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How COVID-19 Medical Supply Shortages Led to Extraordinary Trade and Industrial Policy

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Early in the COVID-19 pandemic, a global shortage of hospital gowns, gloves, surgical masks, and respirators caused policymakers globally to panic. China increased imports and decreased exports of this personal protective equipment, removing supplies from world markets. Shortages led to European Union and US export controls as well as other extraordinary policy actions, including a US effort to reserve supplies manufactured in China by a US-headquartered multinational. By April 2020, China's exports had mostly resumed, and over the rest of the year its export volumes surged. But China's export prices also skyrocketed and remained elevated through 2020, reflecting severe and continued shortages. This paper explores these and other government actions, such as US trade war tariffs and US industrial policy in the form of over $1 billion of subsidies to build out its domestic personal protective equipment supply chain, as well as potential lessons for future pandemic preparedness and international policy cooperation.

Key words: COVID-19, export restriction, industrial policy, personal protective equipment, supply chain, tariff

JEL codes: F13

1. Introduction

The early days of the COVID-19 pandemic brought fear and panic to the world for many reasons. A global shortage of basic personal protective equipment (PPE) was an important one. Nowhere to be found were hospital gowns and gloves, surgical masks and respirators, goggles, and face shields. Health care workers needed them in higher volume to take care of the unending surge of sick patients. But suddenly so did many others whose jobs put them in close proximity to coworkers, customers, or vulnerable populations.

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For policymakers in the USA and Europe, the PPE shortage of early 2020 was stupefying. Trade, especially with China, has been accused of being a major source of the problem. Policymakers have launched investigations into how things went so wrong, demanding change as a result. For example, shortly after assuming office in January 2021, President Joe Biden issued an Executive Order, saying, "this will never happen again in the United States, period. We shouldn't have to rely on a foreign country—especially one that doesn't share our interests or our values—in order to protect and provide for our people during a national emergency."[1]

This paper clarifies what is known about trade in PPE during the pandemic for China, the European Union (EU), and the USA. It also explores a series of extraordinary policies affecting PPE during the pandemic, including trade war tariffs, export controls, directives that multinational corporations prioritize American sales from their foreign subsidiaries, and new US industrial policy – including over $1 billion of subsidies to expand capacity along its domestic PPE supply chain. The present paper describes implications for post-pandemic policy and international cooperation, and explains where additional data collection and research efforts are needed.

2. Background on PPE Production and Trade

PPE includes a range of items.[2] The focus here is on surgical masks and respirators as well as "protective garments" – a broad category that includes hazmat suits, as well as some hospital gowns. The analysis also touches on hospital gloves, as well as goggles, face shields, and medical shoe coverings.[3]

On the demand side, consumption of PPE can be characterized by large positive externalities. The social benefit of wearing PPE during the pandemic was much larger than the (substantial) private benefit, given both the devastating health effects of the disease and its transmissibility via airborne particles. For example, one back-of-the-envelope estimate indicated that the social value of each cloth mask worn by the American public was $3000–$6000, whereas each N-95 respirator worn by a hospital worker could "easily be more than a million dollars" (Abaluck *et al.*, 2020). The divergence between private and social benefits is one motivation for policy intervention.

On the supply side, the USA and EU had pre-pandemic domestic manufacturing for some items, but product-level production data are not yet publicly available to clarify how much. However, the existence of some local production can be inferred from a variety of sources.

For the EU, intra-EU trade (e.g. France exporting PPE to Italy) is possible only with domestic production. Furthermore, in a March 2020 policy announcement (described below), the European Commission (2020a) stated that "production of personal protective equipment such as mouth protection masks in the Union is currently concentrated in a limited number of Member States, namely the Czech Republic, France, Germany, and Poland."

Another source of production information is company announcements; 3M and Honeywell, for example, reported expansions to their N-95 respirator manufacturing

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product lines during the pandemic (3M, 2020a; Honeywell, 2020). A US International Trade Commission investigation in mid-2020 also described anecdotal evidence from industry interviews (United States International Trade Commission [USITC], 2020).

For some products, however, there was apparently little pre-pandemic domestic production, at least in the USA. John Polowczyk, who led the US government's PPE Supply Chain Task Force from March 15 through November 2020, said "we made about 500 million nitrile gloves in America, pre-pandemic. [During the pandemic] we were using 1.8 billion a week. 500 million a year for manufacturing is not like you just get to put on another shift and make more gloves."[4]

Changes in the US domestic regulatory environment were also likely to have impacted PPE availability. For example, one agency (the National Institute for Occupational Safety and Health [NIOSH]) regulated the N-95 respirator for industrial use and another (the Food and Drug Administration [FDA]) regulated it for medical use. Before the pandemic, more than 95% of American N-95 respirator use was in industrial rather than medical settings, to protect workers from dust, chemicals, or other hazardous airborne particles (USITC, 2020; p. 89). (This use likely declined periodically throughout 2020, when lockdowns emerged). In March 2020, the FDA facilitated product availability by authorizing emergency use of NIOSH-approved N-95 respirators in medical settings.

However tempting, it is impossible at this stage to definitively attribute changes in trade flows during the pandemic to policy changes. That is because multiple determinants of domestic supply and demand – and thus imports and exports – were changing alongside many of the policy changes described next. As an example, for a net exporting country of PPE, increased demand for PPE because of a domestic coronavirus outbreak and decreased supply due to an industrial lockdown would each have the same impact – reducing export volumes – as a newly imposed export-restricting policy. Alternatively, relaxing the stringency of the regulatory environment might increase both domestic and foreign supply of N-95 respirators, but without knowing which was bigger, such a change would have an uncertain net effect on imports. In addition to trade data and an economic model, a rigorous assessment requires extremely detailed data on the domestic production and consumption of PPE before and during the pandemic, and these data are not yet publicly available at the level of disaggregation needed.

The following sections present stylized facts on PPE trade flows in light of several major policy actions, although even that effort is confounded by measurement challenges. For example, the most precisely defined pre-pandemic PPE product classifications often also included unrelated items in the tariff schedule (in examining changes over time, the assumption is that there was little pandemic-related change in demand for or supply of those other items). Furthermore, volumes are often measured in weight (e.g. kilograms), not more familiar units often referenced by policymakers, such as number of masks.

Before the pandemic, China was the top exporter of most of the products considered in this analysis (Figure 1). The exception was hospital gloves (Malaysia). The USA and EU applied relatively low most favored nation (MFN) import tariffs on these products.[5]

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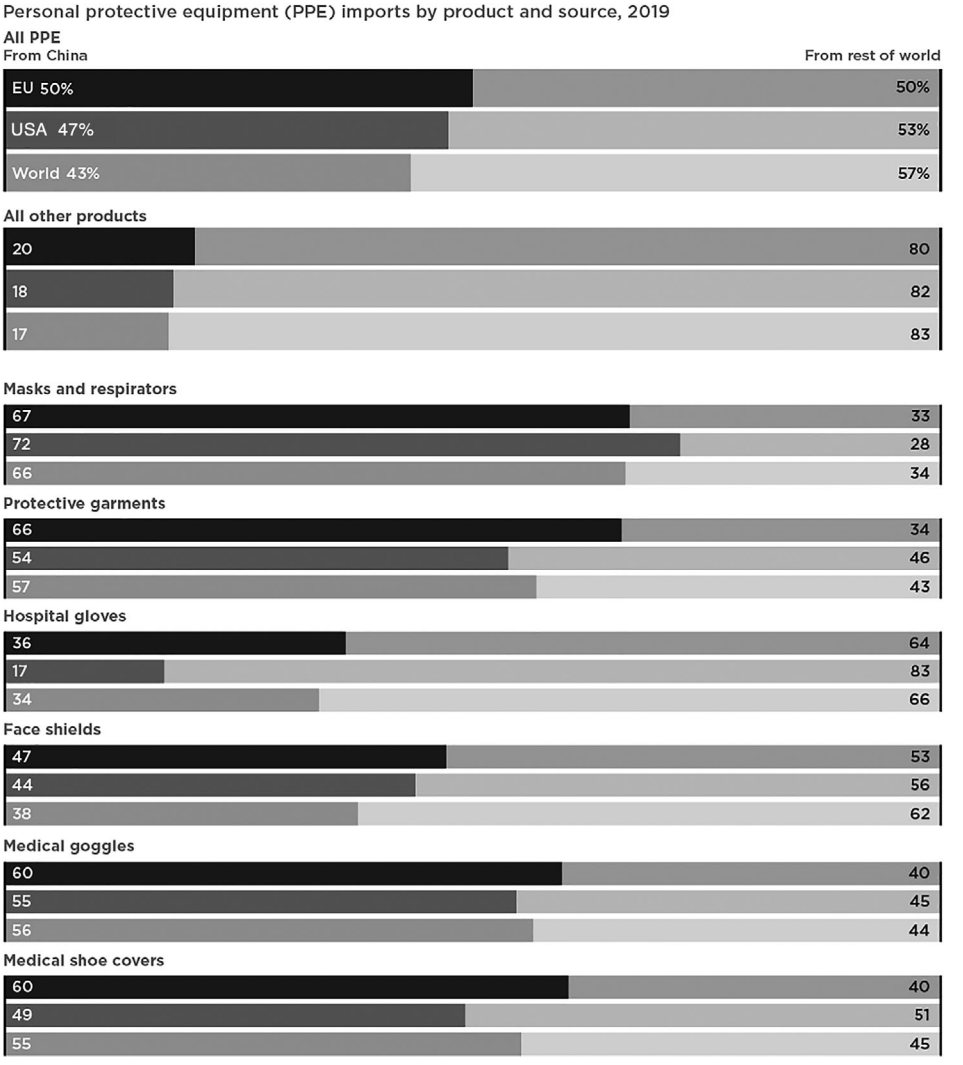

Figure 1 European Union (EU), USA, and world imports of personal protective equipment from China, 2019.

Source: Constructed by the author with data from US Census, Eurostat, and UN Comtrade.

Note: For the European Union, extra-EU imports only.

Supporting Information Table S1 provides a complete timeline of events discussed in the next three sections.

3. What Happened in China

In late December 2019, a novel coronavirus was discovered in the city of Wuhan in China's Hubei province. A month later, on January 30, 2020, the World Health

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Organization (WHO) declared the COVID-19 outbreak a Public Health Emergency of International Concern. The Chinese government locked down parts of the economy, imposed travel restrictions, and even built entirely new hospitals from scratch. China found itself in desperate need of PPE.

International markets at the time worked as expected for most products: China imported more, and exported less (Figure 2a).[6] The change in net exports for each product was dominated by China's reduction in exports. The magnitude of the decline in net exports in February 2020 dwarfed the similar seasonal reduction in 2018 and 2019, associated with the Chinese Lunar New Year (Figure 2b). Cumulating trade volumes over the first 3 months of 2020, China's exports of PPE were significantly lower than in the first quarter of 2019.[7] For example, export volumes were 12.5% lower for masks and respirators and 22.1% lower for protective garments.

Much of the decline in China's exports of protective garments, for example, can be traced directly to Hubei, the source of the outbreak – and of more than one-third of the country's total exports of protective garments in 2019. Hubei's export decline accounted for roughly 75% of the drop in China's total exports of protective garments in the first quarter of 2020.[8] For other products, the link between the COVID-19 shock and export concentration was less tight. For example, Zhejiang, Guangdong, Shanghai, and Jiangsu were the combined source of three quarters of China's exports of masks and respirators, products that also saw a significant export decline in the first quarter of 2020. While media reported China had also restricted PPE exports, the Chinese government denied the allegations (e.g. Hui, 2020).

By early March, the Chinese government announced a significant expansion of domestic PPE production. On March 6, the State Council (2020) indicated that China's daily output of protective clothing had increased from "less than 20,000 pieces in the early stage of the epidemic to the current 500,000 pieces. N-95 masks reached 1.6 million from 200,000, and ordinary masks reached 100 million."

China's net exports regained pre-pandemic (monthly) levels for most products by April 2020. Indeed, that month's mask and respirator exports were nearly double pre-pandemic levels, and exports of protective garments were 60% higher. Export volumes for most products remained elevated through the remainder of 2020.

But even this significant scaling up of export volumes was insufficient to satisfy exploding global demand (Figure 2b), and Chinese export prices (unit values) for most products rose even more than the volume increase. For masks and respirators, they were over 700% higher in April 2020 than before the pandemic, even with the doubling of volumes, and for protective garments they were more than 500% higher. For most products, export prices remained elevated through the end of 2020.

PPE scarcity and exploding prices generated a separate problem: counterfeit products. On April 10 the Chinese government responded by establishing a new system of quality controls for exports of various medical supplies, including nine PPE products.[9] One governmental concern was that a few bad actors could create large, negative reputational spillovers impacting the important Chinese PPE exporting industry.[10]

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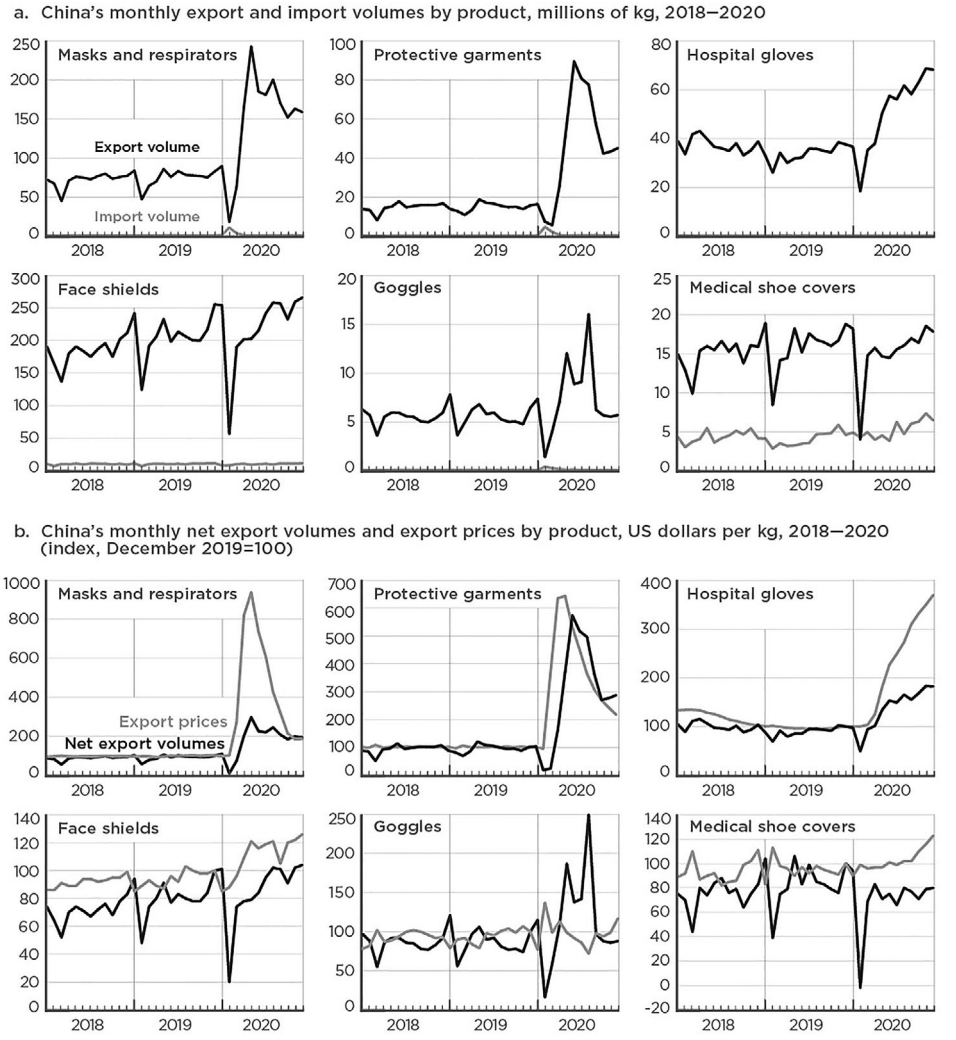

Figure 2 COVID-related drop and then surge in China's personal protective equipment net exports and prices.

Source: Chinese Customs

Note: Export price in trade unit values. For products with multiple eight-digit HS codes, the largest (by value in 2020) is shown. See Supporting Information Table S2

The US government quickly worried that Beijing was taking advantage of its market power and restricting exports for other, potentially political, reasons (see O'Keeffe *et al.*, 2020). Yet the trade data do not suggest that either China's export quality controls or US-China tensions affected China's PPE exports to the USA: the growth in these exports generally followed the same qualitative pattern as China's exports to the EU and the rest of the world.

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Despite the considerable drop-off in the first quarter, China's PPE export performance over the rest of the year was stunning: the value of these PPE exports nearly quadrupled from $22.9 billion in 2019 to $88.1 billion in 2020 (Table 1). Relative to a year earlier, China's export volumes in the second through fourth quarters of 2020 were 130% higher for masks and respirators and 272% higher for protective garments. As terrible as things were early in 2020 when China's decline in net exports left many countries exposed, China's increasing exports over the rest of 2020 likely helped medical workers around the world save many lives.

4. What Happened in Europe

As the pandemic spread globally in early 2020, conditions in Europe began to deteriorate. In February, Italy experienced a spike in cases; Spain and other European countries also suffered, and policymakers panicked. On March 3, France requisitioned PPE for its health workers, and on March 4 Germany banned PPE exports. The French and German curbs applied even to exports destined for other EU member states, including Italy, which went into lockdown on March 9.

The export bans were also problematic because the countries imposing them were home to some of the EU's largest PPE production facilities. On March 15, the European Commission stepped in with a similarly unprecedented imposition of EU-wide export controls on PPE, in an attempt to get EU member states to free up shipments with each other (see, e.g., Bown, 2020b; European Commission, 2020a,b; Keynes, 2020).

Despite Europe's increasing needs, China's PPE exports to the EU declined in the first quarter of 2020, ending up 4–25% lower, depending on the product, relative to the same period in 2019 (Table 1). Even when China's export volumes recovered to pre-pandemic levels starting in April, prices skyrocketed, revealing the severity of the shortage. Compared to December 2019, China's prices of exports to the EU in April 2020 were 1250% higher for masks and respirators and 700% higher for protective garments.

For some products, Europe was not able to substitute imports from alternative suppliers.[11] For protective garments, for example, the decline in import volumes from China in the first quarter was accompanied by only a slight increase in intra-EU shipments, and imports from the rest of the world were flat. Imports of hospital gloves declined from all sources. In April, imports of most products began to accelerate, with the largest increases in imports from China, which continued over the last three quarters of 2020. EU import prices on most PPE also rose sharply, first from China and then from other sources. However, for most products, the price increase of imports from China was much higher than for imports from the rest of the world.

The products that the European Commission subjected to export controls on March 15 tell a mixed story. For many products, extra-EU export sales fell in March and April 2020, the period during which most of the export controls were in effect (Figure 3). However, it is difficult to disentangle how much of the export reduction resulted from EU policy, since other factors were changing at the same time. Internal EU demand for PPE was increasing, imports from China had fallen, and intra-EU exports for some products

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Table 1 China's exports of PPE in 2019 and 2020, by product and destination

Trade values (billions, USD)

	In 2019			In 2020		
Product	Total	…to EU	…to USA	Total	…to EU	…to USA
Masks and respirators	5.4	1.0	2.2	53.8	17.3	14.8
Protective garments	0.9	0.3	0.4	10.8	2.6	2.7
Hospital gloves	1.0	0.1	0.5	3.9	0.6	2.0
Face shields	13.3	2.1	3.5	16.8	2.4	4.4
Goggles	1.4	0.3	0.4	1.9	0.4	0.5
Medical shoe covers	0.9	0.1	0.2	1.0	0.1	0.2
Total	22.9	3.9	7.1	88.1	23.4	24.6

Trade volumes, year-over-year percent changes (volume)†

	In January–March 2020			In April–December 2020			In 2020		
Product	Total	… to EU	…to USA	Total	…to EU	…to USA	Total	…to EU	…to USA
Masks and respirators	−12.5	−11.4	−18.3	130.0	183.1	77.9	99.1	140.4	58.0
Protective garments	−22.1	−22.9	−30.6	271.7	179.4	184.4	210.0	138.3	137.6
Hospital gloves	−3.0	−15.5	−5.4	68.0	171.8	59.9	51.7	120.7	46.0
Face shields	−10.2	−19.3	−10.0	10.7	3.5	19.4	6.0	−2.4	12.6
Goggles	−22.0	−24.5	−15.0	48.7	33.5	58.4	31.6	18.9	38.1
Medical shoe covers	−10.9	−4.4	−10.7	−2.7	3.3	3.7	−4.5	1.7	0.7

Trade prices (unit values), percent changes in Chinese export price†

	In April 2020 versus December 2019			At peak versus December 2019			In December 2020 versus December 2019		
Product	Total	… to EU	…to USA	Total	…to EU	…to USA	Total	…to EU	…to USA
Masks and respirators	720.8	1251.7	542.1	838.0	1251.7	778.1	85.6	149.3	51.3
	536.2	698.8	256.7	543.6	698.8	394.2	116.7	124.4	110.5

Trade prices (unit values), percent changes in Chinese export price†

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Table 1 *continued*

Trade prices (unit values), percent changes in Chinese export price[†]

	In April 2020 versus December 2019			At peak versus December 2019			In December 2020 versus December 2019		
Product	Total	… to EU	…to USA	Total	…to EU	…to USA	Total	…to EU	…to USA
Protective garments									
Hospital gloves	24.8	66.9	15.5	270.4	262.0	279.5	270.4	262.0	279.5
Face shields	9.2	18.5	5.8	26.4	32.4	22.3	26.4	27.2	19.3
Goggles	12.6	57.3	−15.1	36.7	57.3	13.0	16.8	−0.4	5.5
Medical shoe covers	−3.4	−6.4	−0.3	23.3	41.5	35.4	23.3	37.9	28.3

Notes: Values defined using all HS08 codes for that product. Totals may not sum due to rounding.

[†]Volumes and prices (unit values) rely on only the top HS08 code by value in 2020. Percent changes in volume data are year over year for the relevant period. Price changes are month over month as indicated in the table.

EU, European Union; PPE, personal protective equipment.

(e.g. masks and respirators, protective garments) were increasing. Furthermore, domestic production may have been affected – at some points by lockdowns, at others by capacity expansion. The fact that exports did not surge after the EU export control regime expired suggests that low export volumes may not have been the result of policy but were dominated by these other factors, although it is impossible to say without more detailed production and consumption data.

Though the price of some EU PPE exports increased considerably (Figure 3b), the price increase for masks and respirators as well as protective garments was not nearly as high as for Chinese exports (see again Figure 2 and Table 1). This raises the question of whether the EU export monitoring system allocated PPE – in short supply globally – through a mechanism that was less responsive to price.

5. What Happened in the USA

The pandemic similarly hit the USA hard, beginning most famously in New York City, which declared a state of emergency on March 12. By early April, the Strategic National Stockpile for PPE, administered by the US Department of Health and Human Services (HHS), was essentially depleted. China's exports to the USA largely mimicked the European experience, declining in the first quarter of 2020 by 5–31% year-over-year, depending on the product (Table 1). The decrease in US imports from China was not accompanied by a comparable increase in imports from elsewhere.[12]

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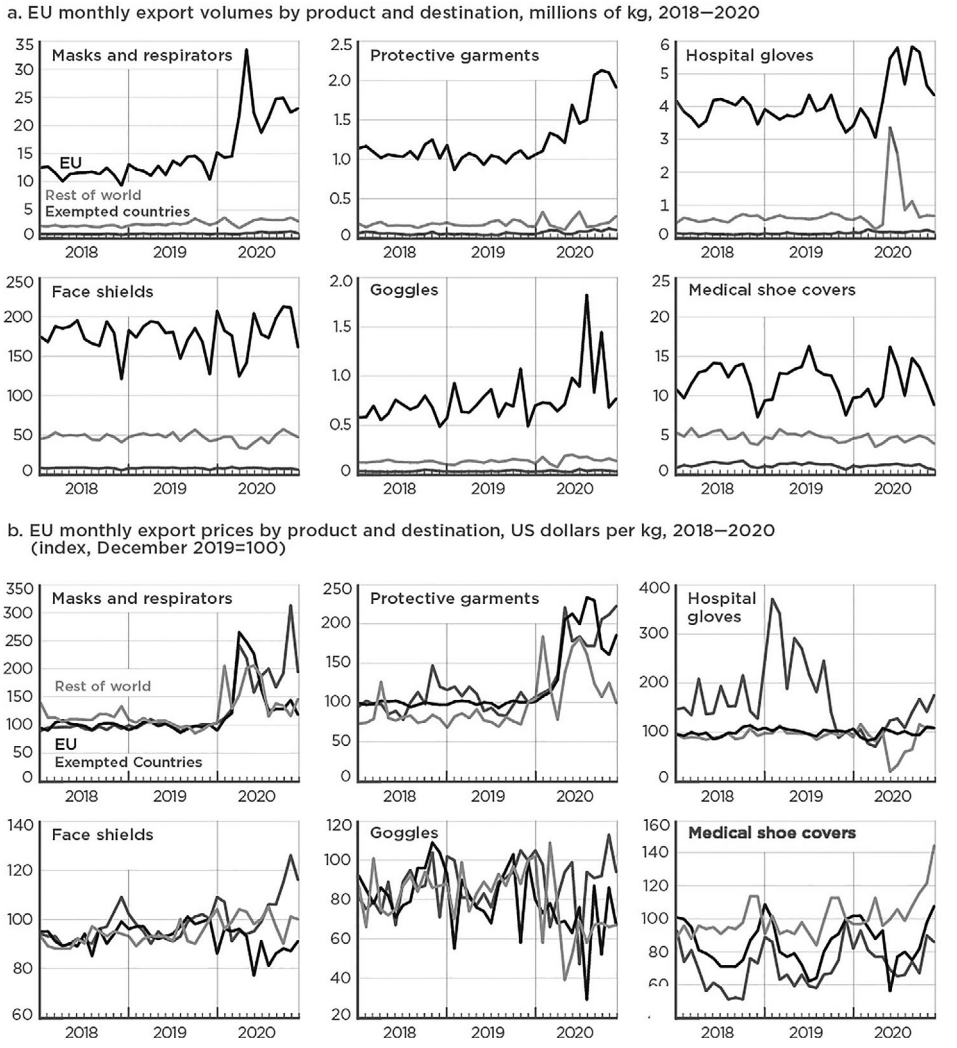

Figure 3 European Union (EU) personal protective equipment exports subject to export controls in March and April 2020.
Source: Eurostat.
Note: Export price in trade unit values. For products with multiple eight-digit HS codes, the largest (by value in 2020) is shown. See Supporting Information Table S2

Chinese exports to the USA also regained pre-pandemic levels by April and then increased considerably. Chinese export prices also skyrocketed, remaining high for much of the rest of 2020, reflecting continued shortages. China was the source of most of the increase in US import volumes in the second through fourth quarters of 2020 for most products. Imports of masks and respirators, as well as hospital gloves, also

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began arriving in significantly increased quantities from Vietnam and Malaysia, respectively.

The volume of China's PPE exports to the USA in 2020 was somewhat remarkable, given that the US government sent mixed messages about whether it wanted imports of Chinese medical supplies. The Federal Emergency Management Agency (FEMA) created Project Airbridge to ship planeloads of PPE directly into the USA, beginning in late March, including from China. But statements from White House official Peter Navarro and Secretary of State Mike Pompeo, as well as President Trump's continued public references to the "Chinese virus," threatened to imperil the bilateral relationship during much of 2020. In addition, there were the US trade war tariffs.

5.1 Section 301 tariffs and US pandemic preparedness

The US administration began a trade war with China in 2018 that ultimately resulted in new US tariffs covering $335 billion, or two-thirds, of its goods imports from China. This included new tariffs on billions of dollars of imported medical equipment, despite warnings from experts that the duties could affect American preparedness for a future pandemic. When COVID-19 arrived, AdvaMed, an industry association, sent the office of the US Trade Representative (USTR) a letter on January 31 urging removal of the trade war tariffs on desperately needed medical supplies, including PPE. The administration stubbornly took many weeks to decide; for example, USTR did not grant temporary exclusions for masks and respirators until March 17.[13]

The trade war tariffs, implemented as part of the US administration's explicit policy goal of limiting imports, likely had a negative impact on US pandemic preparedness.[14] In the 4 months immediately following the September 2019 imposition of new tariffs, the year-over-year change in US imports from China was negative for four out of five PPE products facing those tariffs (Figure 4). By January 2020, for three of the most important product lines – face shields, masks and respirators, and protective garments – that absolute decline in imports was not offset by a commensurate increase in imports from elsewhere.

Overall, this suggests that the American health care system bought less from China and did not restock inventories from alternative foreign suppliers. With higher prices resulting from the tariffs, some American buyers may have also severed commercial relationships with Chinese suppliers that may have been difficult to restart in the midst of a pandemic.

5.2 The Defense Production Act arrangement with 3M's plants in China

In early April 2020, American PPE shortages had become so dire that the US administration invoked the Defense Production Act (DPA). One extraordinary element was its instruction to 3M to import 166.5 million respirators over April, May, and June from its plants in China. The US-headquartered multinational reported fulfilling the obligation by July (see 3M, 2020a; Bown, 2020d).

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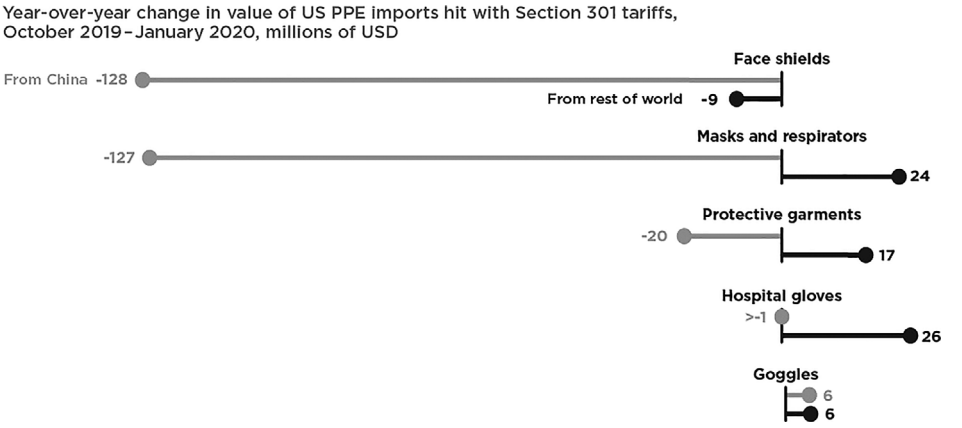

Figure 4 US disadvantage in pandemic preparedness due to trade war with China.
Source: US Census.
Note: personal protective equipment products included in US Section 301 List 4A and subject to new 15% tariff in September 2019.

Figure 5 shows respirator exports to the USA from Shanghai, the location of a 3M respirator plant in China. It plots, by Chinese province, the change in Chinese export volumes (Figure 5a) and the change in Chinese export prices (Figure 5b) for shipments to the USA relative to the rest of the world over the period of that arrangement. Compared to the average across provinces, Shanghai had slightly higher export volume increases, and slightly lower export price increases, to the USA relative to the rest of the world. This is consistent with meeting the DPA objective. However, it is possible that 3M would have increased imports from its Shanghai plant to the USA anyway, or that alternative Chinese suppliers in other provinces exported less to the USA to make up for those 3M orders.

5.3 The Defense Production Act's export controls, and PPE sales to Canada and Mexico

In the face of PPE shortages, a second extraordinary element of the April DPA invocation was US imposition of export controls on respirators, masks, and hospital gloves. On April 3, 3M (2020b) released a surprising statement that the US administration had asked it to "cease exporting respirators that we currently manufacture in the United States to the Canadian and Latin American markets" even though there would be "significant humanitarian implications of ceasing respirator supplies to healthcare workers in Canada and Latin America, where we are a critical supplier of respirators." The initial version of the regulation ignored the concern and limited US exports to Canada and Mexico; the restriction was only removed in the revised version published on April 17.[15]

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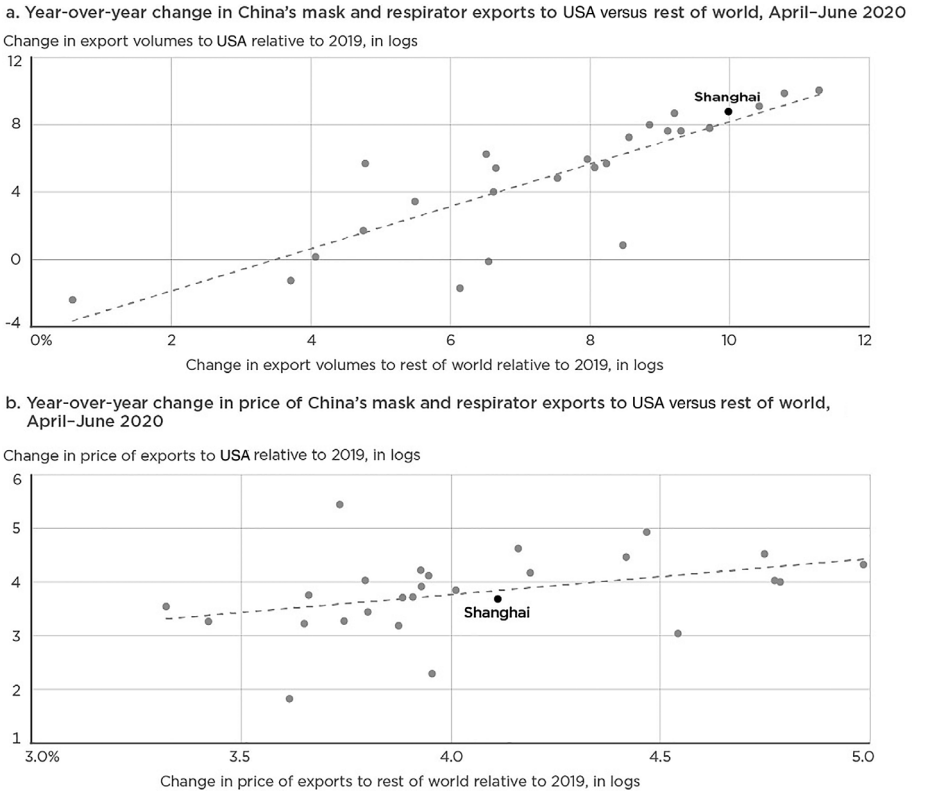

Figure 5 Effect of US arrangement with 3M on export volume and price of masks and respirators from Shanghai.
Source: Chinese Customs.
Note: Dots show data for 22 Chinese provinces, 5 autonomous regions, and 4 municipalities. Not shown are data for Taiwan and the special administrative regions of Hong Kong and Macau. Masks and respirators defined as HS code 6307909889. Data for each panel defined as log[(April + May + June 2020) − (April + May + June 2019)].

Nevertheless, the trade data alone provide little evidence that DPA negatively impacted US exports (Figure 6).[16] Canada and Mexico dominate US exports for each product, with the exception of air-purifying respirators, and export volumes ended up higher in 2020 than in 2019. US export volumes to Canada and Mexico of respirators and masks, for example, were 26% higher in the last three quarters of 2020 relative to 2019. US export prices to Canada and Mexico peaked in April 2020 at 120% higher than pre-pandemic levels, before declining over the rest of 2020. Again, this was much less than the Chinese export price increase, raising the question of whether a side effect of US export controls was to limit PPE price increases during extreme global scarcity. Air-purifying respirators – a product not previously discussed – are even more sophisticated than an N-95 respirator. After a US export surge in March, foreign sales fell

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alongside the imposition of export controls in April, though they increased again later in 2020.

While US exports of these products were higher overall in 2020 relative to 2019, it remains unknown how much higher they would have been without the controls. Estimating the policy's impact must account for the likely increases in both domestic (US) demand as well as foreign import demand; these would have competing effects on US export volumes, independent of the export control policy. The capacity expansion of the US industry (described next) would also increase export volumes, ceteris paribus.

Nevertheless, Canada responded by implementing industrial policy to reduce at least some of its future PPE import dependence on the USA. In August 2020, the governments of Canada and the province of Ontario announced subsidies for a 3M plant to manufacture N-95 respirators domestically (Ontario, 2020).

5.4 US industrial policy in support of the PPE supply chain in 2020

The US government eventually also deployed industrial policy, in the form of $1.2 billion of subsidies over the next year, to directly expand domestic PPE production capacity. It started by subsidizing domestic facilities producing N-95 respirators, beginning in mid-April 2020 (Table 2). Overall, it made nearly $800 million of publicly funded investments in American PPE production capacity expansion, as well as for

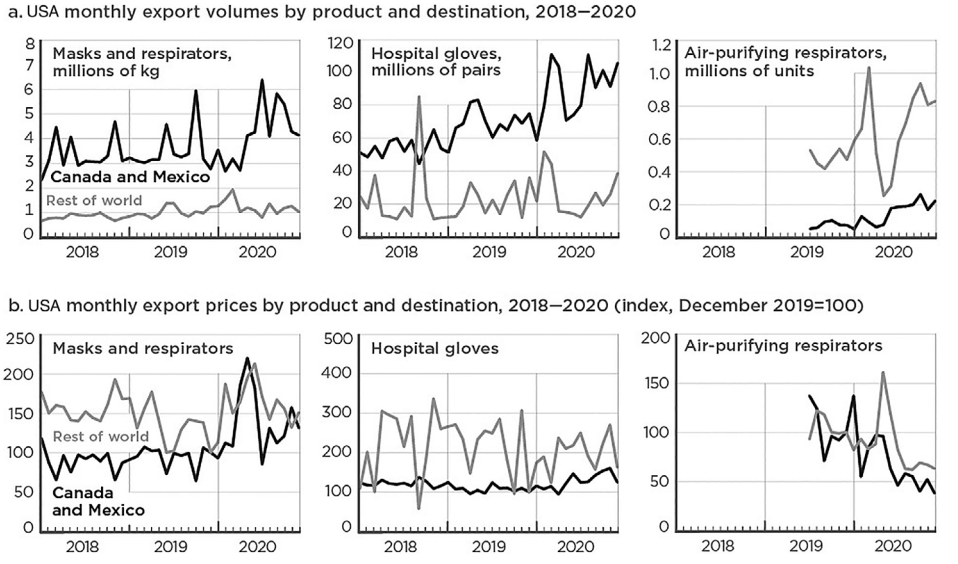

Figure 6 US personal protective equipment exports subject to export controls starting in April 2020.

Source: US Census.

Note: Export price in trade unit values. Data for air-purifying respirators start in July 2019.

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inputs along the PPE supply chain, in 2020. Collaboration between the Department of Defense (DOD) and HHS, led by the DOD's Joint Acquisition Task Force and funded through the CARES Act, paid subsidies to 3M, O&M Halyard, Honeywell, Crosstex, and Medline Industries to add product lines for N-95 respirators or surgical masks. Freeman Manufacturing and others received subsidies to scale up production of hospital gowns. Funding was sent to Hollingsworth & Vose (filters), Lydall (meltblown filtration media), and NPS (meltblown fiber) to expand production of key inputs needed for PPE manufacturers of those surgical masks, respirators, and hospital gowns. Then, in May and June of 2021, the US government spent over $400 million on a half dozen companies to expand capacity – including for key raw material inputs – for nitrile glove production.

Late in 2020, the Trump administration also began a series of actions to potentially withdraw PPE from US commitments under the WTO's Government Procurement Agreement (GPA). Like import tariffs, this would force consumption of locally produced PPE – even if more costly relative to imports. After initially signaling potential support for the policy, the Biden administration reversed course in April 2021, possibly because it would have resulted in trading partner retaliation by withdrawing their own commitments under the GPA, hurting US exporters in other sectors.

In summary, the US policy actions to rebuild or expand the domestic PPE manufacturing sector were unlikely to have affected product availability until late 2020 at the earliest, with the exception of N-95 respirator capacity expansion. Nevertheless, the subsidization combined with the demand shock induced entry by American firms and changed the domestic industry landscape. However, a few months into 2021 prices had normalized sufficiently that some new entrants were starting to organize to request import protection. In May, for example, the American Mask Manufacturer's Association (2021), representing 26 small businesses, wrote to President Biden alleging that China was now "dumping masks on the US market at well below actual costs" and that if this practice continued "54% of our production will go offline in 60 days and 84.6% in less than a year."

US pandemic policy, as well as changing economic conditions, impacted industry structure in ways that also raised important questions for future preparedness policy.

6. Policy Implications

In the face of a global pandemic that created a surge in demand for PPE, an optimal policy mix for a major industrial economy should have involved three components: (i) Incentivize the domestic industry to add capacity and surge production as quickly as possible; and for the period during which surge capacity is ramping up and not yet available, rely on the combination of (ii) previously stockpiled PPE and (iii) imports. For the USA, COVID-19 revealed problems with all three parts of that strategy.

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Table 2 US industrial policy for expanding the PPE manufacturing supply chain in 2020–2021

Date	Department of Defense policy action
2020	
April 11	$132.4 million combined to 3M ($76 million), O&M Halyard ($29 million), and Honeywell ($27.4 million) for N-95 respirator production expansion
May 6	Additional $126 million to 3M for N-95 respirator production expansion
May 28	$2.2 million to Hollingsworth & Vose for production expansion of N-95 ventilator filters and N-95 respirators
June 22	Memorandum of Understanding with US International Development Finance Corporation (DFC) to use $100 million of CARES Act funding to finance projects to help reshore production, including of PPE
June 19	$13.5 million to Lydall for meltblown filtration media production expansion
July 17	$3.5 million to Crosstex for surgical mask production expansion
July 24	$2.75 million to NPS for meltblown fiber line production expansion
September 11	$136 million to five companies for reusable isolation gown production expansion
September 14	$335 million to nine companies for disposable isolation gown production expansion
November 10	Additional $37 million to 3M for N-95 respirator production expansion
November 13	$6.18 million to Medline for surgical mask production expansion
November 20	$565,000 to Freeman Manufacturing for disposable gown production expansion
December 2	$2.5 million to Hollingsworth & Vose for filter media production expansion
2021†	
May 18	$56 million to Rhino Health for nitrile gloves production expansion
May 26	$13.1 million to Renco Corporation for nitrile gloves production expansion
May 27	$63.6 million to US Medical Glove Company for nitrile gloves production expansion
May 28	Additional $35 million to Renco Corporation for nitrile gloves production expansion
May 28	$123.1 million to Blue Star NBR for nitrile butadiene rubber production expansion, a key raw material in nitrile gloves
June 17	$37.6 million to Showa Best Glove for nitrile gloves production expansion
June 21	$96.1 million to United Safety Technology for nitrile gloves production expansion

Source: Constructed by the author from Department of Defense announcements and other sources.
†Through June 30, 2021.
PPE, personal protective equipment.

6.1 Production problems and policy

Why did the US government's industrial policy response take so long?[17] US government subsidies for PPE capacity expansion began to roll out only in April 2020; most

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were not announced until the second half of the year, and some not until mid-2021. Yet private companies saw the changing conditions earlier – 3M, for example, announced capacity expansions beginning in January 2020. Even by February, other parts of the US government recognized PPE shortages – see, for example, the Congressional testimony of HHS Secretary Alex Azar (see CSPAN, 2020).

One explanation is that the government lacked basic information about domestic PPE production. Policymakers cannot target subsidies for PPE manufacturing companies that cannot be found. Missing information included how much and where domestic capacity existed prior to the pandemic, how quickly production could be expanded, and what resources (and other critical inputs in the supply chain) would be needed to make that happen.

Second, for some specific products, there may have been too little domestic production capacity altogether. "You can't surge zero," quipped John Polowczyk, in reference to America's apparent de minimis production of hospital gloves at the outset of the pandemic. This is plausible, but more data and analysis are needed to determine for what products that was such a constraint.

To better support policy going forward, the USA must collect and maintain up-to-date, detailed data on domestic production and capacity for PPE. The relevant industries will need to be subjected to periodic "war games" or "stress tests" to ensure that policy can incentivize a sufficiently quick expansion to surge capacity levels in a future emergency.

6.2 Stockpile problems and policy

Buyers, distributors, and governments collectively held too little inventory in reserve in case of emergency, as was made evident by the early pandemic depletion of the HHS Strategic National Stockpile. The further lack of inventory held by the private sector was, in part, likely the result of cost pressure.[18] A more robust system of preparedness may require regulators to ensure that hospitals, medical distributors, and states – in addition to the federal government – maintain more inventory. Because holding inventories is costly, and profit incentives pressure that part of the supply chain to become more lean, there is a role for regulation.

A separate question involves determining the socially optimal size of stockpiles to manage and for regulators to help oversee. That determination requires detailed projections on demand as well as information on the state of domestic production capacity (as discussed above) and how quickly it can be scaled up under differing pandemic scenarios. One scenario involves a health threat concentrated in the USA: imports would be available, but immediate domestic production might not. In other scenarios, only foreign supplies are unavailable, or both – or neither – sources are available. The global and rolling COVID-19 lockdowns over 2020 and 2021 highlight the importance of geographically diversified production within the USA as well as internationally. Relying solely on domestic production would be excessively risky, as would relying on imports primarily from one source.

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6.3 Import problems and policy

Imports were a critical source of PPE during COVID-19, and should arguably remain an important component of future supply diversification. At the same time, although more data and detailed analysis are needed, imports may have contributed to multiple problems that emerged during the pandemic.

While PPE imports from China over the latter part of 2020 undoubtedly saved American lives, the lack of available imports in February and March likely cost lives. The problem might be characterized as a perfect storm of events. The pandemic arose in Hubei, the largest exporting province in the largest exporting country of the protective garments needed globally by hospital workers. The fact that those Chinese supplies were taken off the global market just when the rest of the world needed them shows that excessive concentration of production is a legitimate worry for American – and global – public health preparedness.

The USA and its trading partners must have a more diversified portfolio of foreign production for PPE. Achieving that objective may require new policy incentives – and forms of international coordination – if strong economic forces of agglomeration work to concentrate production geographically or in favor of the status quo.

Perhaps more so for the USA than other countries, international diversification must be a priority. Trade can be a tool for preparedness only if there is trust between the importer and the exporter – that is, confidence that when times get tough for health or economic reasons, trade lanes will remain open. There is now precious little trust between the USA and China as geopolitical tensions between the two countries remain elevated.

For certain products, imports over the years may have also contributed to insufficient domestic production to enable the government to surge capacity expansion during an emergency. A permanent policy intervention may be needed if optimal pandemic responsiveness requires a larger minimum domestic industry size than would be sustainable under normal market conditions and free trade, due to a positive externality. Policymakers will find tariffs attractive – and tariffs may emerge if better policies are not developed (a group like the American Mask Manufacturer's Association, for example, could petition bureaucrats to impose antidumping duties). However, while import protection does help stimulate domestic production, it also raises prices for consumers (e.g. in the health care system, which is already costly in the USA and many other countries). A more efficient policy to target an externality and achieve a sufficient minimal level of domestic production would be a subsidy.

Overall, the USA should ensure a diverse portfolio of imports of PPE for pandemic preparedness. Foreign sources of production must be transparent and, ideally, imports should come from countries with which the USA has a relationship of trust, to be sure that the source country will share supplies when times are challenging. The pandemic revealed that not many countries always fit the transparency and trust criteria, including the USA.

7. Conclusion and International Policy Cooperation

The PPE shortages and use of extraordinary trade and industrial policy during the COVID-19 pandemic revealed significant failures in preparedness. Trade played a mixed role.

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The experience has triggered considerable rethinking of international cooperation for trade in such medical supplies. Indeed, the new US president's early 2021 meetings with leaders from Japan and the Group of seven countries led to joint statements and communiqués prioritizing PPE supply chain resilience as well as greater geographic diversification of production. Achieving those objectives will require different incentives and forms of international trade policy cooperation than were in place before the pandemic.

A new framework is also needed to define the proactive international policy coordination required at the first signs of the next emergency. A cooperative response of countries jointly and transparently triggering surge production capacity for PPE would do much to prevent a repeat of 2020 – waiting too long, followed by knee-jerk export restrictions.

Finally, the analysis here has focused on major economies with the capacity to push for and sustain domestic PPE industries. That will not be a feasible strategy for many smaller countries with markets that cannot achieve viable economies of scale. For them, challenges in trade and stockpile management will persist. Yet even these countries can learn important lessons from the US experience, including the need for visibility into trading partners' domestic production capacity and export product availability. Transparency is essential for any country seeking to maintain preparedness for public health emergencies.

Notes

1 "Remarks by President Biden at Signing of an Executive Order on Supply Chains," White House, February 24, 2021.

2 See, for example, USITC (2020), Baldwin and Evenett (2020), Evenett (2020), Evenett *et al.* (2021), Espitia *et al.* (2020), Gereffi (2020), Hoekman *et al.* (2020), Leibovici and Santacreu (2020), and Miroudot (2020).

3 This PPE characterization is a by-product of trade statistics classification prior to the pandemic. For example, while surgical masks and N-95 respirators are different products, they were inseparable because they fell into the same code. A similar explanation holds for different types of protective garments. As one policy response, the USA created new product codes for N-95 respirators, surgical masks, and face shields in July 2020 and for surgical gowns in January 2021. Supporting Information Table S2 provides precise product classifications.

4 The interview with Polowczyk is in Bown and Keynes (2021).

5 Depending on the product, applied MFN tariffs ranged from 0% to 7% for the USA and 1.7% to 12% for the EU.

6 At this point in the pandemic, the US government and European Commission were shipping PPE to China for humanitarian purposes (Lenarčič, 2020; Pompeo, 2020).

7 The Lunar New Year means January and February data for China are notoriously challenging to seasonally adjust. Year-over-year comparison here cumulates January–March 2020 and the same months in 2019. China's initial data release of March 25, 2020 did not include separate data for January and February (Bown, 2020a,e).

8 Hubei was a much smaller export supplier of the other PPE products. In 2019, it was the source of 4% of China's exports of masks and respirators, and less for the other. For

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diplomacy-related explanations of regional differences in China's mask and respirator exports through March 2020, see Fuchs *et al*. (2020).

9 See Lin (2020) and Chinese Customs (2020) for export quality controls, and Stevenson and May (2020) and Lau (2020) for quality concerns.

10 China's exports had been negatively impacted by prior failures to regulate product quality. Bai et al. (2021) document the export impact of the 2008 scandal involving melamine-contaminated infant formula.

11 Supporting Information Table S3 provides more detail on EU import prices and alternative sources of imports.

12 Supporting Information Table S4 provides more detail on US import prices and alternative sources of imports.

13 See the testimony in the Section 301 hearings cited in Bown (2020c). Bown (2020d) documents even later requests for tariff exclusions on pandemic-related imports. Unlike other countries, the USA never had a public discussion over suspending MFN tariffs on PPE.

14 Even with the Phase 1 agreement, the explicit policy goal was to keep tariffs on China in place to reduce the bilateral trade deficit (Bown, 2021).

15 The export controls were extended in August until December 2020 and then again until June 2021. Some products were later added and others subtracted. See Supporting Information Table S1.

16 In 2019, US exports of these products were $553 million to Canada and Mexico and $529 million to the rest of the world. In 2020, US exports were $874 million to Canada and Mexico and $643 million to the rest of the world.

17 This section draws in part from interviews with John Polowczyk (Bown & Keynes, 2021).

18 A separate problem involves how the limited PPE stockpiles (and federal acquisitions) were allocated within the USA – that is, according to emerging public health demands (i.e. "hotpots") versus some other formula, such as the share of the national population. See House Committee on Oversight and Reform (2020) and HHS (2020) for the Strategic National Stockpile.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1: Supporting Information
Table S1 Timeline of key COVID-19-related events for personal protective equipment (PPE), 2018–21
Table S2: Personal protective equipment and HS product codes.
Table S3 EU imports of PPE in 2020, by product and source

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