The Face Mask Global Value Chain in the COVID-19 Outbreak: Evidence and Policy Lessons

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This note provides information on the global value chain for the production of surgical masks and N95 respirators in the context of the COVID-19 crisis. It analyses the causes of the current shortage of these key medical supplies needed to prevent the spread of coronavirus, and reviews some short-term and long-term policy options, with a focus on the role of trade and investment policy.

Key findings and main policy implications

- COVID-19 has caused a dramatic shortage in the supply of face masks*, which is mainly explained by a surge in demand.
- Since no country can meet the increase in the demand for masks alone, trade is essential. Export bans are harmful for countries without production capacity, but can also backfire on the country imposing them when they need to import inputs, additional masks or other essential goods. Tariffs or export licenses can delay trade, in addition to increasing prices.
- The smooth operation of transportation infrastructure and logistics, especially air cargo, is critical to support the face masks value chain during the crisis. More attention should also be given to the supply of key inputs.
- But free trade and trade facilitation are not enough to solve the current shortage; an important increase in supply is required in the short-term, requiring government planning and incentives for firms to convert existing assembly lines and create additional capacity. Certification procedures should be expedited to allow masks produced by new companies to be traded as soon as possible
- Looking ahead, it would be excessively costly for every country to develop production capacity that matches crisis demand and encompasses the whole value chain. An alternative, more effective and cost-efficient solution in the long-term may involve the combination of strategic stocks; upstream agreements with companies for rapid conversion of assembly lines during crises (with possible government incentives and co-ordination); and supportive international trade measures.

* The term "face mask" generally refers to surgical masks (also known as "procedure masks" or "medical masks"). This note also covers N95 respirators as they have a similar value chain and trade data do not distinguish them from surgical masks.

COVID-19 has caused a shortage of face masks

- Surgical masks and N95 respirators are used to prevent the spread of respiratory infections. They are part of the personal protective equipment (PPE) used by health workers and are different from other types of masks used to protect from pollution or dust.[1] Surgical masks are loose fitting and designed to trap sprays and droplets from coughing and sneezing.[2] N95 respirators fit more tightly and can also protect from smaller airborne particles. While N95 respirators are designed to protect the wearer from infections, surgical masks are mostly used to prevent the wearer from disseminating germs and viruses (such as in the case of a surgeon operating on a patient). Surgical masks do not offer full protection against the coronavirus but are recommended for health workers, particularly when both the patient and the worker wear one.

[1] Viruses are very small and require specific fabric for effective filtering. The SARS-CoV-2 virus (responsible for COVID-19 disease) has a diameter of approximately 60 to 140 nanometres (i.e. one thousandth of the diameter of a human hair). It is much smaller than bacteria or dust.

[2] Surgical masks provide different levels of protection based on the effectiveness of the filtering. Level 2 (US norms) or FFP2 (EU norms) is regarded as effective against the COVID-19 virus. N95 is the grade required for respirators (it filters 95% of particles smaller than 300 nanometres).

- Both surgical masks and N95 respirators are disposable, explaining the high and recurrent demand. Once used, their external layer may become covered with germs. Moreover, humidity from the mouth slowly alters their filtering properties. Masks are therefore effective only for a few hours (four hours for surgical masks and one day for N95 respirators) and there is a risk of contamination when manipulating them or re-using them. Therefore, the strategy is to have cheap and disposable protective equipment that can be safely disposed of and replaced. Re-usable masks have been found to create higher risks of contamination.[3]
- As the coronavirus is transmitted via droplets of fluid from the nose or mouth, face masks are essential for health workers who are in direct contact with infected patients.[4] They can also play a role in preventing sick people from spreading the virus when coughing or simply talking or breathing. While the recommendation initially was to wear masks only when taking care of people suspected of COVID-19 infection, WHO issued new guidance on the use of masks for healthy people in community settings[5] on 6 April 2020 and health authorities are increasingly recommending the broader use of masks.
- Meeting demand for face masks has become one of the main issues for governments fighting the pandemic. Masks may play an even greater role in the next phase of the crisis, when lockdowns are gradually lifted and economic activity resumes, while the virus remains a threat.

Masks have a relatively sophisticated manufacturing process

Surgical masks are basic products and are relatively cheap (when they are not in short supply).[6] However, their production involves several types of inputs and the assembly of different parts in a relatively sophisticated process.[7] The filtering property of masks is a function of a multi-layered structure made of non-woven fabric. The most commonly used material is polypropylene, a polymer derived from petroleum oil. Polypropylene is "melt-blown" in order to obtain fibres of a small diameter in a random pattern that can trap small particles. The fibres are electrically charged so that particles are attracted while the air passes through (electret treatment).

Different layers of non-woven fabric and textile are then assembled through ultrasonic welding. The minimum is three layers: an inner layer in contact with the mouth that can absorb moisture (generally white), a filter layer made of melt-blown electret non-woven material (as described above) and an outer layer protecting against liquid splashes (blue, to be distinguished from the inner layer). Cotton or other

[3] Re-usable masks may still be one of the solutions to address the current shortage. At the end of March, the US Food and Drug Administration (FDA) issued an emergency use authorisation for a decontamination system developed by the Battelle Memorial Institute that allows certain types of N95 respirators to be re-used. Washable masks, where only the filter is replaced (still ensuring the required level of protection), have also been developed by some companies.

[4] OECD, Beyond Containment: Health Systems Responses to COVID-19 in the OECD, updated 16 April 2020.

[5] https://www.who.int/publications-detail/advice-on-the-use-of-masks-in-the-community-during-home-care-and-in-healthcare-settings-in-the-context-of-the-novel-coronavirus-(2019-ncov)-outbreak.

[6] According to Nielsen Retail, the price of face masks increased by 319% in the United States between end-January and end-February 2020. Before the crisis, a box of 100 masks could be bought for less than USD 4 in the United States. However, at the end of February, there were reports that single masks were being sold for USD 20. The same phenomenon has been observed with respirators, with the price of a box of 20 increasing from USD 17 to USD 70. Several countries are now implementing measures to curb prices and protect consumers.

[7] Chellamani, Veerasubramanian and Vignesh Balaji (2013). "Surgical Face Masks: Manufacturing Methods and Classification", *Journal of Academia and Industrial Research*, Vol. 2(6), pp. 320-324.

types of fabric can be used for the inner and outer layers (but they can also be made with non-woven fabrics).

Nose strips are added in order to bend the mask around the nose bridge, made from metal (aluminium, galvanised iron or steel). Simple masks have ties in the same material as the rest of the fabric, while more elaborate masks have elastic ear loops (made, for example, from nylon spandex), which need to be separately manufactured and attached to the filtering layers. These latter operations are relatively basic and most textile companies can perform them, including with workers manually operating sewing machines for ear loops, for example. But a full production line performing all the operations and combining several machines is more efficient. Starting from bobbins of non-woven fabrics, specialised machines weld the layers together and stamp the masks with nose strips and ear loops. Fully automated production lines can produce up to 1 000 masks per minute for the best-performing, although somewhere between 35 and 200 masks per minute is more usual. Masks are then sterilised before going to testing and packaging.

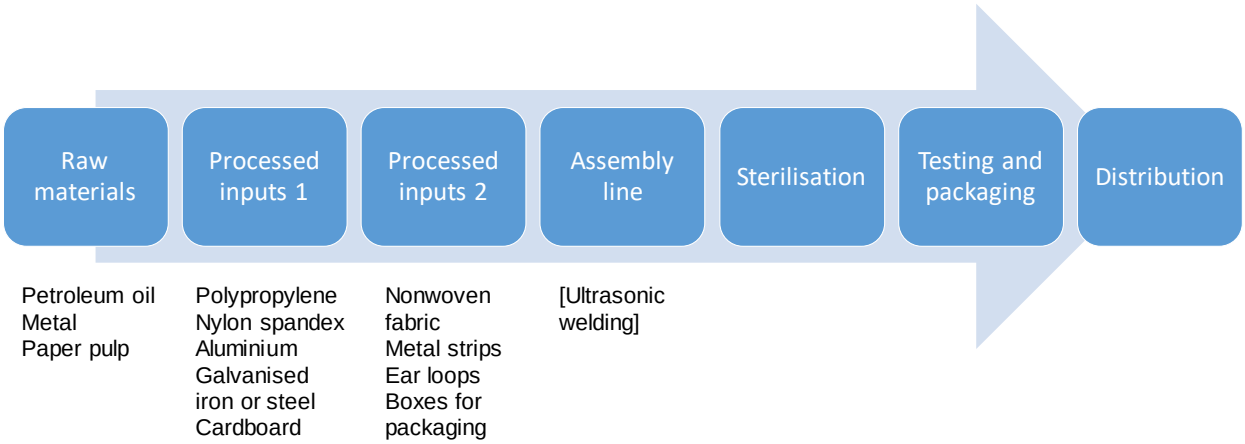
Respirators have a similar production process, with two differences. First, one of the layers passes through high-temperature and pressure calender rollers to become stiffer and form the desired shape. Second, the filtering is enhanced through high efficiency melt-blown electret non-woven material, involving higher tech machines and increasing production costs.

There are bottlenecks in the face mask value chain

Specialised inputs can be in short supply and are hard to manufacture quickly

The face mask value chain is illustrated in Figure 1. In terms of inputs, oil and metal are the main raw materials for the manufacture of non-woven materials, metal strips and ear loops (and sometimes other textile materials such as cotton). Additionally, paper pulp (forestry) is needed for cardboard in packaging.[8] Metal is only needed for the nose strips, and a variety of metals can be used. **The main bottleneck in the value chain in terms of inputs has been the non-woven fabric manufactured with polypropylene**.[9]

Figure 1. The face mask value chain



Source: OECD, based on information provided by manufacturers.

[8] As masks are sterile, they need to be properly packaged when transported. Some manufacturers have seen their production disrupted because basic packaging was not delivered.

[9] "Critical Component of Protective Masks in Short Supply", *Wall Street Journal*, 7 March 2020.

Polypropylene (PP) is one of the most commonly produced plastics in the world and, as a polymer derived from oil, can be easily supplied (although dependent on oil prices and access to oil). Manufacture of PP non-woven fabric is also quite widespread, as it is used in baby diapers, feminine hygiene products, and disposable wipes, as well as in the automotive and construction industries. However, PP electret melt-blown non-woven is a specialised fabric, produced by a limited number of companies globally due to the high initial investment required in heavy machinery, such as hoppers, extruders and melt spinning systems. For this reason, it has been more difficult to increase supply during the crisis, or to find companies that can switch to this production within a reasonable time and without massive investment.

As ultrasonic welding is used in a variety of industries (including, for example, the automotive industry), the rest of the value chain is more accessible, although specialised machines are still needed at the assembly stage. Some manufacturers buy the non-woven fabric and just weld the layers (in particular, those manufacturers who switched to mask production during the crisis). Based on the number of companies in different countries that were able to convert their production lines, it seems that the assembly stage is less of a bottleneck. Most of the potential new manufacturers are currently held back by the shortage in PP non-woven fabric.[10]

Manufacturers of machinery for mask assembly lines – found, for example, in The People's Republic of China (hereafter "China"), Chinese Taipei, France, Germany, Turkey, and the United States – have seen an increase in demand, as have manufacturers of testing machines (testing is important to guarantee the safety of masks). However, while some entrepreneurs are investing in creating new capacity for the future, most supply increases during the crisis have come through conversion of existing production lines.

Distribution has also been a bottleneck – including domestically

Another bottleneck in the face mask GVC during COVID-19 is seen at the distribution stage. Disruptions in transport and logistics have made the delivery of masks to final customers more complicated.

First, in terms of the international supply chain, several countries have put in place export restrictions or equivalent measures (discussed further below), or introduced new authorisation or certification procedures, which can cause delays in exports.

Second, domestic transport and logistics infrastructure, and domestic distribution, have also been disrupted by COVID-19. While varying across countries, including due to the extent of preparedness of the health infrastructure, masks have sometimes been in short supply, not because of a shortage of goods but because they were not reaching health workers. This, essentially domestic, downstream part of the value chain can be as disrupted as the more international part upstream. Here, the main challenge has been in assessing needs in real-time, and prioritising deliveries and anticipating changes at a time when the whole health system is under stress. In addition, the shortage of masks in some countries has led to thefts and the hijacking of some shipments.

Fundamental supply shortages exist, and current demand might be ten times higher than world production capacity

China was the main producer of masks at the start of the crisis, accounting for approximately half of world production. But even this was insufficient to meet its own demand related to COVID-19, and China imported

[10] "New Manufacturers Jump Into Mask Making as Coronavirus Spreads", *Wall Street Journal*, 21 March 2020.

a large quantity of masks.[11] In January 2020, China could produce 20 million masks per day[12], which was insufficient to meet a total demand estimated at 240 million masks per day to equip health, manufacturing and transport workers.[13] As a result of extensive efforts by the government and companies, Chinese production increased six-fold and reached 116 million masks per day at the end of February and possibly 200 million per day at the end of March (a ten-fold increase). The carmaker BYD, a joint venture between SAIC and General Motors, DaddyBaby (a manufacturer of baby goods), Foxconn (the company manufacturing iPhones for Apple), and China Petroleum and Chemical are all examples of companies that started to produce face masks at a large scale (i.e. more than 1 million per day).[14]

China addressed the issue of the supply of non-woven fabric early on by also establishing a plan to increase the production of melt-blown polypropylene. One hundred and three companies were involved in stepping up production so that mask manufacturers would not face a shortage for their key input.[15]

Providing face masks to healthcare workers and COVID-19 patients all over the world already brings global demand to a level above pre-crisis production capacity. There are about 43 million healthcare workers in the world.[16] Masks are generally assumed to be effective for about four hours and need to be regularly changed. Assuming that only around one third of healthcare workers need a mask (accounting for the fact that not all countries are affected at the same time, and not all health workers are in contact with COVID-19 patients), and that each health worker uses on average two masks per day, global demand for surgical masks would be around 28 million per day. Adding in care givers and suspected COVID-19 patients further increases this demand, possibly by another 12 million per day.[17]

As masks are now recommended for a broader use by the general population and an increasing number of countries require citizens to wear them in public places, the estimates provided above for China are likely to be applicable to other countries, leading to a demand for masks possibly ten times higher than before the crisis in countries affected by the virus. To meet this demand, it is important to continue to increase supply. While China has considerably increased its production (by a factor of 10), other producing economies record more modest (although important) increases. For example, production has been multiplied by 3 in France. Other solutions may be needed in the short term, such as the use of alternative masks (i.e. of lower grade) for the general population.

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[11] "China may have imported up to 2 billion masks during the COVID-19 crisis. 'China Delays Mask and Ventilator Exports After Quality Complaints", *New York Times*, 11 April 2020.

[12] There are no official statistics sufficiently disaggregated to provide information on the output of masks. Figures in this section are estimates based on press articles and the information released by the Chinese government. In 2019, China produced 4.2 billion masks according to the government, thus implying a world output of about 22 million masks per day.

[13] Estimates provided by Hua Chang Securities. Even if the whole population may not need one mask per day, governments who give masks to their whole population (e.g. Chinese Taipei and Korea) distribute two or three per week for people above 15 years old. In China, the population above 15 years old is 1.1 billion, thus giving an estimate of between 320 and 480 million of masks per day for the whole population to have access to a similar number of masks each week. The estimate of 240 million masks needed each day in China is therefore already conservative.

[14] "China pushes all-out production of face masks in virus fight", *Nikkei Asian Review*, 19 February 2020.

[15] "Mask mobilization during wartime from 5 billion to 200 million per day", *Sina Finance*, 16 March 2020.

[16] World Health Organization, *Global Strategy on Human Resources for Health: Workforce 2030*, Geneva.

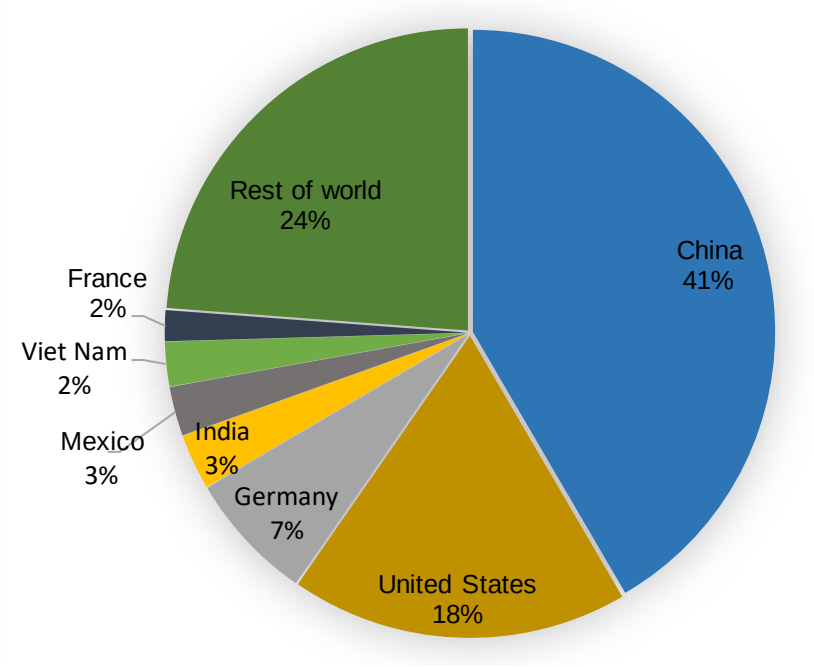
[17] As of 20 April 2020, there were about 2 million active (i.e. not recovered) confirmed COVID-19 cases according to John Hopkins University Coronavirus Resource Center. About one-third of tested people are positive, thus suggesting a population of at least 6 million suspected cases. With their family and care givers, the figure can be multiplied by 2 (with a conservative estimate of one mask needed per day).

Many countries have also introduced restrictions on the export of masks

To address domestic shortages of masks, many countries have put in place restrictions on exports or equivalent measures such as the compulsory purchase by governments of all available stocks. In China, there was no regulation prohibiting exports but a form of compulsory purchase, with all orders in January and February going to the government and exports resuming in March. Chinese Taipei was the first economy to ban exports of masks on 24 January 2020; many others have subsequently introduced export bans (Table 1). These export bans or compulsory purchases are generally temporary, with some already removed. Countries banning exports are not all producers or exporters of masks (see Figure 2 for the main exporters); non-producers can be motivated by a desire to prevent hoarding or to avoid the export of masks already imported to be sold at a higher price abroad.

While some EU countries producing masks have enacted export bans, an EU-wide regulation was adopted on 15 March 2020 introducing export authorisations. Exports are not banned, but the needs of EU countries have to be taken into account before authorising exports.[18] A similar system has been implemented in the United States since 10 April 2020, with a temporary rule from the Federal Emergency Management Agency banning exports of masks, but providing a list of exemptions (e.g. covering pre-existing commercial relationships). Export licenses or permits for face masks have also been introduced in other countries (Table 1).

Figure 2. Share of exports of face masks, by country, 2017



Note: Estimates based on trade flows observed for HS 630790 and using shares calculated with HS8 and HS10 trade data to identify face masks.
Source: UN COMTRADE and ITC Trade Map.

[18] The export authorisation was first for all personal protective equipment and narrowed down to protective masks on 14 April 2020 (https://trade.ec.europa.eu/doclib/press/index.cfm?id=2132). EU licenses are limited to humanitarian purposes and foreign operations of EU governments.

Table 1. Economies with COVID-19 export restrictions covering face masks

As of 14 April 2020

Economy	Date (effective)	Type of restriction
Albania	17/03/2020	Export ban
Algeria	22/03/2020	Export ban
Argentina	28/03/2020	Export licenses
Australia	18/03/2020	Export ban with exemptions for manufacturers not shipping by mail
Australia	30/03/2020	Export ban
Azerbaijan	14/03/2020	Export ban
Bangladesh	14/03/2020	Export ban. Lifted on 2 April
Botswana	28/03/2020	Export licenses
Brazil	18/03/2020	Export licenses
Bulgaria	11/03/2020	Export ban
Chinese Taipei	24/01/2020	Export ban
Colombia	22/03/2020	Export ban
Costa Rica	18/03/2020	Export licenses
Czech Republic	04/03/2020	Export ban
Ecuador	05/03/2020	Export ban
Egypt	17/03/2020	Export ban
European union	15/03/2020	Export licenses
France	06/03/2020	Requisition order
Germany	04/03/2020	Export ban. Lifted on 19 March
India	31/01/2020	Export ban. Lifted on 8 February and reintroduced on 19 March
Indonesia	18/03/2020	Export ban (also covering raw materials to fabricate masks)
Iran	03/03/2020	Export ban
Kazakhstan	30/02/2020	Export ban
Kenya	03/03/2020	Export ban
Korea	06/03/2020	Export ban
Libya	16/03/2020	Export ban
Malaysia	20/03/2020	Export ban
Moldova	11/03/2020	Export ban
Morocco	05/03/2020	Export licenses
Namibia	28/03/2020	Export licenses
Nepal	22/03/2020	Export ban
Oman	26/02/2020	Export ban
Pakistan	24/03/2020	Export ban
Paraguay	17/03/2020	Export licenses
Russia	03/03/2020	Export ban
Saudi Arabia	02/03/2020	Export ban
South Africa	27/03/2020	Export licenses
Switzerland	26/03/2020	Export licenses
Thailand	05/02/2020	Export ban
Turkey	28/02/2020	Export licenses
Ukraine	14/03/2020	Export ban
United States	07/04/2020	Export ban with exemptions for pre-existing commercial relationships
Uzbekistan	16/03/2020	Export ban

Source: ITC Market Access Map and WTO (as of 14 April 2020).

Some countries have facilitated trade in masks and other protective equipment by removing tariffs or by suspending licensing and certification requirements. The importance of keeping supply chains open was emphasised in a joint ministerial statement by Australia, Brunei Darussalam, Canada, Chile, Myanmar, New Zealand, and Singapore affirming their commitment to ensuring supply chain connectivity amidst the COVID-19 crisis. Import tariffs on face masks have been temporarily eliminated in Argentina, Brazil, Canada, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, the European Union, India, Korea, Lao PDR, Malaysia, Pakistan, Panama, Peru, the Philippines, South Africa, Switzerland, Turkey, Ukraine, Uruguay, Viet Nam, and the United Kingdom.[19] It should be noted that in this list Colombia, Ecuador, Malaysia, and Ukraine have both banned exports and removed barriers on imports, which seems logical in order to maximise the availability of masks within the country, but raises the question of what happens if all countries do the same.

Export restrictions have three consequences. First, they prevent some countries with no production capacity from gaining access to masks. Second, they can backfire when countries holding masks need more or need to import other essential medical supplies (or inputs to manufacture masks). Export licenses and authorisations can discourage exports but also delay trade when the export is approved, which stands in contradiction to the emergency nature of the need – generally also one of the criteria for authorising exports. Third, export restrictions push prices up and foster illegal activities (black markets and scams).

Export restrictions can also create uncertainty that impacts firms' investment strategies. In China, several of the main producers of masks are foreign-owned firms. Factories of 3M and Honeywell (United States) or Medicom (Canada) were mainly producing for the Chinese market, but were also unable to export masks in January and February 2020. In France, the government requisitioned masks produced by the Swedish firm Mölnlycke and destined for other EU markets. The main producer of masks in France, Kolmi-Hopen, is also an affiliate of Medicom (Canada). Manufacturers of masks generally favour production close to consumers to build robust supply chains. For example, before the COVID-19 crisis, 3M already had a strategy based on local supply in Asia. Export restrictions could discourage these foreign companies from investing, denying the recipient country the benefits from foreign firms bringing the capital and know-how to create local capacity in the production of medical supplies.

Countries are also tightening investment screening for firms identified as strategic and that may be subject to hostile takeovers. For example, EU guidance issued on 25 March encouraged Member States to make full use of FDI screening mechanisms for investment in healthcare-related industries, and also encouraged Member States that currently do not have a screening mechanism to set one up.[20]

There is a need to find the right balance between protecting domestic firms from opportunistic acquisition during the crisis and avoiding barriers that will jeopardize future investment in the recovery phase. Measures such as nationalisations and expropriations – direct or indirect – could also have implications for future investment.

Trade and global production have an important role in addressing the current shortage

International trade and investment along the global value chain for face masks is an essential part of the policy response to the COVID-19 crisis in the short term. No country can meet the increased demand for face masks alone. Some countries have created new production capacity and supply is

[19] Source: Global Trade Alert, Market Access Map and WTO.

[20] European Commission, "Guidance to the Member States concerning foreign direct investment and free movement of capital from third countries, and the protection of Europe's strategic assets, ahead of the application of Regulation (EU) 2019/452 (FDI Screening Regulation)", C(2020) 1981 final, 25 March 2020.

expected to continue to increase as governments encourage firms to shift production and companies see new business opportunities. But some countries do not have the manufacturing capacity, the specialised machines nor, more importantly, access to inputs. As the shortage diminishes, the objective should be to restore a more co-operative and open trade environment where export bans are lifted and the face mask global value chain can fully deliver to all in need, particularly in countries where the epidemic is expanding.

Transportation and logistics infrastructure (especially air cargo) is critical. Materials to manufacture masks are usually transported by sea, but several manufacturers report having switched to air transport to ensure that deliveries are on time. This poses an extra cost, but one offset by higher prices for the masks.

But free trade and trade facilitation are not enough to solve the current shortage. An important increase in supply is required in the short-term, requiring government planning and incentives for firms to convert existing assembly lines and create additional capacity. Certification procedures should be expedited to allow masks produced by new companies to be traded as soon as possible. While the most efficient 'level 2' surgical masks can be reserved for healthcare workers (with N95 respirators for the most exposed of them), lower grades of masks could be used in other sectors or re-usable washable masks (as already recommended by some governments and health authorities).

Inputs are as important as final products. More emphasis should be put on the access to inputs and the development of capacity in the production of melt-blown polypropylene non-wovens. Governments should prevent hoarding and speculation: producers of non-woven fabric have reported receiving orders from companies not manufacturing masks wanting to resell at a higher price. Measures facilitating trade should also be extended to inputs and co-ordination across countries could facilitate specialisation and division of labour to avoid a situation where companies having invested in being able to produce masks are unable to do so because of limited access to inputs.

Open markets provide access to innovation. Maintaining open trade and investment during the crisis can facilitate access to innovation that can help in combatting the crisis. In the short-term, access to new technologies or products will occur through trade. For example, several companies are working on technologies to safely re-use face masks after a sterilisation process. An open trade environment is key for the diffusion of such technologies.

Ensuring provision of key medical supplies should be part of a global health strategy in the long term

Unilateral actions raise uncertainty and costs. Looking ahead, it would be excessively costly for each country to develop production capacity matching the demand observed during the crisis and encompassing the whole value chain. Lower demand in the absence of pandemic would not make the activity profitable and overcapacity would disrupt the world market for masks and trigger protectionist policies. While some countries could develop some kind of self-sufficiency, it is not clear that this situation would improve the supply of masks in another crisis, due to scale of the surge in demand. It would also be unrealistic for smaller or poorer economies to become self-sufficient in the whole array of protective equipment needed.

A multi-pronged approach is needed to mitigate risks. An alternative, more effective and cost-efficient solution may involve a combination of the development of strategic stocks, upstream agreements with companies for rapid conversion of assembly lines during crises and international trade. As masks can easily be stored over a long period (at least ten years), strategic stocks allow countries to manufacture or import a large quantity of masks over time and then be ready to meet a very high demand during crises. It is a cost-efficient strategy, as through global production and trade, costs can remain low and masks do not need to be bought in the middle of the crisis when prices soar. Stocks can also be built at the country level, through national strategies, but a globally co-ordinated approach could also ensure that all countries are prepared and create solidarity mechanisms that would further mitigate risks.

Countries seeking to develop local production capacity as part of a strategy to address future crisis, need to ensure sufficient local demand. Strategic stocks create such demand, but only with regular public or private procurement contracts. The regular use of masks in the population (as a protection against pollution or during the flu season) can also make production economically sustainable (and is one reason production capacity was higher in East Asia than in the rest of the world at the beginning of the COVID-19 crisis). Yet a crisis may be long and stocks insufficient, so contingency plans and strategies to increase supply during crises will still be necessary. Such strategies involve creating a list of companies that can potentially convert their production lines. These companies need to be prepared with the relevant capital investments and access to inputs (some of which will have to be imported). The government can co-ordinate such efforts and provide subsidies or financial incentives for private companies to participate in a contingency programme.

Robust supply chains require transparency, agility and reactivity. Robust supply chains can ensure that masks can be produced during a crisis by maintaining operations. This is achieved through firm strategies that prioritise risk assessment and planning, information sharing, redundancy in suppliers, agility and reactivity.[21] Some companies might prefer to rely on domestic suppliers to ensure the robustness of their supply chains. But creating constraints through trade and investment policy can result in limiting the options available for firms to maintain their operations (e.g. access to foreign suppliers for redundancy). Multinational enterprises generally have experience dealing with crises and disruptions in value chains and policies should support their efforts in building robust supply chains. A stable trade and investment environment offers them the visibility needed to manage risks.

[21] Brandon-Jones, Squire, Autry and Petersen (2014), "A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness", *Journal of Supply Chain Management*, Vol. 50(3), pp. 55-73.