1.99E+11	−4.08E+10
Psuedo R^2	0.495	0.6	0.786	0.404	0.57	0.434	0.613
Observations	115 473	57 327	14 400	86 400	28 800	86 400	28 800

Note: Estimation results reported by the PPML method. ***, **, and * denote 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are those clustered by country pairs. In all specifications, we control for country-pair fixed effects and trade flow-year fixed effects. "COVID" indicates the number of confirmed deaths (deaths).

19-related essential medical goods in 2019 and 2020 by MFN ad-valorem tariff range. While the United States, Japan, Australia, and New Zealand had all tariffs on these product categories within the range of 1%–5%, those for China were evenly distributed across the 1%–5% and 5%–10% range.

Vietnam, a key player in Asia Pacific in global PPE products trade, had the most restrictive tariff structure on two-thirds of these products, with nearly a quarter of them (nine products) attracting tariffs of 15% or more; Indonesia was the next most restrictive country in terms of tariff barriers with 22% (eight products) attracting peak tariffs of 10%–15%, and 8% (three products) attracting and average MFN tariff ad-valorem equivalent of 15% or more. India, a key player in the global vaccine production supply chain, also ranked among the restrictive tariff regimes among the Asia–Pacific, attracting 5%–10% average import tariffs on almost 89% of these product categories, with peak tariffs of 15% or more on at least three products, particularly vaccine ingredient such as sorbitol.

The data for preferential tariffs charged under bilateral and regional preferential trade agreements (PTAs) under the product level analysis suggest that while some specific trading partners enjoyed tariff-free trade of COVID-19-related essential medical goods, tariff barriers still exist preferentially between developed and developing countries, even in the presence of enforced PTAs. Tariffs are largely eliminated for intra-EU and intra-ASEAN trade between the United States and its PTA partners in the Asia–Pacific, PRC, Hong Kong, PRC, and Taipei, and zero across several product categories among AANZFTA and CPTPP members. However, exceptions do remain for specific products among COVID-19-related essential medical goods, in PPE products, as well as in the vaccine GVCs (Tables 6 and 7). As an example, one key vaccine ingredient, sorbitol, continues to attract high tariffs even in the presence of RTAs among the Asia–Pacific economies, which may explain why ingredients traded by the importing country are not impacted significantly even in the presence of RTAs in Tables 4 and 5. A narrow margin of tariff preference in RTAs for some vaccine supply chain products can also explain why a strong and significant positive impact of RTAs on the exporting country is not observed across the board of all seven medical categories. While Asia–Pacific countries may have benefitted in PPE products from being part of existing RTAs in the region, there is evidence that vaccine GVC trade may have been adversely affected in the lower end of the value chain for importing countries due to lack of regional economic cooperation between developed and developing countries, with the exception of APEC (which does not include European Union or India, two important countries in global trade involving COVID-19-related essential medical goods).[11]

[11]We re-estimate Equation (2) using APEC membership dummy instead of all RTAs and observe that the interaction coefficients were positive and strongly significant for PPE products for both COVID incidence variables. However, for vaccines, this was true only when importing member countries within APEC saw their COVID-19 cases or deaths increasing. The detailed results are not presented due to reasons of brevity and are available from the authors on request.

TABLE 4 Effect of regional trade agreements on trade in essential medical goods due to COVID-19 (cases).

Variables	Personal protective products	Test kits	Vaccines	Ingredients	Vaccine primary packaging	Vaccines secondary packaging	Vaccine administration
Export partner COVID-19	−0.116*** [0.017]	−0.015 [0.017]	−0.006 [0.034]	−0.047*** [0.015]	−0.047*** [0.011]	−0.046*** [0.015]	−0.009 [0.010]
Export partner COVID-19 * RTA	0.133*** [0.025]	0.043* [0.023]	0.101** [0.051]	0.090*** [0.023]	0.082*** [0.023]	0.060*** [0.023]	0.010 [0.022]
Import partner COVID-19	0.050*** [0.010]	0.019 [0.016]	−0.020 [0.035]	0.008 [0.008]	−0.039*** [0.007]	−0.019 [0.011]	−0.042*** [0.014]
Import partner COVID-19 * RTA	−0.015 [0.022]	0.016 [0.024]	−0.030 [0.051]	−0.033 [0.03]	0.067*** [0.02]	0.070*** [0.022]	0.11*** [0.025]
Log pseudo likelihood	−3.24E+11	−2.31E+11	−1.88E+10	−3.71E+10	−1.92E+10	−1.90E+10	−3.82E+10
Pseudo R^2	0.5095	0.6047	0.7245	0.4234	0.6134	0.4595	0.6370
Observations	115 473	57 327	14 064	86 400	28 800	86 400	28 800

Note: Estimation results shown by the Poisson pseudo-maximum likelihood method. ***, **, and * denote 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in square brackets are those clustered by pairs of economies. In all specifications, we control for economy-pair fixed effects and trade flow-year fixed effects. "COVID-19" indicates the number of confirmed cases.

Abbreviations: COVID-19, coronavirus disease; PPE, personal protective equipment; RTA, regional trade agreement.

TABLE 5 Effect of regional trade agreements on trade in essential medical goods due to COVID-19 (deaths).

Variables	PPE	Test kits	Vaccines	Ingredients	Vaccine primary packaging	Vaccines Secondary packaging	Vaccine Administration
Export partner COVID-19	−0.064*** [0.021]	−0.06** [0.024]	−0.036 [0.036]	−0.037*** [0.011]	−0.064*** [0.013]	−0.065*** [0.015]	−0.03*** [0.014]
Export partner COVID-19 * RTA	0.054** [0.025]	0.11*** [0.031]	0.142*** [0.036]	0.084*** [0.032]	0.071*** [0.021]	0.075*** [0.024]	0.046* [0.024]
Import partner COVID-19	0.053*** [0.017]	0.018 [0.027]	−0.075* [0.043]	−0.015 [0.009]	−0.078*** [0.015]	−0.049*** [0.015]	−0.042*** [0.014]
Import partner COVID-19 * RTA	−0.001 [0.025]	−0.005 [0.036]	0.016 [0.05]	0.009 [0.032]	0.099*** [0.027]	0.079*** [0.025]	0.049** [0.025]
Log pseudo likelihood	−2.19E+11	−1.50E+11	−1.49E+10	−3.24E+10	−1.36E+10	−9.96E+10	−2.11E+10
Pseudo R^2	0.4692	0.5612	0.7244	0.4232	0.6038	0.4036	0.573
Observations	115 473	57 327	14 400	86 400	28 800	86 400	28 800

Note: Estimation results shown by the Poisson pseudo-maximum likelihood method. ***, **, and * denote 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in square brackets are those clustered by pairs of economies. In all specifications, we control for economy-pair fixed effects and trade flow-year fixed effects. "COVID-19" indicates the number of confirmed deaths.

Abbreviations: COVID-19, coronavirus disease; PPE, personal protective equipment; RTA, regional trade agreement.

Source: Authors' calculations.

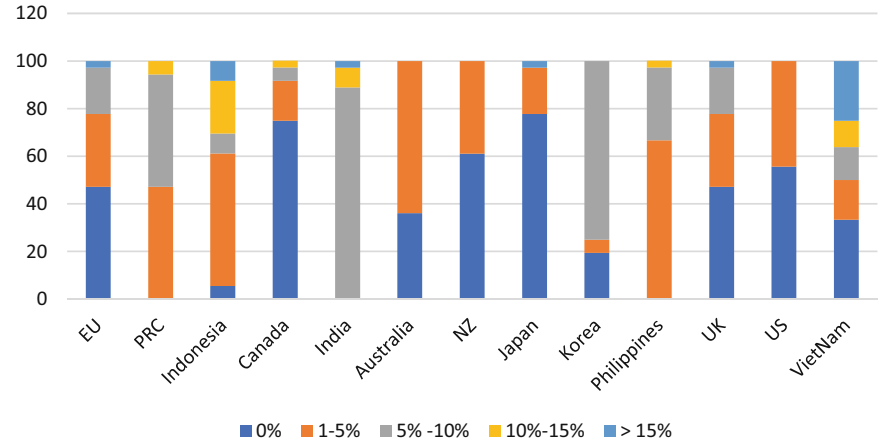

FIGURE 1 MFN ad-valorem tariff range of COVID-19-related essetial medical goods by Asia–Pacific countries, 2020. *Source*: Author's calculations. [Color figure can be viewed at wileyonlinelibrary.com]

It is also important to note that besides trade barriers, nontariff barriers in terms of export restrictions, product standards and regulations, testing requirements, and so forth add on to the trade costs, which would also be important to reduce or eliminate among these countries to enhance access for critical medical goods to developing economies (Gopalakrishnan et al., 2020).[12]

4.3 | Role of trade facilitation measures

As noted earlier, international trade for these goods faces barriers not only in terms of tariffs but also in the form of customs inefficiency that results from inadequate border infrastructure, regulations, and lack of digitalization of trade processes.

The TF score, published by the UN Global Survey on Digital and Sustainable Trade facilitation survey (2021), demonstrates that all countries do not rank high in the initiatives. Prima facie, it shows that while the leading countries involved in two-way trade of COVID-19 essential goods rank high, the countries part of the one-way trade and less developed need to catch up further (Table 8). Clearly, the latter are more vulnerable to external shocks, as seen during the pandemic. This highlights the role of RTAs embedding trade facilitation in the Asia Pacific region, as most of them, including AEC, RCEP, CPTPP,

[12]Due to data limitations involving export restrictions by months on all the products analyzed in our study, our paper is unable to empirically establish the above impact.

APEC, get its participating members to commit for transparent, harmonized and streamlined border procedures.[13] The agreements also include a commitment for customs automation and digitalization, both of which corroborate well with the trade interdependencies of these developing countries both within themselves as well as with the advanced economies as observed by Das and Sen (2022).

5 | CONCLUSION AND POLICY RECOMMENDATIONS

The paper has attempted to analyze the role of economic cooperation through RTAs in seven key product categories of COVID-19-related essential medical goods, incorporating vaccine and its GVC products trade for the first time in the empirical literature.

There are three key findings that emanate from the analysis in our paper. First, trade is an integral part of developing Asian countries in accessing these essential medical goods, and. is crucial for their post-pandemic recovery. Currently, much of the production and trade of COVID-19 essential medical goods are concentrated among a few developed countries and a handful of developing countries, that is, the high- and middle-income ones. This highlights their vulnerability to COVID-19 infections and economic recovery.

Second, trade interdependencies are observed to be higher in PPE products and lower end of the vaccine value chain (primary packaging and storage, distribution, and administration) for Asian economies such as Malaysia, Singapore, Thailand, India, Japan, Vietnam, and Korea. Europe and OECD members play a larger role in the upper-value chain trade of vaccine production, ingredients, and COVID-19 diagnostic testing kits.[14] This highlights the presence of mutual complementarity in the vaccine GVC, where both developed and developing countries would benefit from closer economic cooperation in facilitating access to this.

Third, Regional Economic Cooperation through RTAs has played a crucial role in reversing or at least mitigating the adverse impact of COVID-19 on the cross-border flows of these goods. The relationship is strongly significant for PPE products in terms of magnitude and weakest for vaccine ingredients. Countries that were RTA members were more likely to have mitigated the initial adverse impact of the pandemic on the exports of vaccine supply chain products and test kits and were more likely to also import those essential medical products from RTA partners that participated in the primary and secondary

[13]The logistics performance index (LPI) which is an important tracker of trade facilitation in empirical work, was has only been available in 2023 and therefore was not analyzed in our study.
[14]See Das and Sen (2022) for a detailed analysis of these trade interdependencies.

TABLE 6 Average most-favored nation tariffs on essential medical goods in 2019–2020 by selected economies (%).

Product group	EU	CAN	AUS	NZL	JPN	ROK	CHE	UK	US	PRC	INO	IND	PHI	VIE
Testing kits	0	0	3	4	0	6	0	0	0	5	6	10	2	0
Ingredients	4	0	2	1	2	6	0	4	1	5	5	9	2	2
PPE	4	4	4	3	2	7	3	4	3	7	11	10	7	12
Primary packaging	4	2	4	3	0	7	4	4	2	12	9	11	4	13
Secondary packaging: Storage and distribution	1	1	4	1	0	3	4	1	1	6	8	10	6	14
Secondary packaging: Vaccine administration	0	0	0	0	0	8	0	0	0	6	13	8	1	0
Vaccine for human medicines	0	0	0	0	0	0	0	0	0	3	3	10	1	0

Abbreviations: AUS, Australia; CAN, Canada; CHE, Switzerland; EU, European Union; IND, India; INO, Indonesia; JPN, Japan; NZL, New Zealand; PHI, Philippines; PPE, personal protective equipment; PRC, People's Republic of China; ROK, Republic of Korea; UK, United Kingdom; US, United States; VIE, Viet Nam.
Source: Authors' compilation from the United Nations Conference on Trade and Development. TRAINS Online. https://trainsonline.unctad.org/home.

TABLE 7 Selected product specific preferential tariffs on essential medical goods by importing economy and regional and bilateral regional trade agreements in 2020.

Product	Japan (CPTPP)	India (Japan)	Japan (ASEAN)	China (New Zealand)	Indonesia (South Korea)	Viet Nam (India)
Sorbitol (vaccine ingredient)	12	20	17	8	0	0
Cold boxes	0	15	0	0	12	7
Vials	0	10	0	14	0	7
Hand soaps	0	10	4	7	6	14
Hand sanitizers	0	8	4	7	6	2
Textile face masks (630790)	5[a]	10	0	6	17	5

Abbreviations: ASEAN, Association of Southeast Asia Nation, CPTPP, Comprehensive and Progressive Trans-Pacific Partnership; PRC, People's Republic of China.

[a]Tariff applies for imports from Viet Nam only among Comprehensive and Progressive Trans-Pacific Partnership members.

Source: Authors' compilation from the United Nations Conference on Trade and Development. TRAINS Online. https://trainsonline.unctad.org/home.

packaging and distribution stage of the vaccine value chain. Tariff barriers remain fairly low in developed and developing countries, but exceptions, even in PTA tariffs, remain for specific products among COVID-19-related essential medical goods, in PPE products as well as in the vaccine GVCs, such as sorbitol, a key vaccine ingredient. Implementation of trade facilitation measures, as committed to WTO TFA and UN-ESCAP Digital trade, shows scope for improvement, particularly for less developed Asian economies.

Drawing from the above, the paper provides the following key policy recommendations. First, governments need to keep the supply chains open and increase economic cooperation to prioritize trade facilitation, lowering trade barriers, simplifying the border procedures, and enhancing the provision of "hard" and "soft" infrastructure to improve the accessibility of COVID-19-related essential medical goods across borders. Second, it has been recognized that developing countries in Asia feature relatively low in the top 20 ranks, depend on imports, and have limited capacity to produce. The governments should identify multiple source countries for imports of these goods and enhance investment in the production of these goods, thus diversifying the risks. They could also look for cooperation at the bilateral or regional level to institutionalize ties with bigger Asian economies, thus reducing the possibility of supply chain shocks emanating from the developed countries. In this regard, RTAs

TABLE 8 Trade facilitation (TF) score for countries involved in trade for COVID-19 essential medical goods.

Country	Overall TF score
United States	NA
New Zealand	96.77
Australia	96.77
Singapore	95.70
Belgium	94.62
Netherlands	94.62
South Korea	94.62
Japan	93.55
China	91.40
Mexico	91.40
Switzerland	90.32
India	90.32
Germany	88.17
Canada	88.17
Thailand	87.10
Malaysia	86.02
Philippines	86.02
Indonesia	84.95
United Kingdom	82.80
Italy	81.72
Brunei	78.49
Cambodia	78.49
France	76.34
Poland	72.04
Vietnam	66.67
Laos	63.44

Source: UN (2021).

such as the ASEAN Economic Community, ASEAN+1 Free Trade Agreements, and RCEP assume importance. Even bilateral, regional cooperation among Asia countries increases opportunities for trade and assurance of improved accessibility of these goods.

Finally, as much of the trade for vaccine manufacturing, ingredients, and packaging materials for distribution and administration is happening between developed and developing countries, strengthening cross-continent trade

agreements is crucial. APEC measures and CPTPP have a strong role to play in building strategic relations between the developing Asian countries and the United States and Europe. It is the availability of vaccines and timely testing of cases that will help Asia–Pacific economies recover from the pandemic. Governments should work together to lower or eliminate trade barriers, including tariffs, customs inefficiency, and improve other infrastructure that are essential for the value chain of vaccine manufacturing.

The above recommendations further reiterate the importance of the WTO Trade Facilitation Agreement and paperless trade for cross-border movement of COVID-19-related essential medical goods, as accessibility to the same will lead to the economic recovery of the global economy in 2022 and beyond.

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APPENDIX A

TABLE A1 List of six-digit level codes in the Harmonized System 2017.

	HS-2017	Short product description
	Vaccine	
1	300220	Vaccines for human medicines (pharmaceuticals)
	Vaccine ingredients	
2	285210	Thimerosal (preservatives)
3	283322	Aluminum salts (adjuvants—for stronger immune response)
4	290544	Sorbitol (stabilizers—to keep the vaccine potent)
5	291211	Formaldehyde (inactivating ingredients—to kill viruses)
6	2941	Neomycin (antibiotics—to prevent contamination)
7	290613	Sterols (lipid nanoparticles in mRNA vaccines)
	Vaccine primary packaging	
8	701090	Vials (serum bottles)
9	401699	Stoppers (articles of vulcanized rubber)
	Vaccine secondary packaging: Storage and distribution	
10	4819	Insulated cartons
11	901890	Vaccine carriers
12	392310	Cold boxes
13	841850	Refrigerators/freezer chests
14	841830	Freezers
15	281121	Dry ice
	Vaccine secondary packaging: Administration	
16	901831	Syringes
17	901839	Needles
	Personal protective equipment	
18	340111	Hand soap
19	340130	Hand soap
20	340220	Other cleaning products
21	382499	Hand sanitizer
22	392690	Face masks
23	630790	Face masks
24	900490	Protective spectacles and visors
25	902000	Face masks

(Continues)

TABLE A1 (Continued)

	HS-2017	Short product description
	COVID-19-related testing and diagnostic kits	
26	382200	Diagnostic or laboratory reagents
27	300215	Immunological products
28	382100	Prepared culture media
29	902780	Instruments for physical or chemical analysis

Abbreviations: HS, harmonized system; mRNA, messenger ribonucleic acid; PPE, personal protective equipment.
Source: Authors' compilation from WTO (2021b) and OECD (2021).