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The mutual constraints of states and global value chains during COVID-19: The case of personal protective equipment

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ABSTRACT

Shortages of critical medical supplies during the COVID-19 pandemic have turned global value chains (GVCs) in personal protective equipment (PPE) into a political lightning rod. Some blame excessive outsourcing and foreign dependency for causing shortages, thus urging greater state intervention; others applaud GVCs for their flexibility and scaling up of production, while blaming states for undermining GVC operations. Using policy process-tracing and monthly trade data of seven PPE products across the US, Europe, China and Malaysia, this paper goes beyond the binary debate of either the 'failure' or 'success' of GVCs to show when and under what conditions states interacted with GVCs to produce mixed outcomes in provisioning countries with PPEs. We identify interactions between the type of state intervention and two key structural features of GVCs – geographic distribution of production and technological attributes of the product. Conceptually, the paper demonstrates the *mutual constraints* of states and GVCs, and highlights structural factors involved in the relationship. Looking to the future of GVCs, we caution against wholesale declarations that GVCs should be abandoned or maintained, instead concluding that paying attention to GVC structure, states and their interactions are crucial.

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1. Introduction

The outbreak of the COVID-19 pandemic in early 2020 threw unprecedented attention to global value chains (GVCs) in medical goods, particularly in personal protective equipment (PPE). For example, the once low-key, face mask seemingly became “the world’s most critical commodity” (Subramanian, 2020). Demand surged for such products given their potential to protect frontline workers (WHO, 2020) and citizens from the novel coronavirus. The scramble for medical supplies led to intense public debate over the role of GVCs in their production (Bamber et al., 2020; Gereffi, 2020). This controversy is significant for not just understanding what shapes the COVID-19 response, but also due to broader claims about the future of GVC-led globalization.

One dominant perspective, especially prominent in the United States and Europe, blames the offshoring of production through GVCs for creating foreign dependency and resulting in a failure to provide PPE and other medical products. Instead, they advocate

state interventions and even economic nationalism – in some cases reinforcing prior political objectives. On March 2nd, US President Donald Trump stated “the coronavirus shows the importance of bringing manufacturing back to America so that we are producing, at home, the medicines and equipment and everything else that we need to protect the public’s health” (The White House, 2020). Such sentiment is cross-partisan, to some degree at least, in the United States (Biden, 2020). It also is not limited to US politics. The European COVID-19 recovery plan issued by the Presidents of the European Council and European Commission in April 2020 articulated a “pressing need to produce critical goods in Europe, to invest in strategic value chains and to reduce over-dependency on third countries in these areas” (Von Der Leyen & Michel, 2020: 3). Beyond the political sphere, some experts also suggested that “the pandemic exposes the vulnerabilities of supply chains” (Asian Development Bank, 2020: 2) and argued that the struggle for medical supplies warrants finding a better balance between globalization and self-reliance (Stiglitz, 2020).

A counter-perspective, especially among economists, is that GVCs have not failed during the crisis and that the pandemic does not justify a rethinking of GVCs. Citing the example of Korean companies exporting COVID-19 test kits to more than 100 countries,

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OECD economist Sebastien [Miroudot \(2020a\)](#) argued “GVCs are rather robust during the pandemic” (p.126) in terms of innovation, distribution networks and flexibility, and he emphasised GVC’s “radically scal[ing] up of production of vital medical supplies” (2020: 117). Taking the blame off of GVCs, others have argued that surges in demand were the principal contributors to medical supply shortages, have questioned states’ “turning inward” during the pandemic and have suggested that more trade is part of the solution ([Baldwin and Evenett, 2020](#)). Those with positive interpretations of GVCs amidst the crisis have all criticized plans to move away from GVCs post-pandemic, including the European Union’s Director-General of Trade ([Leonard, 2020](#)), the European Commissioner for Trade ([Beattie & Brundsen, 2020](#)) and the World Bank’s Director of Trade, Regional Integration and Investment Climate ([Freund, 2020](#)).

Given this controversial debate, this article addresses two deeply intertwined questions regarding COVID-19 and medical GVCs, the most critical industries amidst the pandemic. First, were PPE GVCs effective or not during the pandemic? Second, how did states influence PPE GVCs?

We identify state actions and two structural features of GVCs (geography and technology) as critical factors during two stages of the evolving crisis. The first stage is a localized or ‘single-country’ crisis in China only, which runs from the outbreak of the initial health emergency there in January until the end of February. The second phase runs from March 2020 onwards, when the crisis became global and systemic (the World Health Organization declared a pandemic on March 11th 2020), and generated a global demand surge for PPE ([WHO, 2020](#)). We systematically examine the supplies of seven medical products - ventilators, thermometers, rubber gloves, medical garments, protective visors, N-95 masks and meltblown (the key input for N-95 masks) - within the two phases of the crisis. Our empirical analysis focuses on three primary centers of global medical supplies: China, Europe and the United States, along with Malaysia, the global center of rubber glove production.

The paper process traces state policies using media sources, government documents and Global Trade Alerts database. Also, building on prior qualitative-comparative applications of trade data in GVC research ([Dallas, 2014, 2015; Frederick, 2019; Sturgeon & Memedović, 2011](#)), we systematically unpack GVC dynamics through monthly US and EU trade data at the detailed 8- and 10-digit levels. Applying these data, we introduce an analytic framework which differentiates the ‘adaptability’ and the ‘effectiveness’ of GVCs during the two-phase crisis. This is done by comparing GVC operations during the crises to ‘normal’ operations, which we define as the monthly trade averages over a 60-month period (January 2015–December 2019), as a benchmark of what is typical.

The paper goes beyond the failure/success binary to show variations in the provisioning of PPEs during the two phases of the initial COVID-19 crisis. We argue that states and GVCs mutually constrained each other, although this varied widely by product, generating variation in PPE trade. By ‘mutual constraints’ we mean a circular relationship in which, on the one hand, state interventions influence GVC operations; but on the other hand, states are simultaneously limited by two *structural* characteristics of GVCs – the geographic distribution of production and the technological attributes of the product. Depending on the type of crisis and these two GVC structures, state policies proved to be either complementary, detrimental, or ineffective in PPE provision, even when states were maximally proactive. In some instances, structural features of GVCs constrained state actions and even led to policy reversals.

Conceptually, the paper builds on a growing body of literature on the state-GVC nexus. A dominant emphasis in much of the GVC literature is that states have little option but to play a facil-

itator role assisting firms in their territory to participate in GVCs (e.g. [Gereffi, 1994; Horner, 2017; Horner and Alford, 2019; Werner, 2020](#)). If ever there was a moment for decisive and effective state intervention in GVCs, the COVID-19 health emergency provided it, as states were highly motivated to secure as much medical supplies for their own populations as possible. While much literature conceptualizes states as ‘external shapers’ of GVCs, our understanding of ‘mutual constraints’ highlights a deeper interaction between states and structural features of GVCs. Future analyses and policy proposals to re-shape GVCs should consider how GVCs are structurally organized and operate in conjunction with state roles (which are product-specific), rather than blanket recommendations that GVCs should be dismantled or left alone.

The paper is organized as follows. [Section 2](#) explores theoretical literatures and advances our argument on the state and GVCs, before [Section 3](#) introduces our data and methodology. [Section 4](#) contains our empirical work, divided between the period of ‘normal’ state policies and GVC operations under a localized crisis, and then under emergency conditions in Europe and the US during a global, systemic crisis. [Section 5](#) concludes.

2. Global value chains and states

Since the 1980s, an amalgam of factors led to the major re-organization of production in the global economy, resulting in ever-increasing fragmentation of production and deeper specialization. Many production ‘tasks’ were internationalized and in need of functional re-integration ([Dicken, 2011; Feenstra, 1998; Gereffi, 1994](#)). Large-scale social forces have been proposed to explain this global transformation, such as the declining costs of information-technologies ([Baldwin, 2016](#)) and financialization ([Milberg & Winkler, 2013](#)). Regardless of the original causes, the end result of GVCs is that production is fragmented across geographically dispersed suppliers ([Gereffi, 2018](#)), while also embedded in particular locations ([Coe & Yeung, 2015](#)).

To understand this globalization of production and its implications for suppliers and workers, research on GVCs (and prior global commodity chains, or GCCs) explicitly broke with state-centric approaches to analyzing economic development and instead provided firm-centric perspectives focused on the novel forms of private governance ([Gereffi et al., 2005; Kaplinsky, 2005](#)). The GCC and GVC frameworks became popular analytical toolkits as the dominant economic development strategy switched from import-substitution to export-orientation ([Bair, 2005](#)).

In GVC literature, the state has mostly been understood as simply a facilitator in export-oriented development ([Gereffi, 1994; Horner, 2017](#)). Such a role involves states assisting firms, whether local or foreign-owned, to participate in GVCs, and occasionally supporting firm upgrading within GVCs ([Giuliani et al., 2005](#)). The facilitator role has also been the main emphasis of broad economic development and trade policy recommendations (e.g. [The World Bank, 2019](#)).

Different explanations exist as to why states adopted facilitator roles in GVCs. Most center on there being few alternatives for states to navigate globalization, given power asymmetries with transnational corporations ([Dicken, 1994: 123](#)). World Trade Organization (WTO) membership also limited the “development space” for states by restricting the use of certain policies, concerning foreign direct investment, subsidies, and intellectual property rights, among others ([Wade, 2003](#)). While this perspective emphasizes the limits globalization places on states ([Hess, 2008: 454](#)), others stress how globalization can ‘enable’ states ([Weiss, 2005](#)). Through liberalization policies, for example, states created the conditions for GVCs to emerge ([Gibbon & Ponte, 2005](#)). Certain states can even

choose to outsource different forms of governance to private actors (Mayer and Phillips, 2017).

More recently, states attracted growing attention in terms of their influence on GVCs, including their roles as regulator, buyer (through public procurement) and producer (state-owned companies), in addition to the longer-recognized facilitator role (Horner & Alford, 2019). Since the 2008–09 financial crisis, states have gained further relevance in GVCs as they grew more protectionist through means like discrimination against international business and selective subsidization (Evenett, 2019). The renegotiation of NAFTA, Brexit and the US-China trade war have all given the issue further momentum.

However, influenced by the inter-firm foundation of the framework, analyses of states' influence on GVCs have mostly focused on the state as an "external shaper" of GVCs. While the GVC framework conceptualizes states as external influences on value chains, the global production network (GPN) approach (Coe & Yeung, 2015; Henderson et al., 2002) situates states as actors within a network and offers greater attention to how states are in turn constrained by their position within GPNs. However, although some recent GPN research has begun to develop this understanding (Alford & Phillips, 2018; Smith, 2015; Werner, 2020; Yeung, 2016), this insight has been insufficiently elaborated in work on GVCs. In sum, the GVC literature generally conceptualizes GVCs and states as analytically distinct entities and, for the most part, understands states as externally acting upon GVCs, such as through regulation or facilitation.

Building on this growing literature, we demonstrate a deeper relationship between states and GVCs. While states undoubtedly influence GVC operations, we demonstrate the significant impact of key structural features of GVCs on state policies, which persists even in the most extreme circumstances involving some of the most powerful states (in Europe, China and US), when they were engaged in emergency policy-making during a massive crisis. In fact, structural constraints are perhaps most observable under crisis conditions, and may fade into background conditions during more normal times. Our use of 'mutual constraints' has three interactive features: 1) instead of stressing relationships between firms and with other individual actors at a more micro-level, it highlights the impact on states of structural characteristics of GVCs, in particular geography and technology, which are features resulting from the actions of numerous interacting firms over many decades, but not by any particular firms' intentional designs; 2) these structural features of geography and technology are empirically shown to constitute the outer boundaries within which state policies operate; and finally 3) within these structures, states facilitate, regulate or otherwise impact GVCs, but do so back at the micro-level of firms, dyadic linkages and chains.

It is important to note first that mutual constraints rest upon a differentiation between individual GVCs that are usually governed by one or two lead firm(s), and GVCs as emergent structures, which are not dependent on the behavior of any particular firms, even powerful ones – an idea developed in some GVC research (e.g. Feenstra & Hamilton 2006; Mahutga, 2019; Milberg and Winkler, 2013). Second, there is a certain non-equivalency between structural features of GVCs and state actions in that they do not directly interact. While individual or interlinked firms directly interact with states, GVC structures determine the outer limits of state action, but not by *directly* influencing state policy-making; likewise, the policies of individual states generally do not transform GVC structures, but they do impact firms, links and chains. Thus, schematically, GVC structures can be thought of as an outer layer that determines the contours, inside of which states and individual firms and chains interact. We highlight the mutual constraints of this state-GVC relationship, and demonstrate many empirical instances of it below.

The paper focuses on two structural features – the geography of production and technological complexity, both of which are well-known in GVC literature. First, the geography of production has long been recognized as a key characteristic of GVCs (Gereffi, 1994). Over the course of recent decades, trade through GVCs has generated an iterative deepening of cross-national specialization in production tasks, geographic agglomeration, and divergent pathways of national development (Feenstra & Hamilton 2006). Second, technology and the partitioning of knowledge across national borders have influenced GVC governance and organization. In some GVC research, technology (broadly defined) is recognised as a primary source of rents by erecting barriers to entry for developing country firms (Kaplinsky, 2005); in other research, it is a key determinant of GVC governance impacting the complexity and codifiability of inter-firm information (Gereffi et al., 2005). This paper focuses on the *relative* technological sophistication of PPE products and their substitutability.

Apart from GVC theory, the paper also builds on nascent policy (e.g. Bamber, Fernandez-Stark, & Taglioni, 2020; Miroudot, 2020b; Qiang, Li, Liu, Paganini, & Steenbergen, 2020; OECD, 2020a; OECD, 2020b; OECD, 2020c) and academic analyses of COVID-19 and GVCs, which are far more informative than sensationalist media headlines and political statements. A useful synthesis (OECD, 2020a) identifies four channels through which Covid-19 has impacted GVCs – halting production directly due to lockdowns, supply chain disruption due to lockdowns or transport disruption elsewhere, demand impact and trade and investment policy risk due to changes such as export bans. In addition to trade policy changes, and in contrast with other industries which experienced a collapse of orders and jobs (e.g. Tamru, Hirvonen, & Minten, 2020; Anner, 2020), our analysis examines cases of major spikes in demand. Our contribution builds on initial research which has successfully mapped PPE value chains (Bamber et al., 2020; OECD, 2020b), including the case of face masks in the United States (Gereffi, 2020), through a systematic analysis of trade patterns in key products and how states and GVCs interacted to produce varied outcomes.

3. Data and methodology

In addition to extensively utilizing media sources, government documents and the Global Trade Alert database, the paper's primary empirical contribution consists of a comparative, qualitative analysis of narrow product categories using detailed monthly trade statistics (8-digit and 10-digit) from Eurostat and the US Census Bureau. This work builds upon prior qualitative GVC research utilizing large-scale trade data (Dallas, 2014, 2015; Frederick, 2019; Sturgeon & Memedović, 2011; see Sturgeon 2019 for summary), including 'trade-data archeology' (Feenstra & Hamilton, 2006). Through keyword searches of US Census Bureau trade data and with the help of existing studies (e.g. OECD, 2020b; WTO, 2020), we identified the HS codes of seven medical products,¹ which were critical items during the early months of the pandemic and ones

¹ We use PPE as a short-hand because many products examined in the paper are PPE, including (with first the European and second the US Harmonized System codes in parentheses): N-95 respirators (90200000; 9020008000), protective visors (90049010/90; 9004900000), disposable medical garments (62101092/9092, 63079092; 6210100000, 6307909995), and rubber surgical gloves (40151100/1900, 39262000; 4015110100, 40151900, 3926201010). Other items include critical medical supplies which faced shortages in hospitals, including ventilators (90192000; 9019200000) and clinical thermometers (90251900/20/80; 9025198040). Finally, because it was impossible to find the upstream intermediate inputs for most of these products, we are able to include only lightweight man-made fiber meltblown of less than 25 g/square-meter (56031100; 5603110000) which is the key input to N-95 respirators. All of these trade data come from Eurostat and the US Census Bureau.

which governments most frequently targeted through interventionist trade policies (see [Global Trade Alert](#), 2020, hereafter GTA).

To conduct the analysis, the paper makes several assumptions about trade patterns under crisis conditions. First, it examines trade between countries over the early months of 2020, and compares that to a “typical” or average month of trade (value, quantity, unit prices) – defined as the simple average over the 60 months from January 2015 to December 2019. This timeframe is used to average out seasonal variations and exceptional events, so we can create a baseline of ‘normal’ trade. Second, although it is difficult to directly observe a country’s ‘true’ demand by observing trade data alone, another assumption of the paper is that during the COVID crisis, demand for PPEs should *always exceed* a typical or average month of imports. Third, because demand for PPEs skyrocketed simultaneously and worldwide, the paper primarily focuses on the major producing and exporting countries/regions (China, Europe, USA and Malaysia) and export trade policies. However, even for these major producing countries, including China, imports still provide critical additional supplies at the margins. This is why we primarily focus on trade, rather than individual countries’ attempts to increase domestic production. Indeed, our trade data confirms that import quantities (in tonnage) and prices often multiplied many times over, indicating that domestic production consistently fell short of demand, even for a country like China – the world’s manufacturing powerhouse.

A key feature of our analysis is the distinction between the ‘adaptation’ of GVCs from their ‘effectiveness’ in resolving PPE shortages. We identify a GVC as successful in ‘adaptation’ when it dynamically and flexibly adjusts to demand shocks – a moving target as the crisis turned systemic in March. In terms of measurement, a GVC *appropriately* adapts when import quantities (usually tonnage) of a product increases even when the crisis hits, relative to an average month from 2015 to 2019. Furthermore, GVC adaptation is considered exceptional if unit prices remain relatively stable compared to a typical month. However, even if GVCs appear to appropriately adapt to crisis-induced demand shocks, they still sometimes prove *ineffective* in provisioning sufficient quantities (tonnage) to the crisis-hit country – often due to structural factors that are endogenous to the GVC itself and the scale of the demand spike under crisis. These include the geographic structure of global production, and a product’s technological attributes, including upstream–downstream interactions.

A brief example may help to illustrate the important distinction between GVC adaptation and effectiveness. In January, European suppliers certainly proved adaptable by exporting 15 tons of medical garments to China under lockdown, which astonishingly is *seven times more* than a normal month (2015–2019). However, this seven-fold increase was still essentially ineffective given that a typical month of China’s exports to Europe averages 2230 tons. Differentiating adaptability and effectiveness is important because GVCs were often quickly blamed whenever supplies fell short of crisis demands. We push against this binary ‘success/failure’ rhetoric partially by distinguishing GVC adaptation and effectiveness as two distinct concepts.

4. The mutual constraints of GVCs and states under two phases of the COVID-19 crisis

This section empirically examines the mutual constraints of states and GVCs – first during January and February’s localized crisis in China (Section 4.1) and then under a systemic crisis starting in March in Europe (Section 4.2) and the United States (Section 4.3). Between February and March, state interventions (especially in Europe) also fundamentally shifted from ‘normal’ politics that lar-

gely complemented GVCs to ‘emergency’ beggar-thy-neighbor politics under a systemic crisis.

Overall, this section finds that GVCs appropriately provisioned China in January and February when the crisis was localized and state policy was complementary with GVCs. With the exception of meltblown, PPE value chains flexibly adapted as one might predict, and effectively assisted a single country in crisis.

However, as the world moved into a systemic crisis – a truly global demand shock – the picture becomes empirically more muddled, but also GVC structures became more impactful in terms of the constraints they imposed. With the notable exceptions of rubber gloves and US ventilators, most GVCs either proved ineffective or maladapted under conditions of systemic crisis, coupled with emergency state policies and the structural constraints GVCs imposed on them. Of course, a truly systemic and global demand shock is something that any organizational arrangement would have difficulty solving quickly, and so GVCs must be appropriately judged within this unprecedented context.

4.1. Mutual constraints under localized crisis in China: Complementarity between states and GVCs

Following the first reports of a “viral pneumonia” picked up by the WHO’s Country Office in China on December 31st, and initial major lockdowns in the country on January 23rd, GVCs adapted quickly and appropriately to the localized crisis by provisioning China with N-95 masks, ventilators, clinical thermometers, rubber gloves, protective visors and disposable medical garments. Price data also reveals that foreign suppliers profited handsomely in some products. GVCs proved maladapted and ineffective only in meltblown during January and February’s localized crisis, even with highly accommodative state interventions (Fig. 1).

However, despite their successful adaptation, American and European suppliers were only able to *effectively* contribute to China’s supply shortages in N-95 masks, ventilators and thermometers; and Malaysia effectively provisioned China’s shortage in rubber surgical gloves. In visors and garments, China’s demand was equally enormous. However, global production in medical garments and visors are already geographically concentrated in China – 53% for the former and 54% for the latter in 2018 (UNComtrade), which are conservative *under-estimations*.² Thus, in garments and visors, there was no practical alternative but for China to be ‘self-reliant,’ even before the crisis turned global and systemic. Despite its prodigious capacity to scale up production, we know China still experienced shortages because of the many-fold increases in imports of garments and visors (see Section 4.1.3 below).

Before turning to product-by-product analysis, it is worth noting that during January and February, some governments actively facilitated exports of medical goods to China, surprisingly even the US. For instance, the office of US Representative Katie Porter noted that “as recently as March 2, the Trump Administration was encouraging American businesses to increase exports of medical supplies, especially to China” (2020: 1–2). Indeed, the *Washington Post* (2020) reported (April 16th) that the US Embassy in Beijing was emphasizing the services it was offering to supply US PPE to China as late as March 3rd. Thus, when the crisis was still widely believed to be China-centered, some US government agencies considered the crisis in China to be a market opportunity for American medical industries.

² This is because we treat European countries as individual countries, rather than a bloc, leaving intra-European trade disaggregated. China’s share (and Malaysia’s in rubber gloves) would be significantly higher if the EU was considered a single bloc (country) and all intra-EU trade was removed from our trade totals.

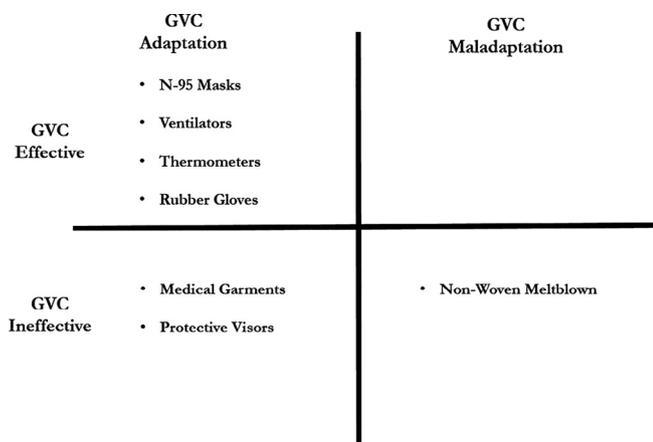


Fig. 1. GVCs under Localized Crisis and Normal GVC Politics in China. Source: authors' construction based on analysis in section 4.1.

4.1.1. Successful adaptation and effectiveness – ventilators

If there is a single product which reflects the ideal of successful GVC adaptation and effectiveness under the localized crisis in January and February, it is perhaps ventilators, the expensive and complex machines for patients with severe breathing problems. European and US firms jumped at the opportunity to ship ventilators to China in February, and unit prices even remained stable, unlike other PPEs. For instance, between 2015 and 2019, Europe exported to China (including Hong Kong) a monthly average of €6.75 million in sales, and weighing 42.6 tons with an average price of €158,000 per ton.³ While January 2020 saw little deviation from these averages, European exports of ventilators to China more than doubled in February 2020 to €17.25 million but with a minor price increase of only 20.3%. This price hike may sound substantial, but is actually less than half of typical or average monthly price swings (positive or negative) of 44%.⁴ US exports essentially mirror Europe's, but at much larger scale, jumping 400% from a normal \$12.4 million to almost \$50.5 million in February and even remained at 270% above normal throughout March. Under systemic crisis in March, European ventilator exports to China in tonnage (nearly 50 tons) still exceeded the monthly average of 42.6 tons.

4.1.2. Adaptation and effectiveness in the meltblown-mask value chain – A mixed picture.

Meltblown⁵, the crucial upstream input, and N-95 masks⁶ adapted to the crisis in starkly opposite ways. Considered as a solo product in its own right, meltblown represents our only example of poor GVC adaptation and effectiveness in January and February.

³ 'China' always includes Hong Kong since much of China's imports and exports flow through the city. While this introduces some error, we find that not doing so introduces even more error and anomalies.

⁴ Even removing four major outlier months of price swings, all in excess of 100% (one month even as high as 400%), the average price swing is still 28%.

⁵ Meltblown is a non-woven fabric made of man-made fibers and the key ingredient for masks – involving plastic filaments which also go into a variety of other products such as jackets, nappies, air conditioners and more. Meltblown is a mesh of synthetic polymer fibers which composes the inner (filtration) layer of a mask. The layers in a mask, including the filter, are usually formed from polypropylene which is turned into 'melt' and then 'blown' into rolled sheets, thus known as meltblown.

⁶ Medical masks come in three main types – disposable procedural, disposable surgical and respirators. The surgical masks are sterile, while the procedural ones are not. Unlike the respirator masks, neither of the two disposable masks play much role in protecting the wearer from inhaling infectious airborne particles. The well-known N-95 mask (similar to the EU FFP2 standard) can filter up to 95% of particles and is intended to filter out bacteria and viruses (Fiorini et al. 2020, 65). Although it is often hard to know which type of "mask" is being referred to in media reports (unless specifically stated), our trade data focus on respirators, except for Section 4.3.

Because meltblown production is capital-intensive with large scale economies, its technological rigidities meant that scaling up requires substantial time, costs and specialized knowledge. Luckily and by comparison, N-95 masks were well-provisioned to China during the early crisis, providing time for meltblown producers to catch up. Thus, one's judgement of their adaptation and effectiveness depends on whether to evaluate them as separate products or together as a single up-downstream value chain.

Compared to other PPEs, China was simply not appropriately provisioned with meltblown from abroad in January and February. Europe and the US actually supplied China with less than normal amounts of meltblown in those months. Europe supplied China with only 55 tons by the end of January, far lower than a normal month of 209.5 tons, and the supply volume remained at less than 1/3 of the normal monthly average in February. Total US exports of meltblown to China in January and February also fell below the average by 40% and 10% respectively. Price data do, however, reflect China's skyrocketing demand for meltblown. The average price for one ton of China's meltblown imports from Europe rose from a normal monthly average price of €4160 to €9000 in January, and by another 23.5% in February to €11,100 per ton.⁷ If skyrocketing European unit prices are any indication, these US percentages likely over-estimate the actual tonnage exported to China.⁸ Although future research is needed to explain this trade paradox, meltblown GVCs clearly did not quickly adapt to market pressures. It should be noted that no country imposed export restrictions on meltblown itself, so trade politics seemingly played little role in this shortage – one of the few GVC failures, unadulterated by trade policy.

Although GVCs proved ineffective, the Chinese state took matters into its own hands by mustering substantial resources to make up the difference through playing a producer role under the guidance of its petroleum state-owned enterprises (SOEs). PetroChina and Sinopec were immediately galvanized to serve as direct state producers in January, and to provide polypropylene and polyvinyl, the raw materials for both meltblown cloth and other non-woven man-made fabrics (Liu, 2020).⁹ By early March, Sinopec setup two production lines in Beijing for meltblown fabrics, which could be used to produce four tons of fabric per day, which in turn could provision "1.2 million N95 respirators or six million surgical masks a day" (Bermingham & Tan 2020, March 12).¹⁰ Sinopec also invested 200 million yuan in ten meltblown production lines, which were provided by its subsidiary Yanshan Petrochemical (Feng & Cheng, 2020). One report (Feng and Cheng 2020) quoted a staff member at Xuzhong Guozhong (a major supplier of meltblown in Hubei province) that the cost of meltblown had gone from less than \$6000 a ton to \$60000 – nearly identical to the prices charged by European firms in our trade data.

Despite the large resources mustered by SOEs, meltblown is a technically sophisticated and capital-intensive product, meaning that there are production rigidities in the value chain to transform raw chemical fibers into blown fabric. The machines to make

⁷ Since China's decision to lockdown was so unforeseen, if price data were available only for the very last week of January, it would surely have been much higher.

⁸ European exports in Euros are about 2 to 2.5 times higher in January and February compared to in tonnage terms (given the price increases), and even measured in Euros, meltblown exports were only 57% and 81% of a normal month.

⁹ In another indication of the seriousness of the Chinese government's response, Pinghui and Xin (2020, 3rd February) report that while the Ministry of Industry and Information Technology had initially been responsible for provision of face masks, they were replaced by the more central, inter-ministerial National Development and Reform Commission (NDRC). The switch was prompted by the shortages of protective equipment.

¹⁰ In a usual year, three million tons of nonwoven fabric are produced in China, with less than 1% of that meltblown, according to Feng and Cheng (2020, March 16) who cited a statistic from the Nonwoven and Industrial Textiles Association.

meltblown, which melt plastic material into flat sheets of fabric for face masks and other products, are costly. One report suggested a price of €3.8 million (\$4.23 million) each and quoted a sales director at Haigong Machinery, which assembles machine parts for meltblown lines from imports, as saying: “everyone is considering mask manufacturing, but they don’t understand the process. Once they learn the cost of these machines, they give up” (Feng and Cheng, 2020).

N-95 masks offer a very different story, in that US and European firms fortunately were able to make up for the failures in meltblown. Fig. 2 visually illustrates that the upstream meltblown and downstream masks adapted in starkly opposite directions, illustrating the technological rigidities of the former and the greater flexibility of the latter. In a normal month, Europe exports about 10 tons of respirators to China at nearly €106530 per ton. Even as early as January, although prices remained almost unchanged, Europe shipped about 90% above an average month. Even as February prices declined to €84000 per ton, an astounding 188.5 tons of masks – over 1800% more than normal – were shipped to China. To put this in context, the volume of average monthly exports of respirators from China to Europe is about 25 tons and, in 2019, the highest export volume in any single month was 61 tons in October. American exports of masks to China largely mirror European, except they “only” exceeded a normal month by 400% in February and 250% in March (in dollar terms). Furthermore, even with the onset of a systemic, global crisis in March and the erecting of Europe-wide export bans and licensing in masks, Europe still managed to export nearly 28 tons – a severe reduction compared to February, but still over 180% more than an average month (though prices increased to a degree too).

Although the Chinese state was positively proactive in scaling up production, there were also reports of requisitioning of PPE supplies from foreign firms located in China. While this quickly became a global media frenzy with allegations of hoarding, a number of press releases by companies in China lend some credence to these claims, especially considering the inherent risks to firms in criticizing government policy. These include reports by UK-headquartered JSP group (JSP, 2020) concerning the requisitioning of their two China factories to make respiratory protective equipment (JSP, 2020), by US-owned 3M which reported that the Shanghai municipal government took control of some of their facilities (Eilperin et al., 2020), and by Taiwanese-owned Makrite that their facilities in Hubei and Dongguan had been commissioned by the Chinese government (Makrite, 2020). Thus, the Chinese state intervened in GVCs in multiple ways. However, given that the crisis was still considered localized in China, such forceful requisitions were not nearly as detrimental to GVC operations as under a systemic crisis, when European and American governments began their own game of requisitions.

In summary, GVCs adapted successfully for N-95 masks as Western countries supplied China rapidly and, even with favourable price declines in February, were also effective in terms of sheer quantities. By contrast, meltblown failed as a standalone product due to technological and production rigidities, leading US and EU provisions to fall universally short for the critical month of February, even though prices rose substantially. Chinese SOEs tried to rapidly increase production, but technological rigidities imposed time constraints.

However, if considered in combination as a single value chain, the adaptability of N-95 masks bought China and the world precious time for new meltblown production to come online, whether those built by Chinese SOEs or foreign multinationals. Then, once the upstream meltblown had a chance to catch-up to the evolving crisis, it helped ameliorate the situation when the world entered a truly systemic crisis in March. Of course, because meltblown is used so broadly across many products, the upstream input and downstream final masks were able to play even more complementary roles, compared to other products in which up-downstream linkages are much more asset-specific. Thus, the complementarity and good timing of the meltblown-mask linkage is not a general feature of all GVCs, but only of this particular one.

4.1.3. Ineffective adaptation in medical garments and visors, and the special case of Malaysian rubber gloves

Although GVC provisions of medical garments, visors and rubber gloves seem to mirror the complementary relationship between China and the US and Europe in ventilators and N-95 masks, they proved to be ineffective during China’s February crisis. In all three products, both European and American firms adapted ‘appropriately’: Europe and US exports of rubber gloves to China increased by 1000% and 2335% in February, respectively; protective visor exports rose 600% and 900%; and medical garments rose a seemingly unbelievable 62,736% from Europe and nearly 2000% from the US. However, these increases are merely a function of the incredibly small amounts that are normally exported to China. Neither the US nor Europe exports more than 1 million Euro or dollars’ worth of visors or gloves to China in an average month. And as mentioned previously, Europe exported nearly 13,000% more of medical garments even when measured in tonnage. But this minuscule 15 tons of European exports in February contrasts with China’s average monthly exports of over 2230 tons to Europe. Thus, both Europe and America could never ‘effectively’ provision China, even if firms adapted appropriately. Furthermore, these data imply that despite China’s emergency scaling up of domestic production, Chinese demand still far exceeded supply, leading the country to soak up global supplies. The key difference is that the geographic structure of production meant China had only itself to rely on in a crisis.

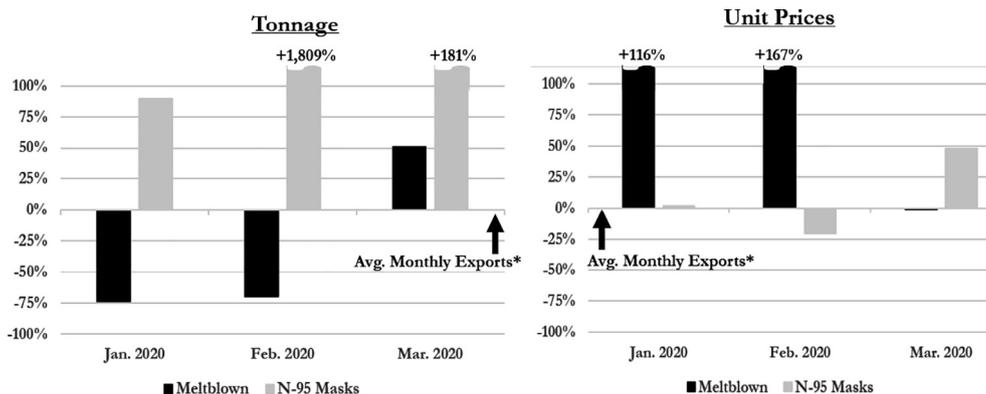


Fig. 2. EU Exports of Meltblown and N-95 Masks to China, January to March 2020.

Rubber surgical gloves are different despite also being a light, technologically simple product. Malaysia, the global leader in rubber gloves, almost certainly made up for what the US and Europe could never provide. Like for much of the world, 47% of Europe's US\$2.68 billion in imports (in 2018) of surgical rubber gloves comes from Malaysia, as does 61% of the US's \$2.5 billion and 71% of China's imports (UNComtrade). Malaysian firms also dominate the industry, including appropriately-named Top Glove, Hartalega, Kossan, and Supermax (Bamber et al., 2020). Detailed data on monthly Chinese-Malaysian trade were unavailable. Yet it is reasonable to assume that China was well-provisioned by Malaysian exporters, given that they very effectively supplied Europe and the US from January through June at prices even below normal monthly prices, while also increasing exports by 30–50% (see Section 4.2.1 below).

4.1.4. Localized crisis summary

In sum, during the single-country crisis, most GVCs adapted well, given the complementary state policies, including EU and US state facilitation of exports and China's direct production through SOEs. However, in a couple of cases (garments and visors), GVCs appropriately adapted but ultimately proved ineffective, forcing China to be self-reliant— not because of ill-advised trade politics but because of GVC geographic concentration there. Meltblown was the only relative failure in terms of both GVC adaptation and effectiveness, due to technological rigidities. Even highly proactive state policies were not able to reverse these constraints, as evidenced by China's best efforts with SOEs and their alleged attempts to requisition foreign-owned factories in China.

4.2. Complex mutual constraints under systemic crisis: State intervention and GVCs in Europe

This section examines GVCs and states under a global, systemic crisis with a focus on Europe. The continent is a major PPE buyer and producer and witnessed considerable trade interventions in March as the COVID-19 crisis spread. We show that under systemic crisis conditions, the mutual constraints of states and GVC structures became much more empirically evident, and even were used to justify policy decisions.

Many European countries initiated unilateral export bans and licensing restrictions on medical products, which are legal under WTO regulations during health and other emergencies (Hoekman et al. 2020). Italy was the first European country (February 26th) to unilaterally impose export licensing on PPEs (GTA), and was quickly followed by other countries central to production of medical supplies in Europe, including France, Czech Republic, Germany (March 4th) and Poland (March 20th). If legislation was insufficient, Europe (like China in February) also witnessed some government-initiated requisitions in March (Fiorini et al. 2020).

Facing national-level beggar-thy-neighbor trade restrictions, the European Union stepped in to regularize the trade tension. On March 15th, the European Commission reversed course by adopting a single, common EU-wide export licensing scheme, meaning that individual European countries could drop their national trade protections, and instead rely on European-wide regulation. The European Commission was explicit that structural factors, principally the geographic distribution of GVC production, drove their policy decisions, stating, "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" (EC, 2020/402). A subsequent regulation (EC, 2020/426) five days later aimed to expand the March 15th regulation to also include the European Free Trade Association (EFTA) countries, incorporating Switzerland, Norway, Iceland and Liechtenstein (hereafter, "Euro-

pean" trade refers to EU countries plus these four, but excludes the UK, see footnote 12). They acknowledged:

"the single market for medical and personal protective equipment is closely integrated beyond the boundaries of the Union, and so are its production value chains and distribution networks... consequently, subjecting exports of certain personal protection equipment to these countries to an export authorisation would be counterproductive, given the close integration of the production value chains and distribution networks."

The EU's 2020/402 regulation was truly global, impacting 1382 country-products, while 2020/426 impacted an additional 138. On April 24th, these acts were extended for another month to expire May 26th. Finally, Switzerland (March 26th) and Norway (March 27th) quickly passed legislation to ensure there were no weak links in Europe's production–distribution system.¹¹

Internal trade policy changes and tensions still inflicted substantial damage to intra-Europe PPE trade in March, despite the March 15th and 20th interventions which re-liberalized intra-Europe trade, while controlling its external (non-European) trade. In nearly all PPE products (except rubber gloves due to Malaysian supply), there was a net detrimental *decline* in Europe's import tonnage of critical goods, just as the crisis reached a climax. The near universal decline in total European imports across PPEs, despite the critical need, implies that the crisis had become truly systemic in nature. The cascading beggar-thy-neighbor trade policies in Europe are a symptom of the systemic nature of the crisis, but our data shows they also substantially worsened it. It is quite clear that intra-Europe trade relations deteriorated *far more* than Europe's trade relationships with other countries, including China, Malaysia, the US and all other foreign, 'extra-Europe' countries, which also includes the UK by March 2020.¹²

Fig. 3 illustrates the detrimental impact of European policy interventions. In every product *except* rubber gloves, total European imports in tonnage fell below a normal average month and in some cases, very substantially below, like meltblown (–42%), protective visors (–36%) and disposable medical garments (–29%). In the midst of a medical crisis and given that many PPEs are meant to be disposable (thus requiring regular and smooth replenishments), these are disastrous shortages.

However, if Europe were left to its own devices, things would have been much worse. This is because intra-Europe imports fell far more dramatically than European countries' imports from outside the continent (Fig. 3). Clinical thermometers provide a compelling example as intra-Europe imports fell by 63% but imports from beyond Europe increased by 41% in tonnage. A similar phenomenon happened in surgical gloves (intra-Europe: –46%; extra-Europe: +30%) and masks (intra-Europe: –18%, extra-Europe: 26%). Ventilators appear to remain unaffected by the crisis, but as explained below, it is the exception that proves the rule

¹¹ They independently passed legislation to concord with the EU's acts, necessarily imposing their own export licensing schemes, impacting a further 56 and 8 country-products, respectively.

¹² Because the detailed Eurostat trade data (like other trade data) rely on the country that 'declares' what and how much was traded (the 'reporter' or 'declarant'), "Europe" excludes Switzerland, Norway, Iceland and Liechtenstein, which are minor as producers of PPEs – although all of them are included in the EFTA. But, "Europe" also excludes the UK because by exiting the EU in January 2020, it no longer reported February and March data. Thus throughout the trade data analysis, the UK is excluded as a 'reporter' ('declarant') because by exiting in Jan. 2020, it does not permit comparisons before and after 2020. It is included as a 'partner,' in common with all other foreign traders with the EU. However, all of these countries are picked up in our trade data, just like any other foreign exporter to the EU. This analysis includes the following 14 foreign countries as 'extra-EU' trade which constitute the vast majority of non-European imports: Australia, Canada, China, Hong Kong, Iceland, India, Japan, Republic of Korea, Malaysia (for gloves only), Norway, Singapore, Switzerland, UK and US.

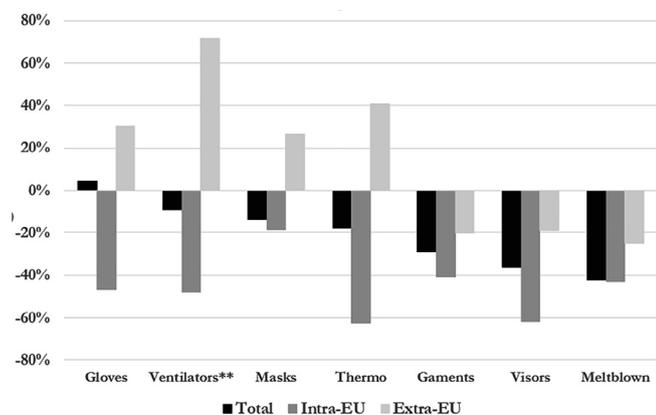


Fig. 3. European Imports in March as a Percentage of Average Month.

because Europe is supplied in equal measure by China and the US. These two countries not only supply technologically very different ventilators, but also were under contrasting COVID-19 conditions and policy regimes in March. Of course, non-European supplies also failed in meltblown, medical garments and protective visors, so there is much variation across products, which cannot be explained by European policies alone, but can be when combined with GVC attributes.

Nevertheless, it is critical to keep in mind that the nearly global and systemic nature of the crisis in March meant that it would not be easy for other countries to make up the difference in sufficient quantities. Thus, during a systemic crisis, GVCs must be judged by their *relative* success in coordinating production and distribution in Europe. Although essential PPE production and medical supplies distribution (including retail) was prioritized by national governments, one would still expect serious degradation of GVC operations everywhere given the huge spike in demand.

We now turn to the product level analysis in March. Under common crisis conditions, what is their *relative* adaptability and effectiveness, and how did our three key factors (state intervention, geographic distribution and technological complexity) shape this?

4.2.1. Adaptive and effective - rubber gloves

Rubber gloves continued to be the unvarnished model of PPE provision even under systemic crisis, due to a combination of enlightened Malaysian policies, the geography of rubber GVCs, and its flexibility as a light industry. First, the geographic concentration of production for this GVC in Malaysia is striking, with a global average of 56% of total imports across all countries in 2018 (UNComtrade). Second, unlike China, Malaysia is a small country with limited domestic needs, relative to its out-sized market share. Finally, the Malaysian government's policies were highly facilitative of GVCs. Even by late May, Malaysia had reported just over 100 deaths and 7000 cases of COVID, with respectably high levels of testing (~14,500 per million).¹³ While Malaysia did initiate a partial lockdown on March 18th called the Movement Control Order, the government explicitly considered its GVC linkages in offering special permissions to ensure the continued operation of selected globalized industries. Arumugam (2020) reported that Senior Minister and Minister of International Trade and Industry and his ministry "reviewed the additional sectors that are allowed to operate based on [their] importance in the global value chain or GVC and the country's exports."¹⁴ Thus, the high concentration of

the rubber glove industry in a small country with limited domestic demand and with competent, GVC-targeted policies functioned incredibly well, even in a systemic crisis.

Altogether, as a result of these factors, rubber gloves were the only PPE product where there was an increase in aggregate European supplies in March (Fig. 3). Under normal, non-crisis or even localized crisis conditions, this is what one might expect from GVCs. But, under a systemic crisis, it was only fulfilled in rubber gloves, and almost all of it by Malaysia. In sheer tonnage in March, Europe imported 23,000 tons of rubber gloves which is 51% more than the normal 15,000 tons/month. Even more astounding, average unit prices were even slightly below the normal monthly average by 10%, meaning that Europe received more, for slightly less, even in crisis. Even China, suffering its own crisis and with a massive domestic population, was at least able to continue to supply its average quantities of rubber gloves to Europe in March, without increasing its prices. However, China was unable to meet any of Europe's increased demand. Only Malaysia's large global suppliers (along with sagacious government policy) both appropriately adapted and had effective capacity (Fig. 4). Considering rubber gloves in isolation, one would be hard-pressed to observe any problems with GVCs or state behaviors at all, even in a systemic crisis.

4.2.2. Adaptive but ineffective - masks

The provision of N-95 masks adapted in similar ways to rubber gloves, but supplies were insufficient to even meet a normal month of European imports, let alone additional emergency supplies. Thus, GVCs proved adaptable but ineffective (Fig. 4). For N-95 masks, an increase in non-European sourcing of 26% helped balance off the decline in intra-Europe trade (-18%). But the 100 tons which arrived from outside Europe in March (at a price hike of 45%) simply could not do enough in what is normally nearly 750 tons of total European monthly mask imports, and thus total mask tonnage declined. Masks are also unique in that they are the only PPE item which both retail consumers and medical institutions were desperately trying to source, putting further pressure on demand. By March, people and hospitals in the US were also much more actively sourcing masks and, unlike in ventilators (below), US exports of masks to Europe declined. Despite doubling, Chinese supplies proved insufficient. Thus, the relative technological sophistication of N-95 respirators (compared to simple masks, discussed below), Europe's normal reliance on internal production and the damage of European trade policy all conspired to ensure they were ineffectively provisioned.

4.2.3. Maladaptation but effective - clinical thermometers

Clinical thermometers present a unique case of *relatively* effective provision (in tonnage) but poor adaptation (to price incentives). Overall, Europe had to make do with 17% fewer imports than normal, which in relative terms, is moderate, although problematic during a crisis. Fortunately, non-Europe imports rose 41% in tonnage, as European trade plummeted by 63%. However, price incentives went in the opposite direction: European supplies were 52% more expensive than normal, but extra-European prices remained largely unchanged. Assuming intra-Europe and extra-Europe imports compete in a unified thermometer market, one might normally expect price convergence under common conditions. Since this did not happen, one might expect the substantially higher intra-Europe prices to incentivize increased exports from intra-European suppliers, and unchanged extra-Europe prices should not; in fact, the opposite happened. In this way, European suppliers failed to properly adapt to price incentives.

However, this paradox may be due to differences in technology and market segmentation. Although intra-Europe trade declined by 456 tons, China's exports to Europe increased by 246 tons, allowing

¹³ See: <https://www.worldometers.info/coronavirus/#countries> Accessed May 25, 2020.

¹⁴ Arumugam (2020), New Straits Times, April 10th, 2020.

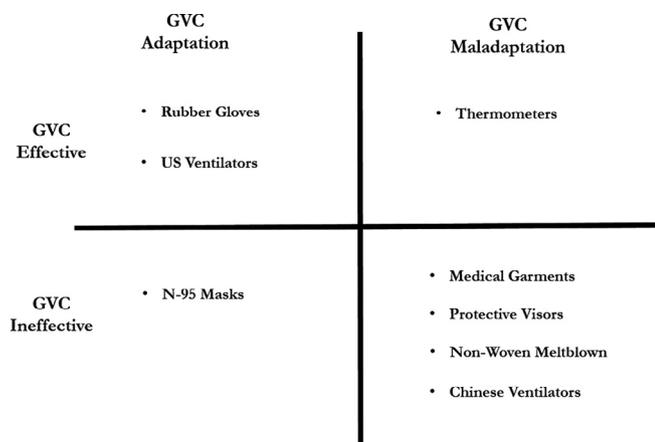


Fig. 4. GVCs Under Systemic Crisis and Emergency Politics in Europe.

relatively effective supplies. This may be because Europe procures cheaper thermometers from China, where average unit prices (2015–2019) are only €29,000/ton, compared to more expensive US (€148,000/ton) and German (€53,000/ton) ones.¹⁵ The flexibility of China-centric GVCs and their capacity to ramp production may be due to the relative technological simplicity of their thermometers.

4.2.4. Ineffective and maladaptation – garments, visors and meltblown

Garments, visors and meltblown provide a common story, in that they were completely undersupplied in the crisis, including from non-European suppliers. However, different reasons underlay these shortages.

In the cases of medical disposable garments and visors, the geographic distribution of production is key. Much like the rest of the world, Europe is also considerably dependent on China. However, unlike much smaller Malaysia, China’s inability to provision Europe in March implies that it was still pre-occupied with self-provisioning. The challenge of garments and visor PPE provision is also shaped by being regularly disposed, requiring constant replenishments.

For medical garments, European countries import 43% of their needs from each other, but China provides an astounding 96% of the remaining shares in a normal month (in tons). Since China shipped 20% fewer garments to Europe in March (at a 56% price premium) and as European countries were in trade conflict with each other, the continent had available almost 30% less garments.

An identical story repeats in protective visors. Europe supplies only 40% to itself, and China fills 62% of the remaining portion. With Chinese imports dropping 52% to only 342 tons (at 60% price premium), and European trade even more severely restricted, Europe had 36% fewer visors than normal in March. Thus, the concentration of garments and visors in China – a huge country under crisis – meant GVCs were unable to adapt, given the sheer dependency involved.

Lightweight, man-made fiber meltblown is quite different partly because Europe is largely self-sufficient, possessing a very different geographic distribution than garments or visors. Also, given its capital and technology intensities, the additional production lines of meltblown do not appear to have come on stream in March, as extra-Europe supplies still declined by 25%. Like other products, the decline in non-Europe imports pales in comparison to the 43% decline within Europe. Moreover, non-Europe imports of this type of light-weight meltblown constituted only 5% of Eur-

ope’s available imports in March, so are unlikely to have made much of a difference anyway. In contrast with the failures to supply Europe with garments and visors, the failures in meltblown were purely European. Since European states did not individually intervene in meltblown, this is purely the result of GVC technological rigidities and geographic distributions.

In all three cases in this section, the causes of GVC ineffectiveness are structural features of GVCs. States would have had few resources to affect the outcomes, apart from pre-emptive stockpiling.

4.2.5. Effective and ineffective – two tales of technology in ventilators

We end this section with what, on the surface, appears to be the strange case of ventilators. Looking at the overall data, it appears that there was no systemic crisis at all. Granted, intra-Europe tonnage declined like all other goods, but only by a very mild 17%, and foreign supplies rose by a negligible 2% meaning that March proved to be an average, uneventful month. But, in the midst of a crisis, how is such stability possible?

First, the crisis was not yet fully systemic: China was in lockdown, but the US still had not taken lockdowns seriously, and Europe sources almost all of its extra-Europe ventilators from either China or the US. Second, like thermometers, the US and China supply technologically very different products. The average unit price (2015–19) of Chinese ventilators is only €16,000/ton, whereas US ventilators cost €50,000/ton. Nevertheless, it appears that Europe bought considerable amounts of both kinds of ventilators in March, though the capacities of China and the US to provision European demand were starkly opposite. European imports of ventilators from China were 47% below normal in March, while the average price of such ventilators leapt nearly 50% in March. Thus, the supply was maladaptive and ineffective (Fig. 4). The US was just the opposite, in that 72% more ventilators (in tons) were imported to Europe and without a price change. Nevertheless, this case study shows that if ventilators are analysed as a single category, they counter-intuitively seemed to exhibit no impact from the crisis. However, once they are differentiated by technological sophistication (China and US), the impact of the crisis becomes very evident.

4.2.6. Systemic crisis summary

The systemic crisis laid bare more starkly the mutual constraints of states and GVCs. European countries sequentially imposed detrimental beggar-thy-neighbor policies until the European Commission re-liberalized European trade, justifying this move as conforming to GVC geography. Nevertheless, Europe was fortunate to be well provisioned by suppliers outside the continent, as intra-Europe trade declined sharply. However, the relative adaptability and effectiveness of GVCs still were always product-specific.

4.3. Inadvertent complementarity: China’s early GVC recovery and delayed reactions in the US

This section focuses on the US’s experience as its federal government belatedly began to take the PPE crisis seriously. Surprisingly, we find that despite the acrimonious rhetoric, GVC operations between China and the US were often highly adaptive and effective in addressing the American crisis. This is partly due to the early recovery of China, loosening its pandemic control restrictions by April, a timing which facilitated its role in addressing the US’s PPE crisis. By contrast, the US federal government was only beginning to face reality. After much reluctance and denial, on April 2nd, the Trump administration finally invoked the Defence Production Act to require production and distribution of various PPEs.

¹⁵ We assume that the primary reason why Europeans would purchase US thermometers that are five times more expensive than Chinese ones, is due to their higher quality and technological sophistication.

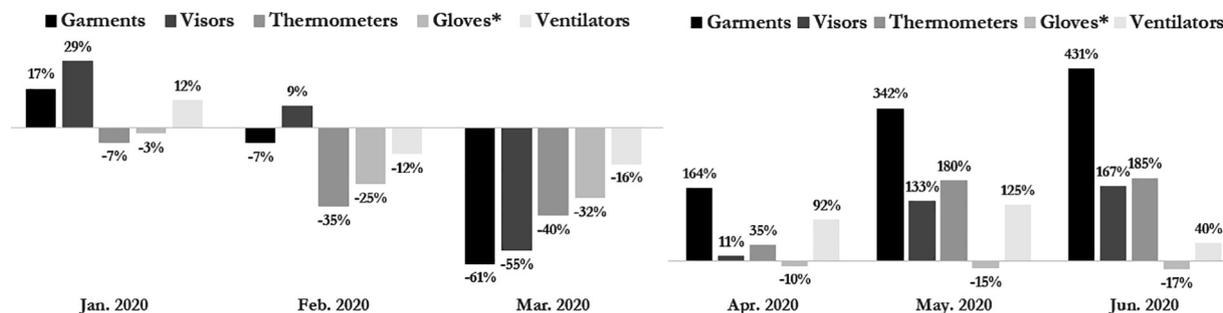


Fig. 5. US Imports from China as percentage of an Average Month, January to June 2020.

This divergence in timing was an inadvertent boon to the operations of GVCs and global supplies, because China’s relative recovery meant that its own domestic emergency demands were reduced and it could export its increased output of PPE. Although China’s PPE exports to the US declined substantially in February and March during China’s initial crisis, by April onwards the US was well-served by Chinese suppliers who had increased production across many products (see Fig. 5). Thus, although unpredictable, the timing and geography of the crisis (and countries’ responses to it) were important factors in determining how long the systemic period lasted and the speed at which GVCs recovered. Because the US and China sit at opposite ends of the COVID-19 timeline among major producing countries, they best illustrate this dynamic.

In terms of policy, throughout this period, the two governments were broadly accommodative, even if the public rhetoric was often acrimonious. For instance, the US actively facilitated its imports, and China re-regulated its exports to accommodate the crisis. On April 3rd, the USFDA lowered import standards, through an Emergency Use Authorization,¹⁶ while China enhanced regulation of its exports, in reaction to many international reports of substandard quality (like N-95s). On April 1st, the Commerce Ministry, State Drug Administration and Customs Bureau publicly announced the names of all Chinese firms that possessed product registration certificates, which was intended to “standardize export order” and “ensure product quality and safety,” thus helping foreign buyers differentiate the licensed suppliers from the fraudsters.¹⁷ The list of government-approved firms included the names of 752 registered suppliers of single-use masks, surgical masks (523), N-95 masks (150), infrared thermometers (236), ventilator (62) and coronavirus detection reagents (23).

Fig. 5 visually illustrates the unwitting complementarity of US-China dynamics. The percentages compare each month of US imports from China in 2020, to a ‘normal’ month of Chinese imports (2015–2019), measured in unit quantities to eliminate price inflation. Clearly, as China entered into crisis in February and March, supplies to the US plummeted across these five PPEs, leaving the US severely under-supplied. China is the US’s major supplier in medical visors, thermometers and garments (reflecting the geographic structure of these industries), typically supplying the US with 61%, 75% and 83% of its imports, respectively. In plastic medical gloves, China supplies nearly 100% of America’s plastic variety, but these constitute only 18% of total medical glove imports, because the vast majority are rubber and heavily sourced from Malaysia.

Given the US’s heavy dependence on China and plummeting imports, it is tempting to declare China-sourced GVCs were ‘inef-

fective’ during March. The problem with this judgment is that the declines are driven by China’s own crisis in March, not by a failure to fulfil US demand. The fact that US import prices remained quite stable in March (with the exception of protective visor prices), suggests that US demand had yet to dramatically increase.

4.3.1. Adapted and effective – masks, visors, garments, thermometers and rubber gloves

By April and especially by May and June, US import deficits were dramatically reversed and Chinese suppliers were able to increase production to provision the US, just as the country belatedly began to face up to its crisis and haphazardly imposed lockdowns. With the exception of plastic gloves, Chinese exports multiplied many times over, compared to normal months (Fig. 5). In some products, unit prices even declined (visors and simple masks, discussed below); in others, Chinese suppliers profited handsomely with unit prices sometimes more than doubling (garments, +113%) or nearly tripling (thermometers, +169%). Regardless of profiteering, from April to June, these GVCs appropriately adapted and effectively provisioned US needs (Fig. 6). Just as before, Malaysian suppliers continued to perform spectacularly, as the US consistently imported 20–51% more rubber gloves than normal between March and June and suffered no price gouging.

4.3.2. Ineffective but differentially adaptive – plastic medical gloves versus ventilators

However, China’s success in provisioning the US was not universal as some GVCs proved ineffective, such as Chinese plastic medical gloves and ventilators. For instance, China supplies nearly 100% of US plastic medical glove imports, but they consistently fell below even a normal month, let alone during this period of emergency demand and even despite a significant price hike of 37%,

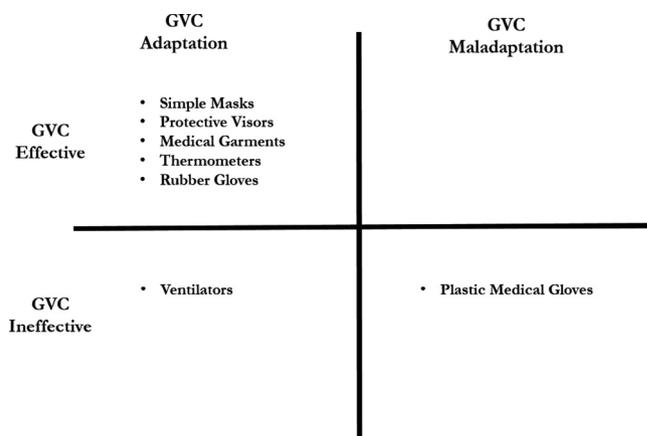


Fig. 6. GVCs during China’s Recovery and the US under Crisis.

¹⁶ USFDA, <https://www.fda.gov/media/136664/download> Accessed June 10, 2020.
¹⁷ See Commerce Ministry, <http://www.mofcom.gov.cn/article/b/e/202003/20200302950371.shtml>

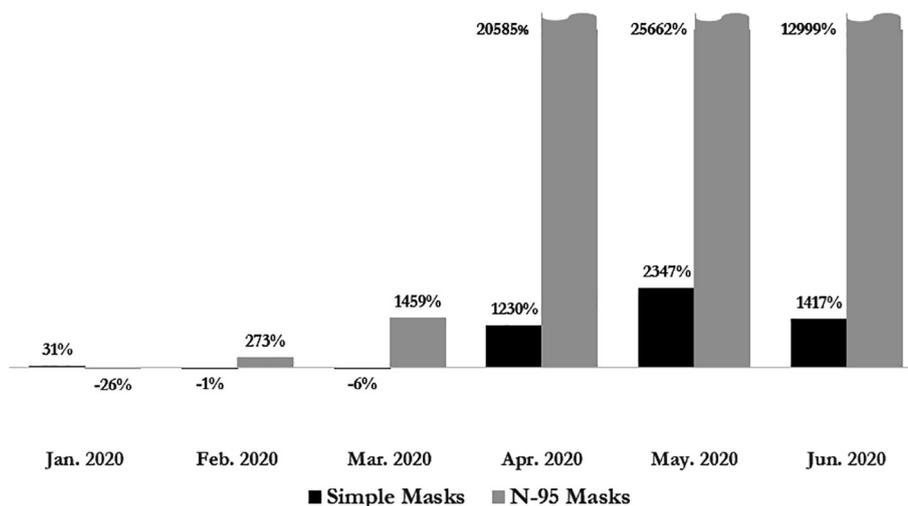


Fig. 7. US Imports from China as Percentage of an Average Month.

meaning Chinese suppliers also poorly adapted. It is not completely clear why this happened but one possibility is that US buyers switched to an easily substitutable and technologically simple alternative – rubber gloves from Malaysia.

Ventilators is a difficult case because Chinese firms did successfully rise to the challenge by supplying tens of millions of dollars more of these vital machines. But this only increased their market share from about 16% to 24%.¹⁸ This is because Chinese ventilators are not easily substitutable with the more technological sophisticated European ones, which sell at prices many times more. Thus, again, due to technological reasons, Chinese GVCs were constrained and relatively ineffective (Fig. 6).

4.3.3. Adaptive and effective – masks

We end with the extraordinary case of masks, analysing both N-95 respirators and simple surgical masks. While N-95 masks are relatively easy to identify in trade statistics, simple masks are buried within several layers of residual categories in trade statistics, which is why they have been ignored in this paper until now.¹⁹

Fig. 7 shows that N-95 masks were quite distinct in that even in February and March, China exported many times more than typical months, even in the midst of its own crisis. This is partly because unlike garments, visors or gloves, mask demand was driven by both medical institutions and everyday consumers. Strangely, however, China normally only supplies about 4% of these types of masks to the US; but by April to June it supplied 80–90%. This massive and rapid reversal may be due to the loosening of import standards by the US and China's rapid manufacturing scale-up, or also a product of mislabelling and commercial dishonesty. Indeed, unit prices plummeted impossibly low to only 11% of normal prices, which almost certainly indicates trade accounting had been undermined with substandard masks and perhaps customhouse chaos. Given concerns over potential data irregularities, we do not locate N-95s on Fig. 6.

These complications were far less of a problem for the simpler surgical masks, which do not have the same exacting production and health standards as N-95s. In no other product is China's manufacturing prowess more evident. While China was likely consum-

ing domestically any excess supplies for its own crisis through March (Fig. 7), the country's exports surged in April. In a normal month, China exports to the US an average of 347 million 'items' in this residual trade category, out of 466 million total US imports (74%). It is unclear what share are masks. But from April to June, this skyrocketed to 4.5–8.5 billion items at lower unit prices, which surely are overwhelmingly masks. Thus, once again, after March, Chinese GVCs were both adaptive and effective in supplying the US.

4.3.4. US-China summary

Overall, China-oriented GVCs were surprisingly adaptive and effective in supplying the US with PPE, despite an on-going systemic crisis. Chinese and American policies were also accommodative, even if rhetoric was not. Nevertheless, it should still be recalled that this bilateral trade facilitation is necessarily built upon structural features of GVCs, such as the distinct geographic concentrations and technical features of each product. Thus, even though most Chinese GVCs adapted appropriately from April, the US was structurally dependent on China in visors, garments, thermometers during normal times, and also masks during the crisis. China's rapid recovery was hence a stroke of luck for the US in those products. In gloves and ventilators, by contrast, there was little that China could do to make up for shortfalls. Facilitation and some luck are always beneficial, but they can only go so far in counteracting structural features of GVCs.

5. Conclusion

Like never before, medical GVCs briefly became the subject of geopolitical tension and intense public scrutiny in the early months of the COVID-19 pandemic. In contrast to much of the political rhetoric, this research provides a systematic analysis of how GVCs in PPE adjusted during this time period. Going beyond a 'success or failure' binary of GVCs, we adopt process tracing and analyse detailed trade data to demonstrate that GVC performance is more complex. We add nuance to judgments of GVCs by differentiating two dimensions – GVC 'adaptation' and GVC 'effectiveness' – which may prove useful in future research as well. In circular fashion, states interacted with two structural characteristics of GVCs – their geographic scope and technological sophistication – to produce mixed outcomes in the provision of PPE during the initial months of the pandemic. Under January and February's localized crisis in China, state policies were largely complementary

¹⁸ Units of ventilators only began to be recorded in 2020, so we use January and February as a rough proxy of a typical (non-crisis) month of US imports.

¹⁹ Since many residual textile products fall within 6307909889, it was impossible to track simple masks in the trade data. It is only in April when masks suddenly became a massive item of trade (see Fig. 7) that we can be assured that the increase is due overwhelmingly to mask trade, and not the many other items in the same trade code.

to GVCs, which operated rather effectively in provisioning PPE to address the health emergency in China. An important exception was meltblown, due to its technological rigidities. In March, the crisis turned global and systemic, state policies became far more interventionist and GVC failures in Europe were more prevalent – though hardly universal. From April to June, the US was fortunate to benefit from China's rapid recovery, allowing many China-sourced GVCs (especially among the less technologically sophisticated) to increase supplies.

Conceptually, the paper builds on research on the state and GVCs. Specifically, the paper advances our understanding of how states and GVC structures mutually constrained each other. State policies certainly do influence GVCs. However, even under emergency interventions, the underlying structures of GVCs, built up over decades, remained influential. In many instances, activist state policy proved ineffective in the face of geographic and technological structures. Such constraints were even explicitly acknowledged in the re-shaping of state policies, such as the reversals of self-defeating EU trade policies and Malaysian lockdown orders. Extending beyond medical industries and COVID-19, we need continued attention to different states roles and how and when they shape, but are also shaped by, global value chains. Our research pointed to geographic scope and technological sophistication as key characteristics of GVCs shaping the possibilities for state policy, insights which could be researched further in other contexts. Although this paper builds upon GVC research which combines together large-scale statistics with qualitative methods, we encourage further systematic testing using quantitative methods, which could include direct measures of technological sophistication (rather than our reliance on relative sophistication), or deepen our nascent intra-product segmentation (e.g. high/low quality ventilators and thermometers).

As regards to arguments over the future of PPEs, little evidence emerges from the case of PPEs to justify a clear cut-case for the wholesale end of GVCs and a shift to nationalized production. Nor does this research necessarily justify maintaining GVCs as they are, especially given the vast scholarship that has demonstrated huge power differences and uneven outcomes from participating in GVCs (Barrientos, 2019; Dallas, et al., 2019; Gereffi, 2018). A long-standing insight of GVC (and related GPN) research is that the structure of different industries matter, and that countries are incorporated in very different ways into these industries. This research follows in that trajectory, emphasizing the mutual constraints in how state policies influence GVCs, but GVC structures also constructed the arena of possibilities for policy-making.

This research is at a very early stage of analysis of COVID-19 and GVCs, and a substantial empirical future research agenda lies ahead, including understanding PPE production outside of, and supply to, countries which are not major producers. It remains to be seen the extent that arguments by political leaders and other commentators for nationalization of production are carried into policy initiatives and the degree to which they succeed. Prior to Covid-19, medical industries were relatively under-explored in GVC research, especially when compared with agricultural, natural resource and textile value chains (De Marchi, Di Maria, Golini, & Perri, 2020). Given their clear strategic significance, as demonstrated during the COVID-19 pandemic, future research on GVCs should pay greater attention to medical industries.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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