

The Covid-19 Vaccine Production Club

Will Value Chains Temper Nationalism?

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Abstract

In the first two months of 2021, the production of COVID-19 vaccines has suffered setbacks delaying the implementation of national inoculation strategies. These delays have revealed the concentration of vaccine manufacture in a small club of producer nations, which in turn has implications for the degree to which cross-border value chains can deter more aggressive forms of Vaccine Nationalism, such as export curbs. This paper documents the existence of this club, taking account of not just the production of final vaccines but also the ingredients of and items needed to manufacture and distribute COVID-19 vaccines. During 2017–19, vaccine producing nations

sourced 88 percent of their key vaccine ingredients from other vaccine producing trading partners. Combined with the growing number of mutations of COVID-19 and the realization that this coronavirus is likely to become a permanent endemic global health threat, this finding calls for a rethink of the policy calculus towards ramping up the production and distribution of COVID-19 vaccines, its ingredients, and the various items needed to deliver them. The more approved vaccines that are safely produced, the smaller will be the temptation to succumb to zero-sum Vaccine Nationalism.

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THE COVID-19 VACCINE PRODUCTION CLUB: WILL VALUE CHAINS TEMPER NATIONALISM?*

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1. Introduction*

That vaccines for COVID-19 were developed so quickly during 2020 was a welcome source of hope in an otherwise bleak year. The approval of several vaccines at the end of last year was seen by many as a turning point in the global response to the pandemic, raising expectations that the threats to public health would soon be tackled through national inoculation strategies and that, ultimately, restrictions on everyday life could be lifted (IMF 2020).

The optimism witnessed in the New Year dissipated in the face of delays to the production of COVID-19 vaccines (Harford 2021)⁶ and reports that mutations of the coronavirus have resulted in new “variants,” some of which pose a greater public health threat than the original strain. The former has resulted in some governments losing trust in certain vaccine manufacturers, which in turn has triggered a controversial trade policy response (Evenett 2021a). The latter has led to the realization that COVID-19 may become a permanent threat to global public health, potentially requiring different approaches by governments and by international organizations as vaccines race against new variants of COVID-19 (The Economist 2021a).

These developments amplify the tension between policy responses that tend to be national and a virus that does not respect jurisdictional borders. In turn this has raised the risk that governments engage in Vaccine Nationalism, taken to be zero-sum steps that come at the expense of the public health of the populations of other nations (Bollyky and Bown 2020, Freund and McDaniel 2020).

Vaccine Nationalism can take the form of overt export bans or limits—that aim at increasing domestic availability of vaccines at the expense of foreign supply—or they can take less transparent but often equally effective forms. Subtle mechanisms that are available to governments of vaccine producing nations include delays in shipments and conditioning delivery abroad on imports of vaccine from other production locations (Evenett 2021a). Finger-pointing between governments in February 2021 highlighted the potential for both covert as well as overt limits on vaccine exports.

Whether the world trading system will fail its COVID-19 vaccine-related stress test will depend on the incentives confronting governments. A potentially important factor in this regard is the existing pattern of cross-border value chains involved in the production and distribution of COVID-19 vaccines. A government that pre-ordered vaccines from producers located abroad may think twice before curtailing exports of vaccines or vaccine ingredients manufactured at home.⁷ This is suggested by the broader hypothesis in the international trade and business literatures that the presence of cross-border value chains reduces the incentive of governments to engage in protectionism (Gawande et al. 2015;

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⁶ Harford notes: “Rasmus Bech Hansen, founder of Airfinity, a life science analytics company, told me that vaccine manufacturers projected they would produce 800m doses by the end of 2020. The reality was something between 20m and 30m doses. The pharmaceutical companies, then, achieved about 3 per cent of what they had announced.”

⁷ Article XX of the General Agreement on Tariffs and Trade (GATT) permits governments to limit exports of goods on grounds of a public health emergency, reducing the scope for multilateral trade rules to act as deterrent on export curbs on vaccines (Pauwelyn 2020). As noted below, WTO nondiscrimination rules apply in principle to the application of any such curbs (Horn and Mavroidis, 2021), but given the duration of the associated dispute settlement processes and the current abeyance of the WTO Appellate Body, there is no effective legal deterrent to the use of export curbs. As discussed in this paper, this does not imply that other forms of deterrent cannot bite.

Blanchard et al. 2017, Baldwin 2018, Krugman 2018, World Bank 2020).⁸ Could vaccine-related value chains provide a bulwark against Vaccine Nationalism, to the benefit of populations at home and abroad? If so, during the current pandemic this particular configuration of international business would have broader societal as well as commercial benefits by inducing governments to keep trade routes open. The backdrop to these vaccine-related developments is the return of geopolitical rivalry and associated Economic Statecraft (Baldwin 1985; Aggarwal and Reddie 2020, 2021), which may color the policymaking calculus.

Recent actions and statements by large trading countries make clear that the risk of export curbs on vaccines and vaccine ingredients cannot be discounted. The purpose of this paper is to examine the degree to which international value chains implicated in the production of COVID-19 vaccines satisfy the necessary conditions to temper resort to this form of Vaccine Nationalism—between states where final vaccine manufacturers are located, between final vaccine manufacturers and producers of vaccine ingredients, and between states within and outside the COVID-19 vaccine value chains.

We use information from detailed regulatory filings to identify the key ingredients of COVID-19 vaccines, other ingredients that are used in vaccine production, and selected products used for distribution (Annex Table 1). We then draw upon a number of commerce-related data sources—monthly customs data for the EU, annual global trade flows data from UNCOMTRADE, and firm-level data on pharmaceuticals’ headquarters and affiliates from Orbis—to obtain a picture of the supply chain of COVID-19 vaccines. The data clearly point to high concentration and self-reliance in COVID-19 vaccine production among a group of 13 countries⁹ that we refer to as the “COVID-19 Vaccine Producers’ Club” or simply the “Vaccine Club”.¹⁰ These countries are not only where the headquarters of the companies currently producing COVID-19 vaccines are found—they are also where 91% (783 out of 857 subsidiaries worldwide) of the subsidiaries of these companies are located. They also account for 60% of total confirmed advance purchasing agreements with pharmaceutical companies for vaccine doses.

The trade data show that vaccine producers are both the main source and destination of exports of COVID-19 vaccine ingredients, especially when we narrow down the analysis to key ingredients. Trade data for the 2017-19 period show that vaccine producers sourced 88.3% of key ingredients from other vaccine producers. The shares of imports of key ingredients from other vaccine producers as a group ranged from a low of 76.4% (India) to 98.7% (United Kingdom). In contrast, 68% of vaccine producers’ imports of all goods came from the Vaccine Club. The two top exporters of key ingredients are the United States and the European Union, which accounted for half of total exports, followed by United Kingdom, Japan and China with significantly smaller shares. Monthly data for the European Union show that extra-EU imports and exports of vaccine ingredients took off sharply from the second quarter of 2020. Extra-EU imports grew faster from vaccine producers than from non-vaccine producers, strengthening the dependence of the European Union on the Vaccine Club—a pattern that would most likely apply to other vaccine producers as well.

What are the implications of the current structure of the COVID-19 supply chains for trade policy and the production and distribution of vaccines worldwide? To differing degrees, members of the Vaccine Club have leverage over other members; that is, they can retaliate along the COVID-19 vaccine

⁸ The policy-induced disruption to cross-border value chains in medical goods in response to the Covid-19 pandemic offers an important test of the validity of this hypothesis. See, for example, Evenett 2020, Fiorini, Hoekman, and Yildirim 2020, Gereffi 2020, Miroudot 2020, UNCTAD 2020.

⁹ The countries are Argentina, Australia, Brazil, Canada, China, European Union, India, Japan, Korea, Russian Federation, Switzerland, United Kingdom, United States.

¹⁰ In this respect, COVID-19 vaccines follow the longstanding pattern of geographically concentrated production found in other vaccines (Wang et al. 2020). There is no suggestion in this paper that certain governments came together to form this club. The evidence presented in this paper based on international trade flows suggests that a web of sourcing arrangements generating this club predated the COVID-19 pandemic.

supply chain. Governments outside this club, which constitute the overwhelming majority of nations, have no such leverage. However, other options are available to the latter nations (a statement of fact rather than an endorsement, as will become clear.) The existence of differential options may account for differences in how governments across the world react any outburst of Vaccine Nationalism, the risk of which will remain so long as glaring excess demand for COVID-19 vaccines remains unmet.

Our analysis yields four types of recommendation for both the private sector and the public sector. Although trade policies are implicated and should be carefully monitored, trade policy alone cannot eliminate the shortages of COVID-19 vaccines. We urge that particular attention be given to the private sector incentives involved, including the way government policies affect those incentives and have been shaped by unfortunate legacies from the past. We also identify a critical coordination problem that the creation of a clearing house could alleviate. The transfer of tacit knowledge—as opposed to ceding codified knowledge in the form of patents—between vaccine creators and vaccine manufacturers has been identified by numerous experts as essential to ramping up COVID-19 vaccine production. We therefore discuss means by which that knowledge can be transferred and the attendant capabilities of developing countries nurtured. As such, our approach departs from those seeking to suspend certain multilateral trade disciplines on intellectual property rights.

Our focus on the location of producers of COVID-19 vaccines and their ingredients, and on the resulting international trade between nations, addresses only one facet of the global distribution of vaccines needed to quell the current pandemic. Other recent analyses have emphasized different aspects of the global distribution of vaccines including transportation and trade facilitation challenges (ADB 2021; OECD 2021); the role of national and international intellectual property rights regimes (Abbott and Reichman 2020; Mercurio 2021; Nicholson Price, Rai, and Minssen 2020); allocation, affordability, and deployment of vaccines (Wouters et al. 2021); and the incentives created when procuring vaccines (Ahuja et al. 2021).¹¹

Moreover, the ongoing race to develop and ramp up production of vaccines should be seen in light of longstanding concerns about the strength of private sector incentives to develop vaccines (Xue and Ouellette 2020) and the legacy of societal responses to previous pandemics, including the influenza A (H1N1) pandemic of 2009-10 and the West African Ebola virus epidemic of 2013-16. As will become evident, actions taken during the latter two episodes are likely to have influenced public and private sector decision-makers this time around.

The remainder of this paper is organized as follows. The next section outlines the current risks of policy-induced delays to vaccine exports and finds them credible. The third section deploys empirical evidence consistent with the existence of a club of COVID-19 vaccine producers. The fourth section discusses the policy implications of such a club and infers several implications for policy and the design of international cooperation. Concluding remarks on the impact of cross-border value chains on Vaccine Nationalism are offered in a final section.

2. The risk of policy-induced delays to deliveries of COVID-19 vaccines

Once it became apparent last year that a number of candidate COVID-19 vaccines were progressing through the three phases of testing, certain governments sought to pre-order significant quantities of vaccine. These orders were in addition to, and often preceded, those made by the COVID-19 Vaccine Global Access (COVAX) on behalf of dozens of governments, including those of many developing countries.

¹¹ While we recognize it as a dimension of the story, we have abstracted from Vaccine Diplomacy—i.e. the strategic use of vaccines, vaccine ingredients and knowhow to achieve geopolitical objectives. Diplomacy is inherently selective (discriminatory) as it is driven by foreign policy considerations that are idiosyncratic—this is in contrast with the goal of improving global efficiency in vaccine production, which we argue is the priority in the current phase of the pandemic.

For their part, vaccine manufacturers had to consider where to produce vaccines and at what scale. Given the complexity of vaccine manufacture,¹² the evident need to meet demanding regulatory requirements, and economies of scale (reflecting not least high set up costs for manufacturing facilities), there were strong incentives to concentrate production in a limited number of locations. Policy influenced location decisions as well, not least because many governments were offering financial support to vaccine manufacturers.¹³ The policy interventions surveyed in this section relate to nations that together are forecasted to produce more than 87% of the COVID-19 vaccines in 2021.¹⁴

Policy had another influence on location decisions. In 2020 representatives of vaccine manufacturers concluded that any production in facilities located in the United States was unlikely to be exported, an assessment likely informed by the *America First* response to national vaccination of the then Trump Administration.¹⁵ Further evidence that policy influenced production location decisions came from the United Kingdom. In consistent press reports, which have yet to be denied by the UK government, the Secretary of State for Health was said to have vetoed a tie-up between Oxford University and U.S. pharmaceutical company Merck & Co. on concerns that exports of COVID-19 vaccines from the United States would not go ahead as scheduled.¹⁶

Ramping up production of COVID-19 vaccines in Europe has been fraught. In mid-January 2021 Pfizer announced that, in order to expand its production capability of its plant in Puurs, Belgium, there would be reductions in the quantities of vaccines delivered for three to four weeks.¹⁷ A senior Italian official went on record stating that Pfizer had unilaterally cut deliveries by 29%, although whether such a step contravened the contractual arrangements in place is far from clear.¹⁸ It is worth noting that Pfizer intended to supply all of its buyers outside of the United States from this Belgium plant, whose production capacity this year is said to rise to up to two billion doses.

¹² The Economist (2021b) provides a succinct account of the difficulties in scaling up the production of two types of COVID-19 vaccine: cell-culture (used in the AstraZeneca vaccine) and mRNA-based (used in the both the Moderna and Pfizer-BioNTech vaccines).

¹³ For evidence of financial support awarded by governments in 2020 to the medical sector more generally, see Evenett (2021b).

¹⁴ The forecasts used here were taken from slide 8 of Airfinity (2020).

¹⁵ On 8 December 2020, President Trump issued Executive Order number 13692. Section 2 of that Order states: “It is the policy of the United States to ensure Americans have priority access to free, safe, and effective COVID-19 vaccines. After ensuring the ability to meet the vaccination needs of the American people, it is in the interest of the United States to facilitate international access to United States Government COVID-19 Vaccines.” For further details see <https://www.federalregister.gov/documents/2020/12/11/2020-27455/ensuring-access-to-united-states-government-covid-19-vaccines>. A spokesperson for the U.S. Department of Health and Human Services noted soon after “If a contractor is meeting dose requirements to the [U.S. government], then nothing in the contract would prohibit sale of a manufacturer’s excess doses to another country,” suggesting that extant policy did not constitute an outright export ban. See <https://www.rollcall.com/2020/12/08/america-first-order-unlikely-to-save-vaccines-for-americans/> Private sector participants may have legitimate concerns, however, that U.S. policy towards vaccine exports might tighten in the future should delays or other disruptions to vaccine roll-out occur.

¹⁶ *The Economist* reported on 6 February 2021: “Anticipating vaccine nationalism, he insisted that Oxford University sign a deal with AstraZeneca, an Anglo-Swedish pharmaceutical firm, rather than Merck, an American one,” see <https://www.economist.com/britain/2021/02/06/after-a-shaky-start-matt-hancock-has-got-the-big-calls-right>. Likewise, the *Daily Mail* reported on 1 February 2020 “The Health Secretary torpedoed a deal between the University of Oxford and American pharma giant Merck over fears that Donald Trump could ban exports of the live-saving drug,” see <https://www.dailymail.co.uk/news/article-9209697/Matt-Hancock-vetoed-UK-vaccine-deal-DIDNT-guarantee-UK-supplies-first.html>. See also relevant remarks by UK ministers in the account of the UK Vaccine Taskforce in *The Spectator*: <https://www.spectator.co.uk/article/secrets-of-the-vaccine-taskforces-success>.

¹⁷ Pfizer’s mRNA-based COVID-19 vaccine was developed in collaboration with BioNTech, a German company.

¹⁸ See https://webcache.googleusercontent.com/search?q=cache:A6t_KrDzZ-YJ:https://www.bloomberg.com/news/articles/2021-01-15/pfizer-to-cut-covid-vaccine-deliveries-as-it-renovates-factory+&cd=5&hl=en&ct=clnk&gl=ch.

In January 2021 AstraZeneca experienced difficulties in ramping up its production of the vaccine that it developed with Oxford University. A spokesperson for this company stated: “Initial volumes will be lower than originally anticipated due to reduced yields at a manufacturing site within our European supply chain.” The site in question was AstraZeneca’s supply chain partner CMO Novasep, responsible for large-scale viral vector production of the former’s AZD-1222 vaccine in Belgium.¹⁹ After discussions with the European Commission, AstraZeneca agreed it could supply up to 40 million doses in the first quarter of 2021, as compared to the original contracted quantum of 100 million doses.²⁰ Subsequently, on 10 February 2021, AstraZeneca agreed a deal with IDT Biologika, a German company, to expand the latter’s production capacity in Dessau so as to produce “tens of millions of doses a month.” Tellingly, in further evidence that scaling up vaccine manufacture takes time, this new production capacity will not come online until the end of 2022.²¹

Faced with these disruptions and delays, European Union policymakers implemented, to the best of our knowledge, the first overt export control regime on such vaccines. A mechanism to authorize vaccine exports from the European Union and to enhance the transparency of such exports came into effect on 30 January 2021.²² This export control regime allows for an export shipment to be prohibited if “it poses a threat to the execution of Union [Advanced Purchase Agreement] APAs concluded with vaccines manufacturers.”²³ Vaccine manufacturers must seek authorization from the Member State where their production facility is located. Exports of COVID-19 vaccines to many neighboring and low- and middle-income countries were exempted.²⁴ This export scheme, as originally promulgated, will lapse on 31 March 2021.

The European Commission contends that this scheme is “targeted, transparent, proportionate, temporary and consistent with WTO obligations,”²⁵ a formulation found in G20 declarations on trade policy interventions since the onset of the COVID-19 pandemic. This assertion has been contested by analysts. Legal scholars question whether the exemptions to the application of this export control regime fall foul of Article XIII of the General Agreement on Tariffs and Trade (Horn and Mavroidis, 2021).²⁶ The other, non-legal claims made above have been contested by Evenett (2021a), who argues that the text of the Commission Implementing Regulation gives rise to seven areas of concern for trading partners, including those nations to whom exports are exempted from this export control regime.

Remarks by the EU Commissioner for Trade, Mr. Valdis Dombrovskis, that “This is a race against the clock. We cannot lose time because vaccines not being delivered on the agreed schedule”²⁷ suggest that the production delays were indeed the trigger for this policy intervention. In a Question & Answer sheet, the Commission noted that it has committed €2.7 billion of financial support to the development and production of COVID-19 vaccines.²⁸ Subsequently, the European Commission’s approach to vaccine procurement and delivery was defended by President von der Leyen on solidarity grounds:

¹⁹ See <https://www.pharmaceutical-technology.com/comment/covid-19-vaccine-manufacturing-disruptions/> and <https://www.ft.com/content/3dbfe495-5947-4dd0-9f43-5edc5e6d6dc7>.

²⁰ <https://www.ft.com/content/101a1c2c-ac41-4dda-9159-ea4b66eddaed>.

²¹ <https://www.ft.com/content/f654d813-5c4c-4d86-827f-c6a73eea9a30>.

²² See Commission Implementing Regulation (EU) 2021/111, 2021, *Official Journal*, (L 31I) 1, 8.

²³ Article 1(4) of the Commission Implementing Regulation.

²⁴ The exempted countries include the 92 jurisdictions on the COVAX Advance Market Commitment List.

²⁵ Paragraph 9 of the Preamble of the Commission Implementing Regulation.

²⁶ In light of the findings in this paper, it could be argued that the current structure of exemptions may not be incentive compatible: incentives are for the European Union not to hit Vaccine Club countries, even if formally not on the list of exemptions, and to renege on promises to exempt others outside the Club.

²⁷ https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_21_312

²⁸ https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_308

“I cannot even imagine what would have happened if a handful of big member states had rushed to it and everyone else would have been left empty-handed, what it would have meant for our internal market and the unity of Europe...In economic terms it would have been nonsense, and it would have been, I think, the end of our community.”²⁹

In this respect it is noteworthy that, before the EU export control law was put in place, Belgium had notified the European Commission of a draft law that would permit it to restrict the exports of medicines (including vaccines) as well as their ingredients.³⁰ Pauwelyn (2020) notes that Article 36 of Treaty on the Functioning of the EU permits Member States to introduce export curbs on products pertaining to “the protection of health and life of humans” so long as they do not “constitute a means of arbitrary discrimination or a disguised restriction on trade between Member States.” In light of these considerations, one way to frame the policy calculus facing the European Commission was that of weighing the relative importance of the Single Market and intra-EU solidarity on one hand and its adherence to multilateral trade norms (at least as they relate to export restrictions) and its leadership of the global trade-and-health initiative on the other.

This classic tension between internal and external priorities appears to be a pertinent feature of the approaches taken to vaccine exporters by other governments that have not imposed overt export control regimes. India and China have both committed to export COVID-19 vaccines to other nations, sometimes donating these vaccines and on other occasions in return for payment to local manufacturers. Notwithstanding these commitments, concerns about delays or worse in exporting have been voiced by trading partners.

The Turkish health minister has gone on record noting delays of COVID-19 shipments from China (New York Times 2021). Apparently, 10 million doses of the Sinovac vaccine were due for delivery in Turkey in December 2020. However, only three million doses were reported to have arrived in January 2021. A Chinese spokesman for the Ministry of Foreign Affairs addressed this matter on 20 January 2020 as follows: “Currently, China has initiated vaccination of key populations, and the domestic demand for vaccines is huge. While meeting domestic needs, we have overcome difficulties and tried every means to implement Chairman Xi Jinping’s important announcement with practical actions. We carry out international vaccine cooperation in different ways with other countries, especially developing countries, and provide support and assistance within our capacity according to their needs.”³¹ Notice that the capacity to cooperate (export) is linked to levels of domestic demand and capacity with the implication that the latter factors can condition the former.

A similar formulation was deployed by the Union Indian Minister of Commerce & Industry in a parliamentary answer on COVID-19 vaccines, given on 12 February 2021. In addition to presenting monthly data on the volume and value of Indian vaccine exports, the Minister noted: “Government has granted permission to M/s Serum Institute of India Pvt. Ltd., Pune and M/s Bharat Biotech International Limited, Hyderabad for manufacture of COVID-19 vaccines. Close coordination is being maintained through regular interaction between relevant Departments of the Government of India and vaccine manufacturers to ensure adequate availability of COVID-19 vaccines for national vaccination program.”³²

This statement follows a scare in January 2020 when Mr. Adar Ponnawalla, the Chief Executive Officer of the Serum Institute of India, stated publicly that the Union government had banned exports of COVID-19 vaccine. The Government quickly disavowed such claims but the episode was taken sufficiently seriously that it prompted several Indian trading partners, including Brazil, to seek

²⁹ <https://www.ft.com/content/3d3467c7-bfc7-4ce9-b89d-6892dad89c0a>

³⁰ <https://www.bloomberg.com/news/articles/2021-01-28/europe-opens-door-to-vaccine-export-ban-risking-global-backlash>

³¹ Source: https://www.fmprc.gov.cn/web/fyrbt_673021/t1847512.shtml

³² Rajya Sabha, Starred Question No. 131 (titled “Export of Vaccines”) to be answered on 12 February 2021.

reassurances from officials in New Delhi.³³ Subsequently, however, in a message on Twitter posted on 21 February 2021 Mr. Ponnawalla stated that the Serum Institute “has been directed to prioritize the huge needs of India and along with that balance the needs of the rest of the world.” He requested that foreign governments be “patient.”

While the EU export control regime for COVID-19 vaccines explicitly conditions export authorization on the capacity of a local manufacturer to meet domestic needs, the Chinese and Indian official statements do so implicitly. To a trading partner concerned about potential delays or disruption to the delivery of COVID-19 vaccines, the distinction between explicit and implicit linkage may not make much difference in practice.

In principle, the advance purchase agreements that have been negotiated between a number of governments and pharmaceutical companies may have trade effects insofar as the companies entering into such contracts are permitted to export only after having satisfied the advance purchases. The contractual terms a government signs with a vaccine manufacturer can amount to a *de facto* export curb, in particular if they require exclusive or priority supply to the state procurer. On 3 August 2020, the UK government signed an 18-month long contract with Indian pharmaceutical company Wockhardt, that has a subsidiary CP International based in Wrexham, Wales. The latter subsidiary would undertake the critical ‘fill and finish’ stage of vaccine production, providing these “these services for the UK government and producers of vaccines being developed around the world in large quantities,” according to a UK government announcement.³⁴

Six months later, on 10 February 2021, it was reported that the UK government had extended the contract with Wockhardt. A UK Cabinet minister was quoted very recently as saying “By extending our contract with Wockhardt, we will ensure the UK has uninterrupted fill and finish capacity, guaranteeing we have sufficient supplies to protect the British public in the long term.”³⁵ Given Wockhardt may have contracted with foreign buyers, including foreign governments, how can supplies to the UK government be guaranteed without the implicit threat of an export curb should there be a subsequent shortage in Great Britain and Northern Ireland? What guarantees, if any, has Wockhardt and its subsidiary given the UK government? This follows other statements from UK government ministers that their contract with AstraZeneca requires exclusive supply, at least for the vaccines manufactured in the United Kingdom.³⁶

This is not a hypothetical question as similar concerns have been raised by officials from UK trading partners about repeated references by UK ministers to protecting and assuring vaccine supply for the UK population. In a formulation not that dissimilar to the Chinese and Indian cases mentioned above, on 1 February 2021 the UK Health Secretary, Mr. Matt Hancock, is reported as stating the government “will protect UK supply and we’ll play our part to ensure the whole world can get the jab.”³⁷ UK officials should not be surprised if trading partners do not give it the benefit of the doubt. Indeed, in these fraught times the perception of trading partners may be as important as the reality.

Our final example comes from the United States. Legal counsel there have warned that provisions of the Defense Production Act could be invoked so that deliveries from affected vaccine manufacturers with “priority contracts” with the U.S. government move to the front of the queue, potentially at the

³³ See <https://www.hindustantimes.com/india-news/misinformation-health-ministry-says-no-ban-on-export-of-covid-19-vaccine/story-ojAzo9BFLd1ZecdqQM51yN.html>. Brazil’s representations to the Government of India are described in this article <https://www.livemint.com/news/world/brazil-scrambles-for-india-made-covid-vaccines-11609821133052.html>.

³⁴ <https://www.gov.uk/government/news/government-further-boosts-uk-vaccine-manufacturing-capacity>

³⁵ <https://economictimes.indiatimes.com/industry/healthcare/biotech/pharmaceuticals/wockhardts-covid-19-vaccines-supply-deal-with-uk-govt-extended-for-6-months/articleshow/80786104.cms?from=mdr>

³⁶ A UK minister is quoted making these claims in <https://www.spectator.co.uk/article/secrets-of-the-vaccine-taskforces-success>.

³⁷ <https://www.theguardian.com/world/2021/feb/01/hancock-uk-will-be-generous-around-world-with-covid-vaccine>

expense of shipments to foreign buyers (Mims, Raphaelson & Kim 2021). Once again, the threat of potential future delays arises.

In summing up, we return to the goal of this section: assessing the risk of policy-induced delays to deliveries of COVID-19 vaccines. Unlike last year, when many governments adopted explicit export control regimes for personal protective equipment and other medical goods, to date this year only one major COVID-19 vaccine producer has instituted a formal export authorization regime. To the best of our knowledge, no government where COVID-19 vaccines are produced has implemented a formal export ban or limit. However, as the reaction to the implementation of the EU's authorization scheme has shown, this has not eliminated perceived risks of policy-induced delays.

Instead, governments may be concerned that trading partners have deployed murkier export curbs which have already delayed exports of COVID-19 vaccines or could delay them in the future. Add in the suspicion attendant to geopolitical and regional rivalries as well as the diminution of trust brought about by the limited multilateral cooperation in recent years, then expectations rather than hard facts may heavily risk assessments of the disruption of COVID-19 vaccine supplies.

That a credible risk of trade disruption exists does not imply that it will materialize. Whether the deliveries of COVID-19 vaccines are disrupted depends on the decisions taken by governments and this may be influenced by the industrial organization of the sector in question. This is where the longstanding theoretical prediction in the international business and trade literatures comes into play: specifically, that the presence of extensive cross-border value chains shifts the political calculus away from beggar-thy-neighbor policies. In the next section we examine whether certain necessary conditions are in place for such value chains in the COVID-19 vaccine production to restrain contemporary Vaccine Nationalism.

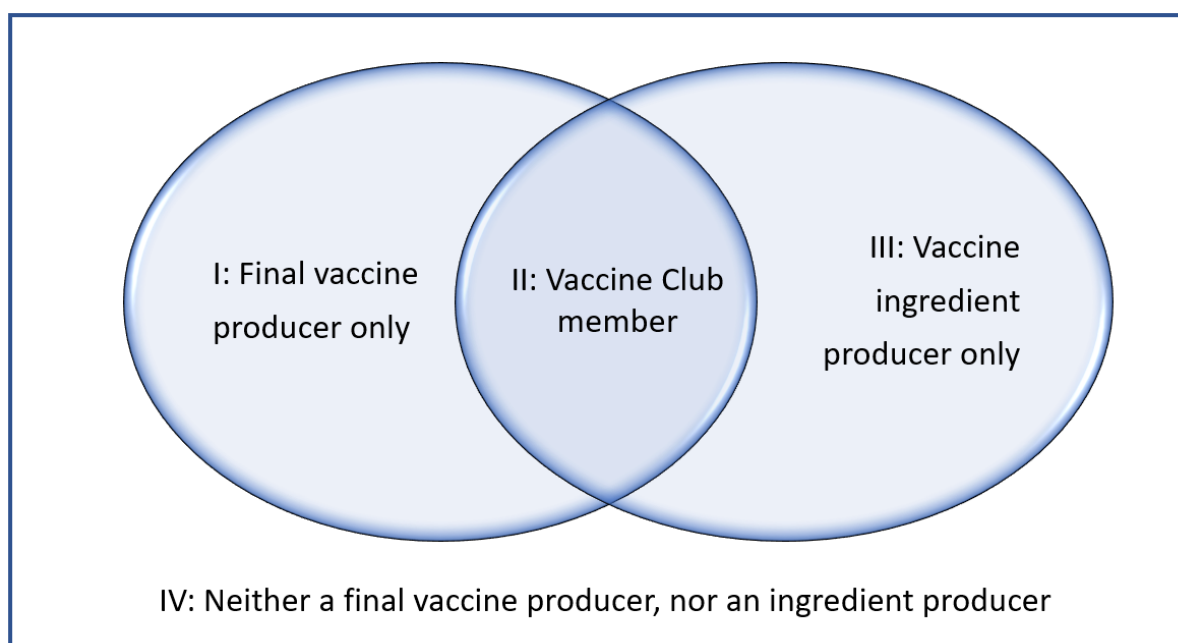
3. The COVID-19 Vaccine Producers Club

A government seeking to limit disruption of its plans to inoculate its population must take into account not only the supply of the vaccine, but also the supply of the ingredients as well as the items necessary to distribute the vaccine (such as nitrile gloves, syringes, and borosilicate vials). Technically speaking, the government should be interested in each potential bottleneck up and down whichever COVID-19 vaccine value chains it has sourced from. Detailed data on transactions within such value chains is not available but fine-grained trade data at the national level is.

For this reason, initially our analysis focuses on whether the necessary conditions for a trading partner to have leverage over a particular government are present. It is worth differentiating between several cases. First, the government of a nation where final vaccines are manufactured might fear retaliation from those governments where it sources both final vaccines or the ingredients for those vaccines. Given the uncertainty last year as to which vaccine development strategies were going to be successful, it is not surprising that several governments hedged their bets and pre-ordered vaccines from some producers based outside of their jurisdiction. Such hedging strategies may limit the risk of export curbs among major vaccine producers. A vaccine producer may also fear retaliation from governments where critical vaccine ingredients are exported, although the cost of switching between suppliers is also a legitimate consideration.

Second, a government of a nation whose firms produce vital vaccine ingredients may have leverage over those governments where final vaccines are produced. This is the case for existing export markets for such ingredients but also for potential markets in which vaccine manufacturers are scaling up and may soon need additional sources of ingredients. Third, in economies where firms produce neither the final vaccine or vaccine ingredients, their governments have no leverage over final vaccine manufacturers on account of the particular value chains.

Figure 1: Nations fall into four groups—one of which constitutes the Vaccine Club



These considerations can be summarized in a Venn Diagram where there are four types of economy and whereby governments fall into four groups (see Figure 1). Ultimately, the empirical question addressed here is how many nations are in each group? In particular, is group II much bigger than groups I and III implying that, essentially, each final vaccine producer is also a vaccine ingredient producer? If so, the world divides between those nations inside and outside the Vaccine Club.

3.1 Evidence from the European Union

To date, the EU is the only jurisdiction to introduce an export authorization regime for COVID-19 vaccines. The EU is therefore a good place to start examining what the state of pre-pandemic cross-border sourcing of vaccines and vaccine ingredients reveals about the incentives facing governments that contemplate banning final vaccine exports to a trading partner.

Another advantage of starting with the EU is that it reports very fine-grained product level international trade data. Using regulatory statements and specialist industry publications we were able to identify a total of 20 vaccine ingredients and items needed to distribute vaccines. The eight-digit product code in the EU's COMEXT trade nomenclature associated with each of these 20 products was identified and are listed in Appendix Table 1. On the basis of commentary in specialist publications, the ingredients were split into two groups: key and other.

Annual extra-EU import data were used to identify, for each of the 20 products, the top three foreign sources of imports in each of the years 2017, 2018, and 2019. To see how frequently a foreign trading partner was a source of one of these 20 products, weighting each year by one-third, the total number of products for which a trading partner was in the top three sources was calculated. This procedure identifies which nations, if any, recur among the top sources for vaccine materials that the EU sources from abroad. If the value-chain-discourages-protectionism thesis applies, the EU may be more hesitant about banning vaccine exports to these trading partners.

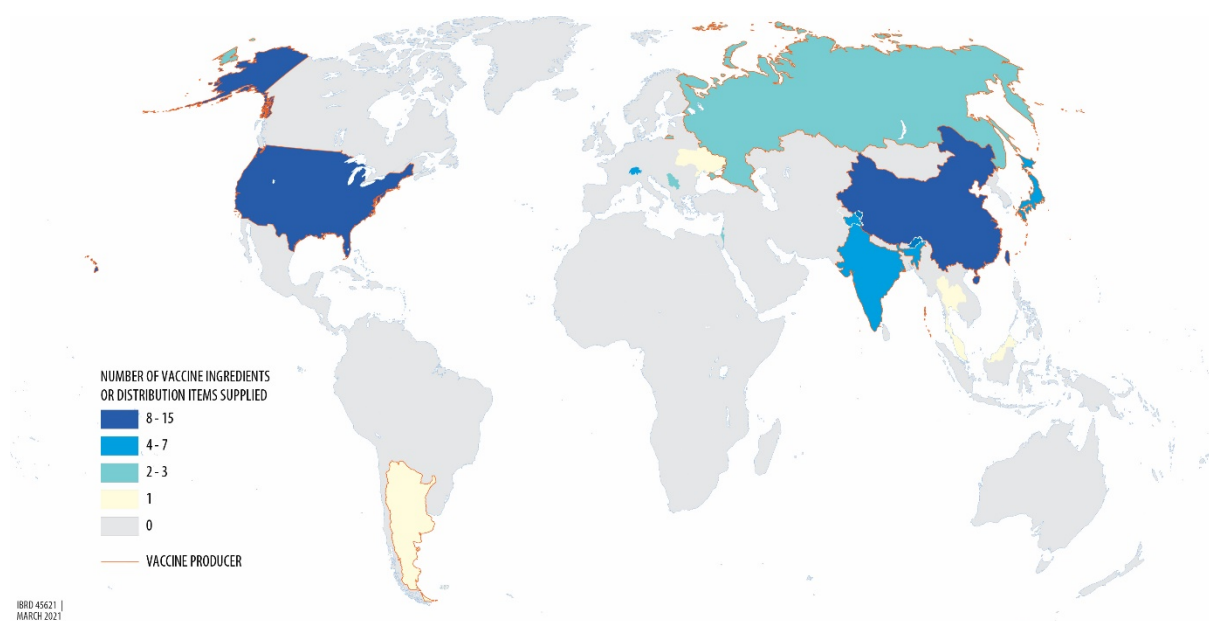
China and the United States stand out as the top sources of vaccine ingredients and vaccine distribution items (Figure 2). China and the United States are top-three suppliers for 14 out of the 20 items. Switzerland and Japan are the next most frequent sources for the EU, being top-three suppliers for, respectively, seven and five items. What is revealing is that almost every one of these top-three

suppliers is also expected to produce COVID-19 vaccines in 2021 (at least according to Airfinity 2020). The exceptions are Israel, Malaysia, Serbia, and the Ukraine, none of which is a top three supplier for more than two of the 20 vaccine ingredients or vaccine distribution items.

In short, the EU sources much of its vaccine ingredients and distribution items from nations that also produce final vaccines. Indeed, only three nations expected to produce COVID-19 vaccines in 2021 (Australia, Brazil, and Canada) were not already major suppliers of vaccine ingredients and distribution items to the EU before the COVID-19 pandemic. Moreover, only Malaysia is a major vaccine distribution item supplier that is not also a final vaccine producer. In terms of the Venn Diagram in Figure 1, groups I and III are sparsely populated, group II involves the major trading countries, and the rest of the world is in group IV.

That the EU sources so many vaccine ingredients and distribution items from the major vaccine producers begs the question whether this degree of concentrated sourcing is unusual. In 2019, the last year for which trade data is available before the pandemic, 70.2% of extra-EU sourcing of vaccine ingredients and distribution items came from nations that were final vaccine producers. In contrast, 64.8% of all extra-EU imports came from the same set of final vaccine manufacturers.³⁸ That the EU sources so many vaccine ingredients from the very nations it exports final vaccines to ought to strengthen the disincentive to curb exports of the latter.

Figure 2: The EU sources most of its vaccine ingredients from final vaccine producers



Source: Map based on eight-digit COMEXT extra-EU import data for the 20 vaccine ingredients and distribution items listed in Appendix Table 1 for the three years preceding the COVID-19 pandemic (2017-2019, with each year weighted equally). Due to the BREXIT transition period, imports from the UK are not classified as extra-EU imports for the years in question and hence the UK's contribution is omitted from this map.

Further evidence of the limited sourcing of vaccine ingredients and distribution items from outside the Vaccine Club is provided in Figures 3 and 4. The EU is a producer of many of these items and so the question arises as to whether extra-EU exports of an item could meet domestic demand should that surge as inoculation strategies are implemented across the Union. One way to gauge this is to identify which of the items are ones that the EU is a significant net importer of. An indicator of which was calculated for 2019 by subtracting total extra-EU exports from extra-EU imports of an item and dividing the

³⁸ The same gap exists in the extra-EU trade data for 2017 and 2018 but is smaller.

difference by the sum of extra-EU imports and exports of that same item. Figure 2 plots this variable along the horizontal axis and reveals that the EU is only a net importer of three vaccine ingredients and distribution items.

The vertical axis of Figure 3 plots the share of extra-EU sourcing from nations that do not produce final vaccines. The findings reveal that, if there are any worries about over-dependency on a trading partner outside the Vaccine Club, it is confined to a single vaccine distribution product.

Figure 3: The EU is a major net importer of 3 of 20 vaccine inputs & distribution items

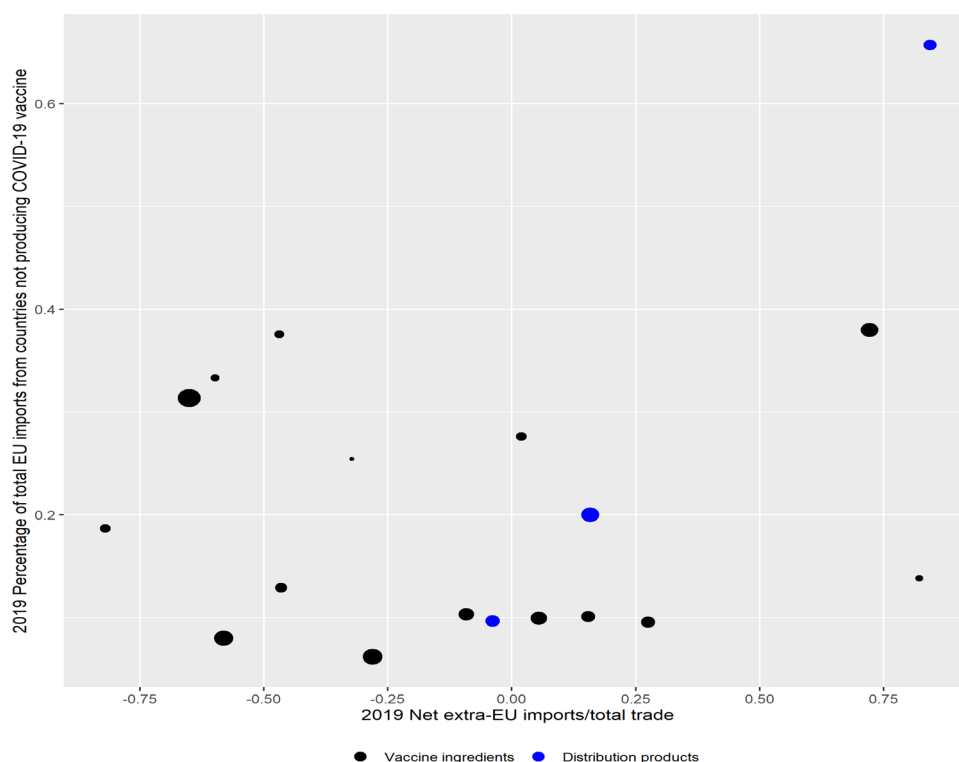
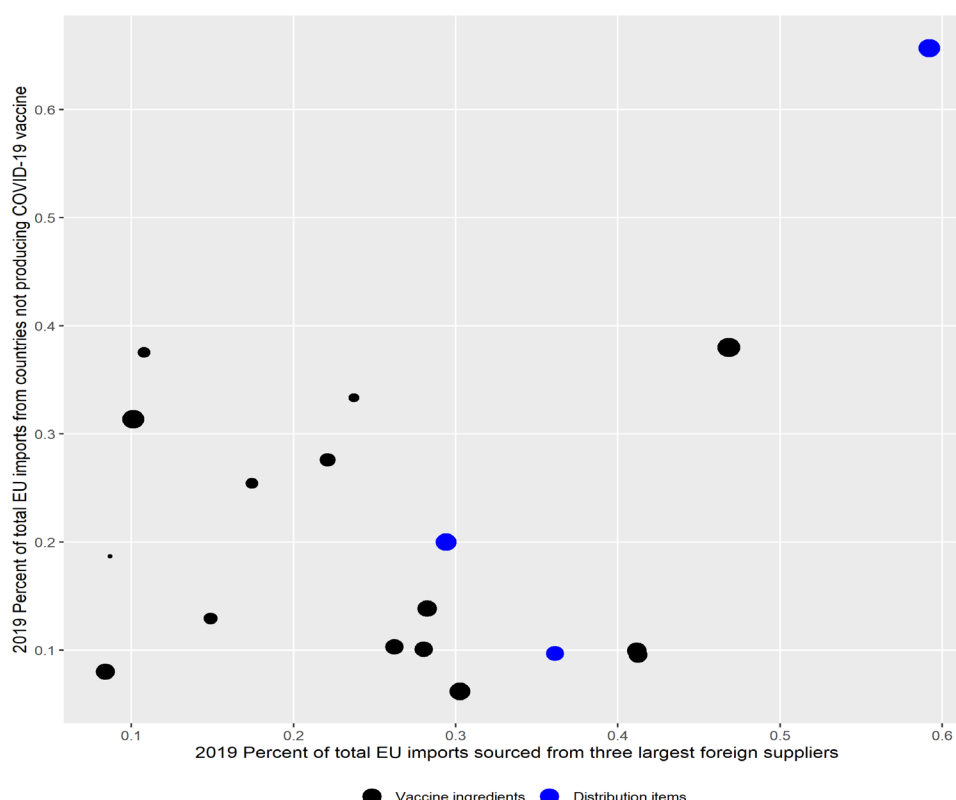


Figure 4 has the same vertical axis as Figure 3 but, instead, the horizontal axis reports the percentage of EU imports from the largest non-EU foreign suppliers in 2019. This reveals whether there is over-dependence on a small number of suppliers inside and outside the Vaccine Club. While there are three products where the top-three suppliers are responsible for 40% or more shipments to the European Union in 2019, only one of those products involves a large share of imports from outside the Vaccine Club.

What these three Figures imply is that, to the extent that the EU sources vaccine ingredients and distribution items externally, it tends to do so from other nations that manufacture vaccines. The pattern of existing cross-border value chains in COVID-19 vaccines would lead to a prediction that, if EU is worried about potential retaliation, then the EU would be more inclined to block vaccine exports to nations outside of the Vaccine Club. An alternative prediction is that the EU would delay, suspend, or ban vaccine exports to non-members before doing so to Club Members. The latter group may not include many large trading countries (or G20 members) but it does constitute huge swathes of the lower- and middle-income countries.

Figure 4: Only one vaccine distribution item is mostly sourced outside the Vaccine Club



Source: COMEXT extra-EU & overall EU import data for 2019 for the 20 products listed in Appendix Table 1.

An interesting question is whether the sourcing patterns witnessed before the COVID-19 pandemic broke down during 2020. To explore this matter, the latest fine-grained product level monthly extra-EU import and export data for the European Union were analyzed (see Figure 5). As both panels of Figure 5 show, extra-EU imports and exports of vaccine ingredients and associated distribution products took off sharply from the second quarter of 2020. Extra-EU imports grew faster from vaccine producers than from non-vaccine producers, strengthening the dependence of the European Union on the Vaccine Club.

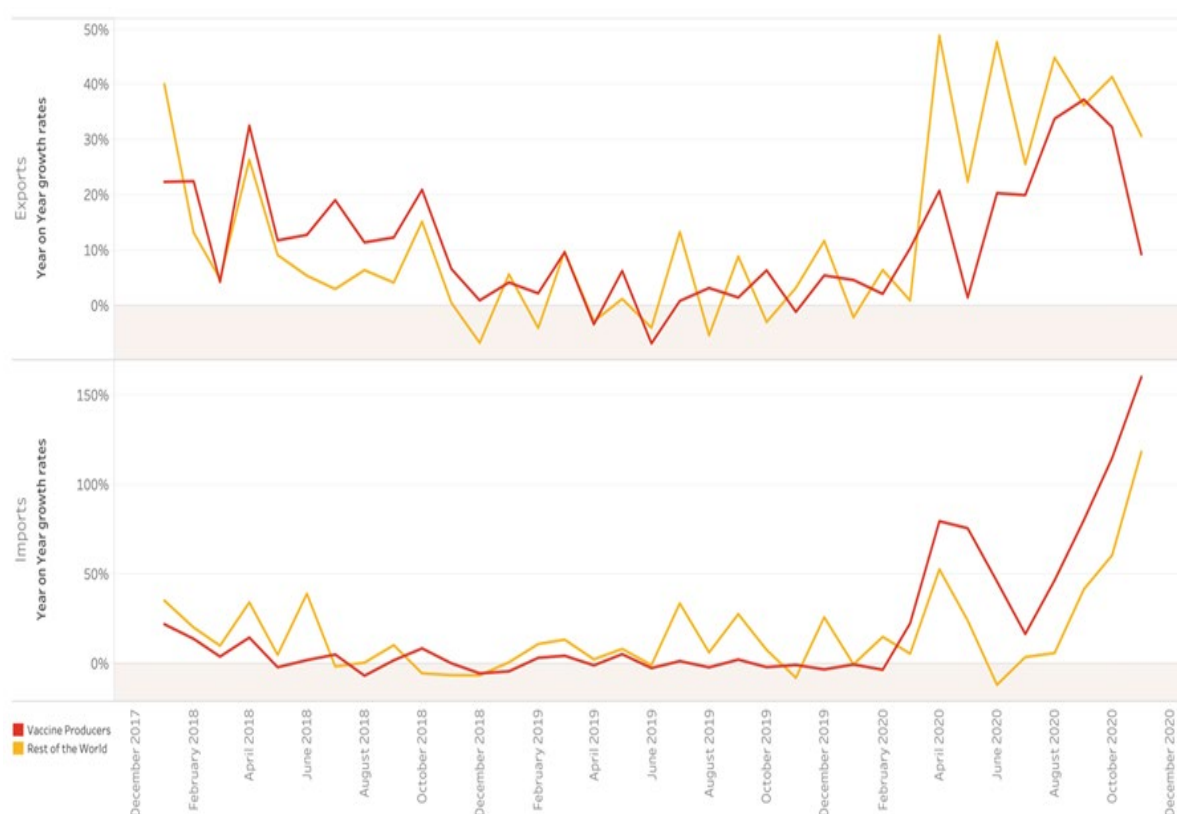
In contrast, extra-EU exports of ingredients grew relatively faster to non-vaccine producers, in principle giving the European Union more leverage over those outside the Vaccine Club. Even though the year-on-year growth rates of extra-EU exports of vaccine ingredients to the Vaccine Club fell in the October and November 2020 (in contrast to earlier months), the value of EU shipments to that club was still higher than the year before.

In sum, the latest available monthly trade data reinforces the finding of the importance to the European Union of a largely self-supplying Vaccine Club. Whether there is evidence of Vaccine Club in global trade data flows is examined next.

3.2 Evidence from global trade flows

Can evidence of a Vaccine Club be found in global trade data? Figure 6, based on data from the World Integrated Trade Solution (WITS), summarizes the global pattern of pre-pandemic cross-border sourcing of vaccines and vaccine ingredients. To ensure consistency in product categories across different reporting countries, we employed aggregate data at the six-digit level of the United Nations Harmonized System of traded products. Such data are therefore more aggregated than the EU trade statistics reported in the previous sub-section. To limit the influence of anomalies, we computed the mean trade values for each product examined for the years 2017, 2018 and 2019. For countries with incomplete direct trade data for the product categories of interest, we used mirror data.

Figure 5: Extra-EU trade in vaccine ingredients 2017-2020 (annual percentage change)

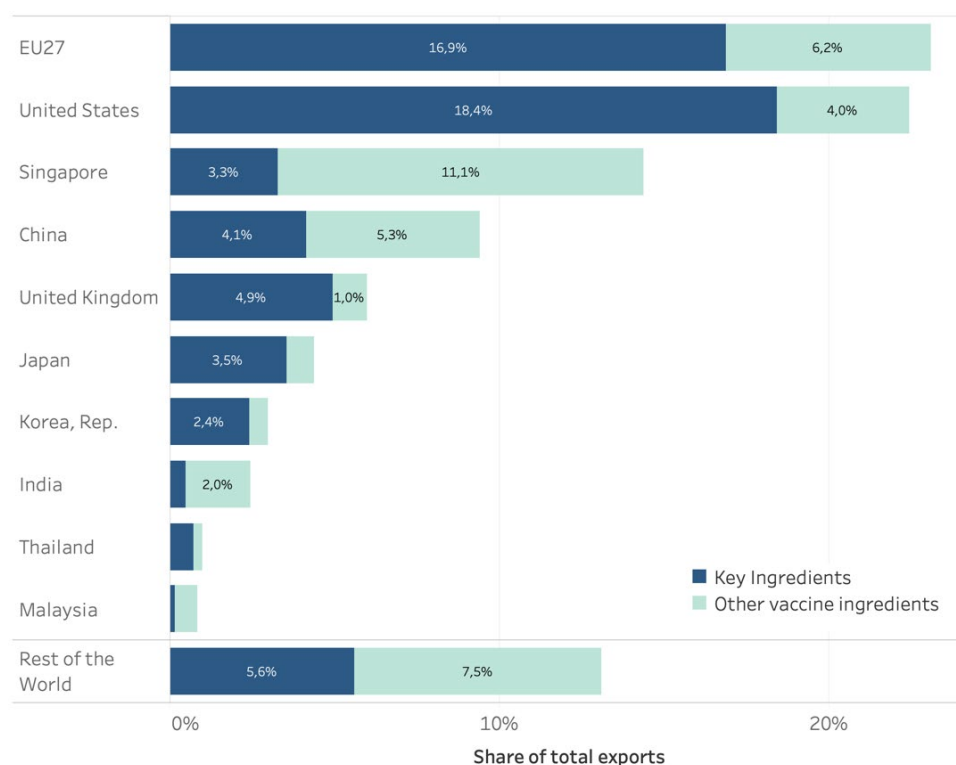


Source: COMEXT extra-EU & overall EU import data for 2019 for the key vaccine ingredients listed in Appendix Table 1.

The data reported in Figure 6 reveal that global markets for COVID-19 vaccine ingredients are highly concentrated. The top-five exporters of these products (the EU, United States, Singapore, China, and United Kingdom) accounted for around three-quarters of total pre-pandemic imports. For the key ingredients, those needed to make COVID-19 vaccines boost the immune system, the shares of imports from the top exporters were even higher and close to 80 percent, concentrated mainly in the United States, the EU, United Kingdom, China, and Japan.

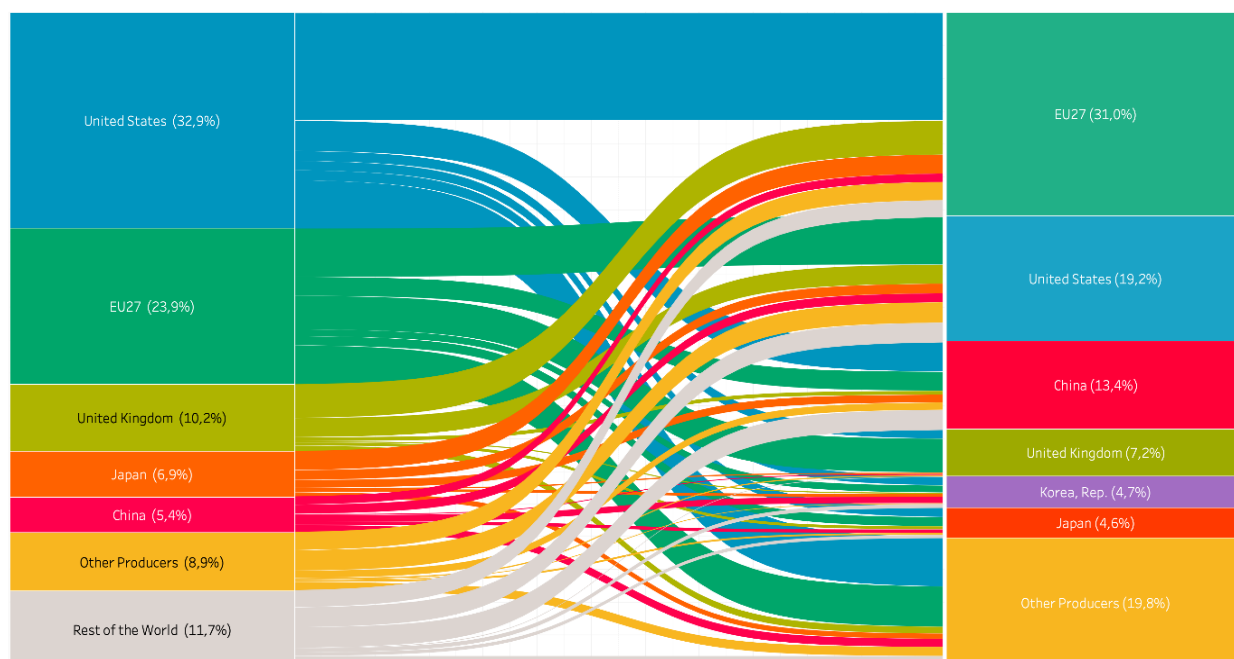
Vaccine producers are both the main source and destination of exports of key ingredients (Figure 7). The interdependence of the Vaccine Club is apparent from the data: vaccine producers sourced 88.3% of key vaccine ingredients from other vaccine producers. Appendix Table 2 provides further detail, reporting exports by destination for the ten top exporters of key ingredients to the group of vaccine final producers. The shares of imports of key ingredients from other vaccine producers as a group ranged from a low of 76.4% (India) to 98.7% (United Kingdom). In contrast, 68% of vaccine producers' imports of all goods came from the Vaccine Club. The two top exporters of key ingredients to other vaccine producers were the United States and the European Union, which accounted for half of total exports; the other top exporters (United Kingdom, Japan and China) were responsible for significantly smaller shares. Even top exporters from outside the Vaccine Club, such as Singapore, rarely accounted for more than 10% of total imports of key ingredients by the vaccine producers.

Figure 6: Top-10 exporters of COVID-19 vaccine ingredients



Source: World Integrated Trade Solution (WITS) for 2017, 2018 and 2019 for the 20 products listed in Appendix Table 1.

Figure 7: Top-5 sources of key COVID-19 vaccine ingredients by vaccine producers



Source: World Integrated Trade Solution (WITS) for 2017, 2018 and 2019 for the key vaccine ingredients listed in Appendix Table 1.

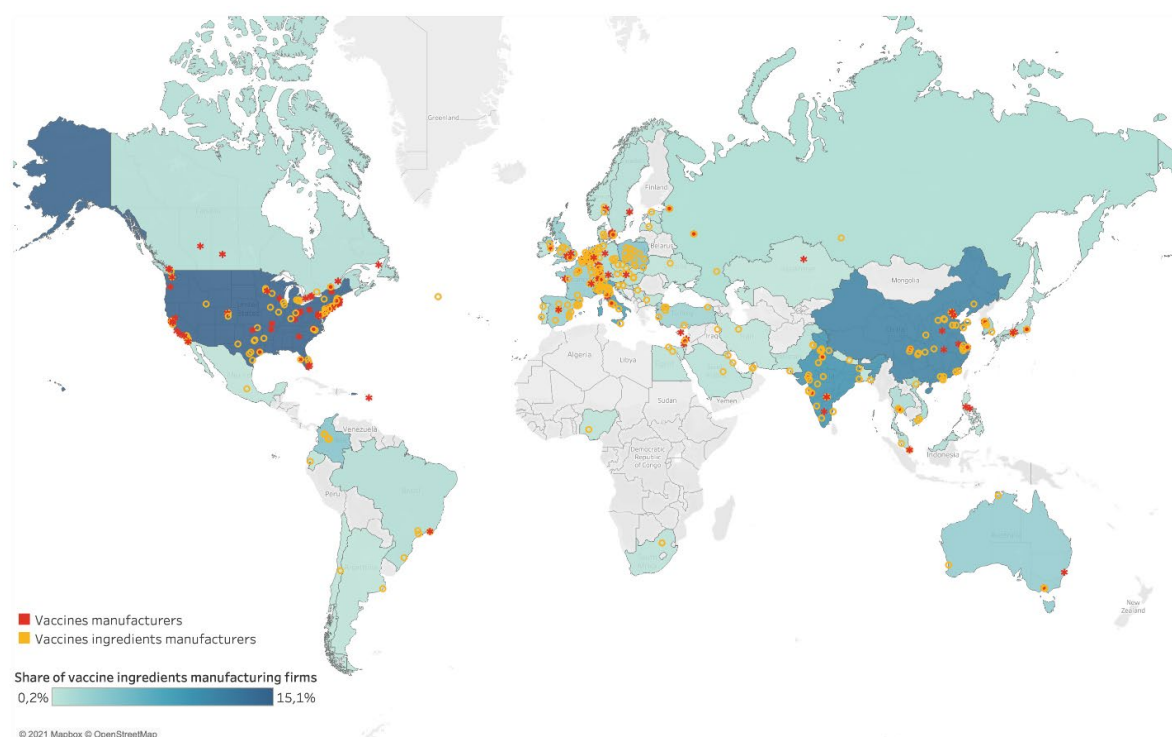
We also examined whether there was product level interdependence between members of the Vaccine Club. Appendix Table 3 reports the shares of imports by product of vaccine producers from other vaccine producers. The darker shades of red indicate those products where interdependencies were more pronounced, while darker shades of green indicate the opposite. For key ingredients before the pandemic

the shares of imports from the Vaccine Club were well above 50% for all products and, in most cases, they were above 90%. For other (non-key) ingredients the shares of imports of vaccine producers from the Club were less pronounced, but still very high for a majority of products. An exception is sodium chloride for which the dependence on other vaccine producers was less severe. Among the vaccine distribution products, vials, and syringes tend to be mostly sourced within the Club, while the shares of nitrite gloves sourced from other vaccine producers were substantially lower.

3.3 Evidence from firm-level data

Another source of information to shed light on the global footprint of the COVID-19 vaccine supply chain is firm-level data. The Asian Development Bank has combined information from different sources³⁹ to identify the location of manufacturers of vaccines and vaccine ingredients that could be relevant for the COVID-19 supply chain.⁴⁰ As can be observed in Figure 8, the manufacturers of ingredients used in the preparation of vaccines tend to be located in the countries where final vaccines are manufactured. Specifically, more than 70 percent out of 444 firms identified by the ADB as manufacturers of ingredients that are relevant for COVID-19 vaccines are located in the European Union (156 firms), the United States (70 firms), China (49 firms), and India (43 firms).⁴¹

Figure 8: Distribution of vaccine and vaccine ingredient manufacturers



Source: Asian Development Bank (ADB) Supply Chain Maps for Pandemic-Fighting Products.

³⁹ For more information on the data sources and methodology see <https://www.adb.org/multimedia/scf/#/>

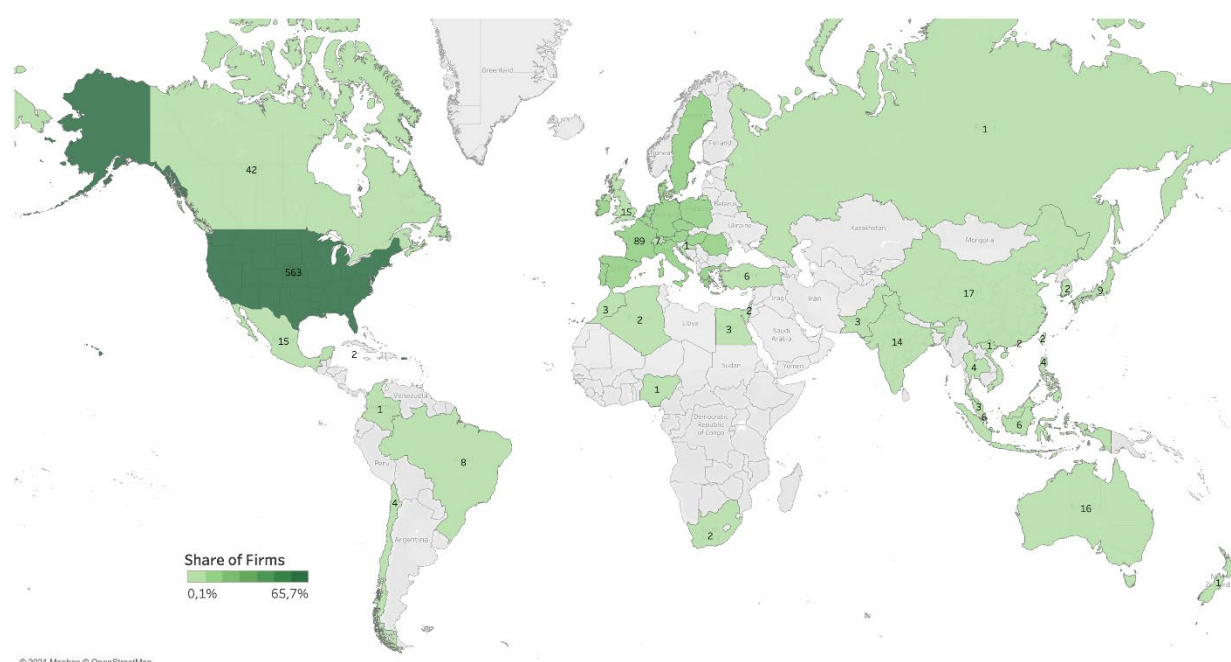
⁴⁰ The list of ingredients that the ADB has identified as relevant for the COVID-19 supply chain is based on ingredients of generic vaccines that could be relevant for the production of the COVID-19 vaccine components. These products differ from the list of COVID-19 ingredients that are presented in Appendix Table 1 and include: aluminium salts, emulsifiers, egg proteins, formaldehyde, polypropylene, sorbitol, thiomersal and yeast proteins.

⁴¹ Some caution is needed here as the number of firms operating within a jurisdiction need not be closely correlated with the total production of COVID-19-related vaccine ingredients within the jurisdiction.

Data on firm ownership ties also suggest that most of the subsidiaries of the companies that are currently manufacturing COVID-19 vaccines and that operate in a sector that is related to the production of ingredients for the vaccines are located within the Vaccine Club. Specifically, we employed data from the Bureau Van Dijk Orbis database provides to identify the locations of the subsidiaries of 10 manufacturers that are currently producing the COVID-19 vaccine:⁴² Johnson and Johnson, Pfizer and Novavax, with headquarters in the United States; GlaxoSmithKline and AstraZeneca with headquarters in the United Kingdom; Sanofi and Valneva with headquarters in France; and Curevac, Medicago,⁴³ and Sinovac with headquarters in Germany, Japan, and China, respectively. We restricted the sample of listed subsidiaries⁴⁴ to those firms that manufacture pharmaceutical products and pharmaceutical preparations.⁴⁵

Figure 9 reveals that subsidiaries that could potentially supply vaccine ingredients are largely located within the COVID-19 Vaccine Club. Specifically, vaccine producers have a total of 857 subsidiaries worldwide. Most subsidiaries (91%), represented by 563 firms, are located in the US, followed by the EU (89 subsidiaries), Canada (42), China (17), Australia, (16), United Kingdom (15), India (14), Japan (9), Brazil (8), Switzerland (7), Republic of Korea (2) and Russian Federation (1). Other countries that are not COVID-19 vaccine producers such as Mexico, Turkey and Indonesia host between 6 and 15 subsidiaries of COVID-19 vaccine manufacturers.

Figure 9: Distribution of subsidiaries of COVID-19 manufacturers whose main activity is related with production of vaccine ingredients



Source: Bureau VanDijk Orbis database.

⁴² No data are available on Orbis for Gamaleya Research Institute and Acellena Contract Drug Research and Development, the producers of the vaccine Sputnik V.

⁴³ Medicago is itself a subsidiary of Mitsubishi Chemical holdings corporation.

⁴⁴ Subsidiaries are defined as firms that belong to another company (parent or holding company) which controls more than half of its stock.

⁴⁵ Specifically, we filter the subsidiaries that are active in at least one of the following codes under the standard European nomenclature of productive economic activities (NACE): 2100, 2110, 2120 and 2121.

To conclude, whether one consults fine-grained trade data or firm-level ownership data, a small number of nations are responsible for the lion's share of the production and cross-border supplies of both COVID-19 vaccines and other ingredients. *A priori* there is no reason why the nations of the world essentially divide so cleanly between membership of the Vaccine Club or not. This state of affairs has important policy implications at a time of significant shortages of COVID-19 vaccines, to which we now turn.

4. Policy analysis and implications

Before discussing the policy implications of a COVID-19 Vaccine Club, it is worth putting this finding in context. Public health experts estimate that, taking account of age profiles, the prevalence of underlying health conditions, and data on the reluctance of a part of the population to get vaccinated, between 3.2 billion and 4.1 billion persons will need to be vaccinated worldwide (Wang et al. 2020). As many COVID-19 vaccines require two shots, the total global demand for vaccine shots likely lies between six and eight billion doses. This is the scale of the challenge before policymakers and the private sector. These totals could rise further if booster shots are needed to limit the threat to livelihoods from new variants of COVID-19.

In addition to this public health imperative, the quicker the vaccines are distributed globally the sooner the world economy can claw back lost output. In October 2019 the IMF forecasted that the world economy would grow by 3.4% in 2020. In January 2021 the IMF estimated that world GDP in fact fell 3.5% last year. Given the world economy was estimated to generate \$87.8 trillion in 2019, the gap between the pre-pandemic growth path and the 2020 outcome implies a loss of potential output of \$6 trillion (with the actual output loss equal to half that amount). One study reported the combined monthly cost of the health and economic impact of the pandemic to the United States as being of the order of \$800 billion per month (Ahuja 2021, interpreting the findings of Cutler and Summers 2020). These stakes should be borne in mind when assessing the costs of the proposals discussed below.

4.1 Excess demand and attendant pressures on policymakers will not dissipate quickly

Demand for COVID-19 vaccines is likely to outstrip available supply for many months to come. This is not because of lack of ambition on the part of the private sector. Wouters et al. (2021) report that ten vaccine producers have set production targets of one billion or more doses this year. In November 2020 leading consultancy Aitfinity presented estimates that vaccine producers in 19 nations planned to produce 11.7 billion doses by end the end of 2021. Some caution clearly is warranted: The CEO of the same consultancy is also on record stating that COVID-19 vaccine producers had delivered 3% of the doses they had promised to date by the end of 2020.⁴⁶ If production of 11.7 billion doses is achieved, however, such an outcome would represent a dramatic expansion in the global production capacity for vaccines.

A survey by the World Health Organization to determine global production capacity for seasonal and pandemic influenza vaccines in 2019 noted that production capacity had changed marginally since 2015, rising from 1.47 billion doses to 1.48 billion doses (Sparrow et al. 2021). The same study reported that “potential maximum annual production capacity increasing from 6.37 billion to 8.31 billion doses,” a finding that the authors urged should be interpreted cautiously on the grounds that it was a best-case scenario reliant on several assumptions coming to pass. The authors argued it would take more than six months to repurpose existing production facilities to reach maximum production capacity. They also present a “moderate case scenario” where 4.15 billion doses are produced during 2021. Considering the vaccine production delays witnessed to date, the potential for further delays, and the pressures on

⁴⁶ See footnote 1 above.

policymakers from their populations for speedy inoculation and an end to limits on commercial and personal freedoms, this is a heady mix that is not necessarily conducive to sound decision-making.

4.2 Export controls on vaccines: A fragile status quo

At this time of writing, no COVID-19 vaccine producing country has implemented explicit export bans, quotas, or specified limits on shipments of final vaccines. However, the fact that many members of the Vaccine Club are also countries that have ordered large amounts of vaccines through advance purchase agreements implies that de facto the Vaccine Club may already have had the effect of restricting exports. Australia, Canada, European Union, Japan, South Korea, United Kingdom and the United States have collectively ordered some 4.3 billion vaccine doses, over three times their total population. Confirmed advance purchases of governments negotiated by Vaccine Club members jointly accounted for about 60 percent of all APAs as of end February 2021.⁴⁷ Some of the governments concerned have indicated that excess doses will be made available to other countries – supporting a shift from vaccine nationalism to vaccine diplomacy – the prospect of this scenario materializing depends on the ability and speed with which the Vaccine Club is able to ramp up global supply.

This factor will also play an important role in determining whether the forbearance on use of explicit export restrictions will last – i.e., whether the web of cross-border supply chain linkages in COVID-19 vaccine production create strong enough incentives for governments to resist any temptation for short-term gains at the expense of trading partners in the year ahead. We have both a theoretical and empirical response to this question.

Conceptually, there is a temptation to consider the parallel with the (lack of) resort to nuclear weapons during the Cold War, when the threat of mutually assured destruction (referred to often as the “Balance of Terror”) is said to have prevented a worldwide confrontation between the United States and the USSR. The parallel contemporary logic runs as follows: a government tempted to publicly halt vaccine exports could become the target of retaliation within the Vaccine Club assuming the other producers collectively sanction the deviator by cutting them off from supplies of necessary vaccine ingredients and the final vaccine itself.⁴⁸ To date, there is no evidence of a tacit, let alone explicit, enforcement accord of this nature among the Vaccine Club. The parallel to the Cold War largely breaks down because there are more than two members of the Vaccine Club.

Even if the Vaccine Club governments refrain from disrupting vaccine shipments to each other, they face no disincentive to restrict exports to nations outside of the Club. Maintaining such cooperation within the Vaccine Club is not the basis of a solution to the global health and economic imperatives noted above. Non-club members might search for goods of significant value that they export to the Club and consider restricting shipments of those. The systemic damage to the world trading system could then compound. As Evenett and Winters (2020) have argued, once governments fear that sourcing from abroad is unreliable on account of (actual or potential) foreign export curbs the incentive to liberalize imports is diminished. Restraint on resort to export controls is an overlooked pre-condition for reciprocal import liberalization of goods deemed essential. As a matter of incentives, then, the logic of deterrence within the Vaccine Club would inflict collateral damage, some of which will ricochet back on to the Club members’ export interests.

⁴⁷ Note that some of these orders are for vaccines that have not yet been approved and may not prove to be effective. Other major APAs were concluded by COVAX (1,120 million doses) and the African Union (670 million doses). These figures are based on data reported by the Duke Global Health Innovation Center. See <https://launchandscalefaster.org/covid-19>, last updated March 1, 2021.

⁴⁸ If this logic of mutually assured destruction applied with force to vaccine exports then it would have one important implication for the design of multilateral trade rules. A ban on export controls would be counterproductive under these particular circumstances.

In understanding the current export policy stance of the COVID-19 vaccine producers, this game-theoretic logic falls short. In fact, the evidence presented in Section 2 above shows that the actual outcome within the Vaccine Club is not a complete disavowal of export limits on vaccines, but rather resort to murkier forms of export controls. Such murkiness may involve advance purchase agreements, delays or curbs on a fraction of a nation's shipment. The murkiness renders perfect monitoring of trading partner's policy choice impossible and is a recipe for instability.

As Green and Porter (1984) showed long ago, in the presence of imperfect monitoring, decision-makers focus on what outcomes can be observed (e.g., arrival or non-arrival of vaccine shipments) and use that to update their assessment of the choices of other players. When observed outcomes are so dire, the inferred probability of malfeasance by another player is revised up to a level that triggers retaliation.⁴⁹ On this logic, unanticipated delays and hold ups in production in one nation may reduce vaccine shipments to others that induce retaliation by trading partners.

On this view, so long as there is the potential for sufficiently large disruption to final vaccine production or to supplies along the vaccine supply chain, there is always a positive probability that some export curb will be introduced in the future. What may appear now as restraint need not last. If we have captured the essence of the incentives facing governments today, then the status quo is fragile and the risk of export controls being copycatted across the Vaccine Club cannot be discounted. Put differently, in the absence of actions to address excess demand for COVID-19 vaccines, neither national self-interest, nor existing multilateral trade rules, nor the exhortations of the G20 or other groupings offer protection against policy-induced disruption to the global distribution of COVID-19 vaccines. In what follows we discuss measures that could be taken to reduce the prospect of this negative scenario materializing.

4.3 De-risking production capacity investment is the priority

Our starting point is that the members of the Vaccine Club are less likely to curb COVID-19 vaccine exports the more vaccines are produced in the first place. On the face of it, this may seem a rather obvious proposition, but it touches upon a factor little remarked upon: the incentives faced by the private sector to expand vaccine production capacity. While discussions of pharmaceutical supply are often polarized, a balanced approach requires recognition of both the global health imperatives and the incentives facing companies to ramp up production capacity.

The needed capacity investments are sizeable and very risky. For example, public statements by Pfizer reveal that it has invested some €500 million in recent years in its production facility in Puurs, Belgium. Admittedly, some of this expenditure predates the pandemic and targeted vaccines unrelated to COVID-19, but these are not trivial sums to ask shareholders to commit.⁵⁰

Moreover, the one-off nature of many pandemic vaccines—that is, once the vaccine shot is provided there is no follow up treatment—creates another risk: the recovery on any production costs and investment in production capacity must occur during a relatively short period of time. Under these circumstances there is no potential for future revenues, although there may be other payoffs in terms of know-how acquired during vaccine development.

⁴⁹ In this context one can view the government's decision problem as a choice of what percentage of vaccine produced in their jurisdiction is diverted (in a non-transparent or hidden manner) from foreign buyers to local needs. The amount of vaccines produced in each nation would not be deterministic but subject to random factors, capturing the impact of unanticipated, idiosyncratic production shocks. A more elaborate approach would have vaccine producers choosing their output levels and governments deciding what share of that output can be shipped abroad.

⁵⁰ See also the remarks of Mr. Adar Poonawalla, Chief Executive Officer of the Serum Institute of India, on the risks his organization decided to take in the second quarter of 2020 in scaling up production before knowing which of the COVID-19 vaccines, if any, would be eventually approved (March 1, 2021 podcast by *The Economist*: <https://www.economist.com/podcasts/the-jab-a-new-podcast-from-the-economist>).

Worse, uncertainty over the scale of a pandemic implies that total revenues ultimately earned may well fall short of outlays. This is not a theoretical conjecture. One by-product of the 2009 and 2010 H1N1 pandemic being milder than original expected was that several European governments cancelled vaccine orders. That governments were entitled to cancel some orders is not contested; what is relevant to the argument being developed here is that the revenues of the vaccine producers fell short of expectations.⁵¹ In light of that experience, Mr. Richard Hatchett, the Chief Executive Officer of the Coalition for Epidemic Preparedness Innovations (CEPI) is reported to have remarked that drug manufacturers “have very clearly articulated that ... the current way of approaching this — to call them during an emergency and demand that they do this and that they reallocate resources, disrupt their daily operations in order to respond to these events — is completely unsustainable.”⁵² This remark is also useful in highlighting the reallocation of scientific talent and management expertise necessary to prepare a vaccine at speed. It is not only a matter of the financial outlay to establish a new production facility or to expand an existing one.

As noted earlier, there are other policy-induced risks that rational private sector decisionmakers factor into their calculations. Risk assessments on potential investments in jurisdictions will take into account whether governments have a track record of nationalist trade policy. If there is a possibility, based on past behavior, that a government may ban exports of vaccines, expected revenue streams within that jurisdiction alone determine the commercial viability of any capacity investments. Moreover, to the extent that foreign governments are likely to ban exports of vital vaccine ingredients this further adds to the riskiness of any investment in production capacity. The absence of meaningful multilateral restraints on export curbs and the widespread resort to export controls on medical goods and equipment by governments in 2020 (Evenett et al. 2021) suggests that any properly conducted assessment of risks and financial viability will take such policy-induced risks into account.

Another risk-enhancing factor relevant to the COVID-19 pandemic is that this is the first time that vaccines were successfully developed using mRNA technology. Given the lack of experience in large scale production of vaccines based on this technology, plausible concerns about production delays, production oversight and quality control, backlash from governments, etc. may also weigh on private sector decision-makers.

Reducing the risks associated with expanding production capacity is clearly a priority. To some degree governments have understood this, with some public authorities partially financing the building of new facilities. However, more could be done. The trade policy dimension has already been alluded to. More generally, steps taken to limit all forms of policy-induced disruption to the supply of ingredients, assuring availability of key qualified personnel (including through their cross-border movement), as well as internal and cross-border trade facilitation would be valuable.

That variants of the original COVID-19 strain have arisen could transform the commercial calculus associated with investing in new production capacity. If COVID-19 and its variants become a longer-standing—and, in the limit, permanent—feature, then regular “booster” jabs will be needed for much of the world’s adult population. Should this come to pass then instead of COVID-19 vaccine development being a “one-off” event with a burst of revenue earned for a few years, the production and distribution of booster jabs creates a multi-year revenue stream and thus more likely to support a higher level of production capacity.

Given that funds will need to be raised at the global level to ensure developing countries can gain access to these booster jabs, developing a multi-year understanding between governments, the private

⁵¹ See these press reports in *The Guardian* and the *Wall Street Journal*, respectively, <https://www.theguardian.com/society/2010/apr/06/swine-flu-vaccine-stockpile-glaxosmithkline> and <https://www.wsj.com/articles/SB126335633266727463>.

⁵² For other telling remarks and examples of the risks involved, see <https://www.statnews.com/2018/01/11/vaccines-drug-makers/>

sector, and the international organizations involved would seem a natural development. Such an initiative could also reduce the likelihood of coordination failures, which compound the risks identified above.

A concern with uncoordinated de-risking of investments in vaccine production capacity is the possibility that too much capacity is created. Recall, however, the health-related and economic costs summarized earlier that are being borne now. If anything, the costs of over-expansion are almost certainly smaller than the harm done by under-expansion. Suppose over-expansion resulted in over-production of 12 billion doses. At an estimated cost of \$20 per dose, this would involve a “waste” of \$240 billion. That appears to be a lot of money until one recognizes that it constitutes approximately 0.25% of world GDP.⁵³

4.4 Facilitating matches between vaccine developers and vaccine manufacturers

Strengthening the incentives to augment vaccine production capacity is not the only way to expand the production of COVID-19 vaccines. Repurposing existing vaccine production capacity is another option as is matching contract vaccine manufacturers with vaccine developers.⁵⁴ If the estimates of “potential maximum annual production capacity” cited above are close to the mark, then there is considerable room for repurposing existing vaccine production facilities (Sparrow et al 2021).

High quality information available to facilitate matches between vaccine developers and manufacturers does not appear to be readily available. There appears to be no established mechanism that tracks entry and exit from vaccine production, at the firm level or the plant level. Instead, in preparing their estimates of global vaccine production capacity, WHO officials relied on voluntary responses to a survey instrument sent to 36 vaccine manufacturers (Sparrow et al. 2021). Seven manufacturers did not complete the survey but did confirm their business operations continued and reported their production capacity. A further five firms did not reply at all. This is clearly unsatisfactory and more transparency about final vaccine production and the associated value chain is needed. As sensitive commercial information is involved a trusted collector and aggregator of information will be required.

Some matches have occurred that provide valuable lessons. The Bill & Melinda Gates Foundation has funded the production of the AstraZeneca and Novavax vaccines by the Serum Institute of India and the production of the Johnson & Johnson vaccine by Biological E Ltd, another producer in India. Moreover, AstraZeneca is said to be working with 25 manufacturing facilities in 15 different nations, most likely through licensing arrangements (The Economist 2021b).

The identification of qualified licensees is key. Vaccines are not only subject to regulatory approval and associated testing, monitoring, and reporting requirements, so are the production processes that are used to generate them. Vaccine production is complex and requires expertise (a skilled workforce) and specialized equipment and infrastructure. Production, storage, and distribution logistics are subject to extensive certification to ensure defined good manufacturing practices are used. Compliance with high standards requires rigorous quality controls, complemented by regulatory inspections that need to be accepted (recognized) by importing countries. Recognition is conditional on firms and the countries

⁵³ Castillo et al (2021) emphasize the difference between private and social returns from expanding vaccine production capacity. They estimate “that installed capacity for 3 billion annual vaccine courses has a global benefit of \$17.4 trillion, over \$5800 per course. Investing now in expanding capacity for an additional annual 1 billion courses could accelerate completion of widespread immunization by over 4 months, providing additional global benefits of \$576 to \$989 per course. This dwarfs prices of \$6 to \$40 per course seen in deals with vaccine producers, indicating the wide gap between social and commercial incentives” (Castillo et al. 2021).

⁵⁴ As more biotech companies focus on the development of vaccines and other treatments, the demand for contract manufacturing increases. Such biotech companies are essentially eschewing the vertically-integrated business models of many incumbent vaccine developers.

where production occurs having systems that are trusted and perceived to be effective in ensuring that producers satisfy established international production standards for safety, quality control, contamination, etc.

For all these reasons, numerous experts have emphasized the need for knowledge transfer that is not contained in patents. This includes tacit knowledge about manufacturing processes that is often context-specific and, by construction, difficult to codify (Nicholson Price, Rai, and Minssen, 2020). Mandating such deliberate cooperation is infeasible. Furthermore, meeting the production process-related safety and quality standards will take time—repurposing existing vaccine production facilities cannot happen on demand.

What is needed is more cooperation between the private sector. Competition policy constraints are not a factor impeding cooperation between firms in the vaccine supply chain. Jenny (2020) notes that in the spring of 2020 competition authorities in major jurisdictions including the EU and the US issued guidance on cooperation among firms, stressing that collaboration is permitted if the aim is to expand output and not to increase prices.

In principle, such inter-firm collaboration could be constrained by worries by the holders of intellectual property rights regarding the associated licensing of production and potential competition policy liability. In a recent interview, Bill Gates noted that such rights were not a constraint and the companies involved cooperated effectively to build production capacity.⁵⁵ The more pressing challenges lie elsewhere.

4.5 Policy actions to ramp up vaccine production and its distribution through trade

We propose four inter-related areas for action to support the ramp up of the production of vaccines to meet pressing demand worldwide.

Avoid export restrictions: Implicit and explicit restrictions on exports of vaccines create a chilling effect on investments in new and repurposed vaccine production capacity. Even the threat of such restrictions will distort private sector location decisions, limit the realization of economies of scale, and hold back our collective ability to boost vaccine production. Such restrictions should be avoided. Given the many ways in which exports of vaccines can be curbed, some of which are very subtle, action is needed to improve the monitoring of government policy so as to provide real-time information and to go beyond traditional export curbs.

Enhance transparency of global supply capacity and frictions: Developments in early 2021 have shown how adverse political dynamics are induced by the absence of credible information sharing between governments, vaccine manufacturers, and their suppliers. In a fast-moving situation such as this, there will be inevitable hold-ups and other problems as the vaccine value chain is flexed. Private sector malfeasance is not behind every production or delivery delay—even so, private sector actors must be keenly aware of the acute pressures faced by political decision-makers. No matter its novelty, generating greater transparency along the vaccine supply chain will build confidence.⁵⁶

Capacity investment: Recognizing the significant commercial risks associated with making rushed investments in vaccine production capacity, and in repurposing existing capacity, governments should review every aspect of their trade and procurement policies so as to reduce disincentives to invest. In a global pandemic, time-to-delivery is arguably as important as unit price paid; this is not the best time to

⁵⁵ Kara Swisher, Innovation, Not Trees. How Bill Gates Plans to Save the Planet, *New York Times*, 15 February 2021. <https://www.nytimes.com/2021/02/15/opinion/sway-kara-swisher-bill-gates.html>

⁵⁶ In a 4 March 2021 webinar, referring to possible US restrictions of exports of key vaccine production inputs, Adar Poonawalla, the CEO of the Serum Institute of India, called for “discussion with the Biden administration to explain to them there’s enough to go around.” <https://www.bloomberg.com/news/articles/2021-03-04/largest-vaccine-maker-warns-of-delays-as-u-s-prioritizes-pfizer>.

prize “value for money” public procurement goals over everything else. Taking due account of attendant moral hazard concerns, state support for capacity investment/repurposing should be offered. Such support should be transparent and should not include strings attached that disrupt shipments of vaccines to buyers abroad.

Clearing house to support public-private sector cooperation: In normal times there is significant rivalry between vaccine researchers, manufacturers, and their suppliers, consistent with the competition law objectives of many nations. However, as leading competition agencies have recognized, during a global pandemic certain types of cooperation among the private sector are valuable. The legacy of intense competition among pharmaceutical and biotech companies has also hampered the matching of COVID-19 vaccine creators to firms, some of whom may ordinarily be rivals, which have spare production capacity. A clearing house needs to be established to bring together these private sector parties. Qualified parties with manufacturing capacity could register their potential willingness to supply for defined time periods. Approved vaccine creators should specify their needs and the knowledge transfer they are willing to provide to potential contract manufacturers. Those running the clearing house would monitor the bottlenecks reported by the private sector participants and identify measures governments can take to support the development and strengthening of the capabilities needed to manufacture and distribute vaccines at scale.⁵⁷ In turn, support for such capability development in low- and middle-income countries should be provided through aid programmes and technical assistance.

Many of the international organizations with the expertise, the mandates and strong interest in ramping up the COVID-19 vaccine roll-out are found in Geneva. Creating a clearing house to help address the current emergency may also contribute to learning about how intergovernmental organizations can support public-private policy partnerships to address global crises. Better communications and cooperation between the public and private sector is needed more generally to provide global public goods, be it sustaining an open rules-based trading system, combatting global climate change or attaining the sustainable development goals.

5. Concluding remarks

Like other vaccines, those developed to tackle COVID-19 are produced in a relatively small number of countries. So are the ingredients of these vaccines and, to a large extent, the medical kit needed to distribute them. This paper marshals evidence to demonstrate the existence of a COVID-19 Vaccine Club and, more importantly, draws out its implications for the global distribution of vaccines, a pressing societal imperative given the significant loss of life, millions pushed into poverty as a result of the pandemic, and other threats to livelihoods witnessed around the world.

Once again, in the first two months of 2021 governments resorted to restrictive trade policies following high-profile failures in other areas of government policy, such as government procurement policies.⁵⁸ In March 2021 Italy became the first EU member state to invoke the EU vaccine export control regime, blocking a shipment of 250,000 Oxford/AstraZeneca Covid-19 vaccines destined for Australia.⁵⁹ The US reportedly has restricted exports of certain vaccine inputs, including bags and filters.⁶⁰ Aside from overt restrictions, some governments have taken murkier measures that effectively delay or restrict exports. Our analysis of the incentives created by the Vaccine Club imply that the status quo is unstable, susceptible to policy over-reaction to cross-border shipment delays. If COVID-19

⁵⁷ Findlay and Hoekman (2021) discuss design elements of such public-private platform and related literature.

⁵⁸ Hoekman et al. (2021) find a statistically significant association between characteristics of national procurement regimes and the use of trade policies during the first nine months of the COVID-19 pandemic.

⁵⁹ The government justified the action on the basis that Australia was not a “vulnerable country.” See <https://www.ft.com/content/999f20d3-105f-4b15-b382-8f5ef9882e73>.

⁶⁰ <https://www.bloomberg.com/news/articles/2021-03-04-largest-vaccine-maker-warns-of-delays-as-u-s-prioritizes-pfizer>.

vaccines are equitably distributed worldwide without a significant outbreak of Vaccine Nationalism, it will be by luck not design.

In the rush to sign advanced purchase agreements for doses of COVID-19 vaccines too little attention was given to the fact that vaccines can only be distributed after they have been produced. If you want doses, build factories. Expansion in production capacity will be affected by policy-induced risks faced by vaccine manufacturers thinking of establishing new or scaling up existing production capacity. De-risking investments in supply capacity is a vital next step in ramping up the production of COVID-19 vaccines. The costs of doing too much on this front pale compared to those of doing too little.

Promoting greater transparency along the COVID-19 vaccine value chain is needed to attenuate evident distrust between governments and between governments and the private sector. Better information on available vaccine production capacity worldwide would facilitate matches between vaccine developers, potential vaccine producers, and funding agencies. Pertinent information of this nature is a global public good. To that end, a clearing house needs to be established as soon as possible. COVID-19 is unlikely to be the last global pandemic. The institutions, trust, and practices developed in the year ahead will go a long way to shaping how both the public sector and the private sector will respond to the next systemic threat to public health.

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Appendix Table 1: List of vaccine ingredients and specialist distribution items

EU CN code	Ingredient/product name	Type of Ingredient
29061310	cholesterol	Key Ingredients
29232000	1,2-dimyristoyl-rac-glycero3-methoxypolyethylene glycol-2000	Key Ingredients
29239000	(4-hydroxybutyl)azanediylbis(hexane-6,1-diyl)bis(2-hexyldecanoate)	Key Ingredients
38220000	mRNA	Key Ingredients
39072011	2 [(polyethylene glycol)-2000]-N,N-ditetradecylacetamide	Key Ingredients
25010099	sodium chloride	Other Ingredients
28272000	potassium chloride	Other Ingredients
28273100	magnesium chloride hexahydrate	Other Ingredients
28352200	dibasic sodium phosphate dihydrate	Other Ingredients
29152100	acetic acid	Other Ingredients
29152900	sodium acetate	Other Ingredients
29221900	Tromethamine	Other Ingredients
29224985	disodium edetate dihydrate	Other Ingredients
29232000	SM-102 (heptadecan-9-yl 8-((2-hydroxyethyl) (6-oxo-6-(undecyloxy) hexyl) amino) octanoate)	Other Ingredients
29332990	L-histidine / L-histidine hydrochloride monohydrate	Other Ingredients
31056000	monobasic potassium phosphate	Other Ingredients
34021300	polysorbate 80	Other Ingredients
40151905	Nitrile Glove	Vaccine Distribution
90183100	Syringes	Vaccine Distribution
70179090	Borosilicate vials	Vaccine Distribution

Source: Ingredients sourced from official regulatory statements concerning the AstraZeneca-Oxford, Moderna, and Pfizer-BioNTech vaccines. Vaccine distribution items identified from specialist industry media sources.

Appendix Table 2: Top-10 exporters of key ingredients to vaccine producers

Source/Destination	United Kingdom	Argentina	Canada	Switzerland	Brazil	Australia	European Union	Russian Federation	Japan	Korea, Rep.	United States	China	India	Total
Vaccine Producers	98,7	97,9	97,7	95,6	95,4	93,6	91,6	91,0	89,0	87,2	84,2	76,9	76,4	88,3
United States	20,5	44,1	63,2	23,8	44,1	47,4	52,6	15,6	33,2	29,9		34,5	23,7	32,9
EU27	71,1	30,9	12,5	58,3	26,0	25,3		51,0	29,5	22,0	38,3	21,4	27,4	23,9
United Kingdom		4,7	7,0	5,3	3,5	5,8	16,6	8,6	9,5	3,5	15,1	4,2	2,3	10,2
Japan	2,7	1,6	7,7	5,4	0,9	3,2	9,3	3,6		9,1	7,6	8,7	2,4	6,9
China	1,8	7,2	3,0	1,1	8,3	4,5	4,1	7,9	10,7	20,4	7,1		11,1	5,4
Other Producers	2,6	9,4	4,2	1,7	12,7	7,5	9,0	4,2	6,1	2,4	16,2	8,1	9,6	8,9
Other Countries	1,3	2,1	2,3	4,4	4,6	6,4	8,4	9,0	11,0	12,8	15,8	23,1	23,6	11,7
Singapore	0,6	0,2	1,4	0,7	2,7	4,7	2,9	0,7	5,9	4,6	12,3	11,7	13,1	6,2
Saudi Arabia	0,0	0,0	0,0	0,0	0,0	0,0	1,1	4,7	0,3	1,6	0,0	4,4	5,0	1,3
Thailand	0,0	0,1	0,0	0,0	0,0	0,6	0,1	0,0	2,3	2,4	0,1	5,6	2,1	1,1
Norway	0,1	0,1	0,2	2,6	0,1	0,1	1,5	0,1	0,2	0,2	1,7	0,3	0,2	1,0
South Africa	0,0	0,1	0,1	0,0	0,0	0,2	0,2	0,0	0,1	0,0	0,0	0,0	0,0	0,1
Rest of the World	0,6	1,6	0,6	1,1	1,8	0,8	2,6	3,5	2,2	4,0	1,7	1,1	3,3	2,0

Source: World Integrated Trade Solution (WITS) trade data for 2017, 2018 and 2019 for the key vaccine ingredients listed in Appendix Table 1.

Appendix Table 3: Share of imports from other vaccine producers, by product

		Argentina	Australia	Brazil	Canada	China	EU27	India	Japan	Korea, Rep.	Russian Federation	Switzerland	United Kingdom	United States
Key Ingredients	1,2-dimyristoyl-rac-glycero-3-methoxypolyethylene glycol-2000	99,8%	92,5%	94,3%	95,6%	97,2%	85,3%	80,8%	94,4%	97,1%	85,5%	92,8%	96,6%	89,0%
	2 [(polyethylene glycol)-2000]-N,N-ditetradecylacetamide	94,9%	87,4%	90,4%	99,2%	53,6%	75,7%	61,2%	77,9%	73,3%	86,3%	98,0%	99,2%	86,5%
	(4-hydroxybutyl)azanediyl)bis(hexa...	99,7%	97,7%	99,5%	98,7%	97,8%	99,3%	96,5%	98,7%	99,7%	97,1%	99,6%	99,8%	92,3%
	cholesterol	99,7%	99,5%	97,7%	99,9%	93,2%	99,2%	98,9%	93,3%	99,6%	99,8%	94,7%	98,4%	99,0%
	mRNA	98,8%	94,0%	98,6%	97,2%	92,1%	93,9%	89,1%	92,8%	89,9%	94,6%	94,7%	98,6%	83,5%
Other vaccine ingredients	acetic acid	98,9%	62,8%	100,0%	99,6%	37,8%	88,2%	39,2%	88,2%	86,5%	78,7%	97,5%	98,4%	54,6%
	disodium phosphate dihydrate	99,4%	81,3%	84,1%	92,7%	98,4%	75,8%	97,8%	66,0%	99,0%	97,0%	100,0%	98,3%	90,6%
	disodium edetate dihydrate	97,7%	98,9%	98,8%	98,6%	95,1%	15,2%	96,7%	31,6%	98,5%	96,0%	99,9%	98,7%	23,7%
	L-histidine / L-histidine hydrochloride monohydrate	98,9%	57,2%	97,8%	91,3%	88,1%	94,4%	98,9%	99,4%	98,6%	96,7%	97,9%	95,7%	95,7%
	magnesium chloride hexahydrate	71,4%	83,0%	94,8%	84,8%	89,6%	42,8%	92,3%	81,6%	99,2%	99,8%	97,2%	79,0%	42,8%
	monobasic potassium phosphate	43,1%	60,3%	87,0%	67,9%	60,0%	22,0%	77,6%	89,3%	68,2%	74,4%	96,1%	82,5%	43,6%
	polysorbate 80	92,0%	70,8%	88,4%	96,9%	67,6%	95,9%	80,8%	71,4%	91,1%	96,6%	99,4%	98,6%	82,4%
	potassium chloride	87,0%	97,1%	72,9%	93,0%	99,2%	82,5%	58,1%	89,8%	99,9%	74,2%	96,1%	96,5%	56,3%
	sodium acetate	99,1%	97,1%	98,7%	99,1%	66,8%	98,0%	99,7%	99,0%	99,9%	98,9%	99,9%	99,6%	97,8%
	sodium chloride	18,5%	47,2%	31,3%	45,0%	94,9%	33,9%	51,3%	60,6%	86,5%	4,7%	92,5%	81,2%	43,4%
Vaccine distribution	Tromethamine	99,6%	91,0%	98,0%	98,2%	97,3%	91,4%	92,6%	99,9%	99,9%	49,8%	93,9%	99,8%	95,8%
	Borosilicate vials	96,8%	95,1%	90,1%	88,1%	97,6%	96,1%	84,9%	95,7%	96,4%	94,6%	98,5%	98,8%	79,5%
	Nitrile Glove	9,4%	8,2%	6,7%	19,6%	2,8%	11,9%	1,7%	6,7%	7,9%	32,3%	25,7%	25,1%	12,7%
	Syringes	71,8%	77,9%	67,2%	91,6%	65,7%	83,1%	60,9%	68,4%	83,5%	90,4%	98,3%	93,8%	64,4%

Source: World Integrated Trade Solution (WITS) trade data for 2017, 2018 and 2019 for the 20 products listed in Appendix Table 1.

