



Research on the Impact of COVID-19 on the Global Personal Protection Equipment and Food Supply Chains - A Vulnerability-Oriented Discussion

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Abstract. As a result of the COVID-19 outbreak, global supply chains were hit, particularly in the personal protective equipment and food industries. This paper focuses on the vulnerability factors of the two industries and the manifestations of vulnerability highlighted in the face of the pandemic shock. The vulnerability of the PPE supply chain is mainly reflected in external disaster shocks, geographical concentration and corporate reputation, while the food supply chain has, in addition to similar points for PPE, fluctuations in the input price of food raw materials and rising labour and material costs for processing. At the same time, in the face of pandemic shocks, the paper presents vulnerability factors on the supply and demand side, and explains cost fluctuations in particular periods with a bullwhip effect. Finally, the paper reviews the relevant literature on ways of coping with vulnerability, such as automated supply chain reform, improved predictive demand models, decentralized supply chains, guaranteed labour, appropriate shortening of supply chains, seeking external financial support, and electronic supply chains, in order to prepare theoretically for possible future shocks.

Keywords: Supply Chain · COVID-19 · PPE · Food supply chain · Vulnerability

1 Introduction

COVID-19 has caused a massive economic collapse [1]. The virus is spreading rapidly across the globe and has been classified as a pandemic by the World Health Organization (WHO). In response, countries have begun to implement embargoes and forced social evacuations with the aim of reducing the spread of the virus as a priority, but it has also caused severe economic disruption [2]. Meanwhile, in addition to the pandemic dramatically altering people's consumption habits, the disruption of global supply chains had the greatest impact on business operations and the global economy [1, 4]. A supply chain is a web-like structure around a core business, primarily consisting of manufacturers, suppliers, distributors and end-users connected, starting with raw materials to the final product, which is then delivered to consumers by a distribution network. A recent

report found that 94% of the supply chains of Fortune 1000 companies were disrupted by COVID-19 and a further 75% suffered negative losses [5].

Supply chain issues for personal protective equipment (also called PPE, mainly includes masks, safety goggles, respirators etc.) and food in the face of surging demand are two key challenges during COVID-19 [6]. Despite efforts to alleviate the PPE shortage crisis, less than 25% of the total demand for PPE was successfully delivered from March 20, 2020 to July 2, 2021, according to the US emergency supply plan Get Us PPE [7]. At the same time, food supply chains around the world have been disrupted by pandemic outbreaks, triggering a food crisis that has increased the number of people facing extreme hunger to 265 million in 2020 [8, 9].

The impacts of pandemics on supply chains and solutions are therefore worthy of discussion and research. The various adverse effects of COVID-19 have exposed global supply chains to unprecedented challenges, such as the erratic supply of various intermediate products and the ongoing impact of human mobility [5]. And such challenges can be categorized as supply chain vulnerability in response to pandemic. Supply chain vulnerability is defined as the disruptive nature of a pandemic on the supply chain [10].

Supply chain vulnerability research is a hot issue that needs attention in the current process of supply chain risk management in China and the world. In view of these, this paper focuses on the manifestation of supply chain vulnerability in the event of a pandemic. According to third-party statistics, approximately 50% or more of the world's PPE products originate in Greater China (or South East Asia), with 80% of masks being manufactured in China. The increased reliance on overseas manufacturing capacity for the emergence of the pandemic is a huge supply-side challenge, further reflecting the vulnerability of the supply chain. There is also the need to face a surge in demand from the demand side, for example when a community has a confirmed case, the demand for PPE in that community will surge from 300% to 1700%. Also, in the quarter following the outbreak of COVID-19 in 2020, food supply chain issues led to an average increase in global food prices of 12.9%. Therefore, this paper focuses on the supply chain vulnerability of two areas affected by the pandemic, namely the personal protective equipment and food industries. Finally, the paper provides solutions to address their vulnerability.

2 Factors Influencing the Vulnerability of Personal Protective Equipment and Food Supply Chains

Wang, Wang, & Li introduced the concept of supply chain vulnerability: a state in which a part of the supply chain deviates from expectations and the supply chain system suffers a degree of damage that is difficult to recover from, as the operation of the supply chain is affected by both inherent instability and external disturbances, when the supply chain risk factors are less than the effect of risk-mitigating factors [11].

2.1 PPE Supply Chains

In the case of PPE, supply chain vulnerability is reflected in the nature of the supply chain that is susceptible to severe external disruptions that can have an adverse impact [10].

The factors influencing the vulnerability of the PPE supply chain are discussed in four main areas.

2.1.1 External Environmental Change Disruptions

Natural disasters, pandemics and other immediate shocks to the external environment are extremely disruptive to the supply chain and may cause incalculable damage to the supply chain. The Ericsson case is well known in the field. In 2000, a serious fire broke out at a semiconductor factory in Phillips. This directly led to the disruption of Ericsson's production, which cost the company US\$ 400 million [12].

2.1.2 Scarcity of Key Inputs

Shortages of critical raw materials can affect the material supply chain. For example, cartridges for masks generally have fixed suppliers for mask manufacturers, and the irreplaceable nature of resources like cartridges and tight production arrangements may lead to disruptions in the entire supply chain once the pandemic has delayed or banned some of the logistics of transport.

2.1.3 Geographical Concentration of Manufacturers

Production of medical products is concentrated in one or a few locations, all of which are disrupted by the risk when it occurs and the product is not available properly for a short period of time. Or, when production is concentrated in a few companies or a few locations, any supply problems in these companies could lead to local production paralysis and supply chain disruption. An important feature of the supply chain disruptions caused by the East Asian earthquake was the concentration of many local companies in one particular industry and a large proportion of these products are produced in this area, ultimately leading to shortages worldwide [13]. Additionally, if a multinational company builds a large part of its manufacturing plants in the same country, a sudden shock can have a huge impact on the company's supply chain. In the case of Nike, about three-quarters of Nike's footwear products are produced in Southeast Asia. Of these, footwear made in Vietnam accounts for as much as 51% of the total. In the face of the COVID-19, production restrictions and shutdowns at Vietnamese factories during July and September dealt a major blow to Nike, reducing its footwear production by 180 million pairs during this period.

2.1.4 Corporate Reputation

The reputation and reliability of supply chain nodes can affect the vulnerability of the supply chain. If a strategic alliance is not formed between companies, the supply chain will be disrupted for a short period of time. For example, a company's reputation and credentials in socially responsible supply chain management can give them a long-term competitive advantage while companies with a low reputation will suffer more from precarious cooperation [14].

2.2 Food Supply Chains

According to Aday & Aday, the food supply chain can be divided into five stages, including agricultural production, post-harvest handling, processing, distribution/retail/service and consumption [15]. Influencing factors similar to PPE supply chains are external disturbances and geographical concentration [16]. This section only focuses on two different typical influencing factors listed.

2.2.1 Food Transaction Costs at the Point of Purchase at the Factory

Because shortages and price increases of some raw materials can have a volatile impact on the supply chain [17]. And it is also a major challenge to set a reasonable cost to supply food. For example, a factory that produces processed pork products may not be able to supply pork normally because the pork supplier's area is under control of the pandemic. It had to find pork suppliers on an ad hoc basis, which could lead to higher costs for the plant.

2.2.2 Investing Additional Time and Cost Resources in the Processing Process

In the case of global food supply chains, there is a need to ensure that food can flow in a highly coordinated manner across borders, as the adverse impact of the pandemic on logistics and distribution reduces the accessibility of food. In terms of logistics, higher transport costs, increased frequency of order cancellations and longer transit times. Such as stricter customs and additional prevention and control measures, which increase the vulnerability of supply chains. Particularly for labour-intensive food processing supply chain participants need to bear the increased costs associated with ensuring their own safety (PPE, disinfectants, social distance maintenance, etc.) According to Kaur, at least 462 meat packing plants, 257 food processing plants and 93 farms and production facilities in the US were affected by COVID-19 cases [18]. The consequent increase in labour costs associated with a reduced workforce has had a significant impact on the operations of food-based businesses. In addition, there were additional costs associated with the need to comply with government food safety regulations in the face of the outbreak [19].

3 Analysis of the Impact of Covid-19 on Supply Chains

3.1 Supply Shocks

3.1.1 PPE

For PPE, the embargo policy has affected staff mobility and business operations, particularly the involuntary idling of plants in China due to COVID-19, which has led to a reduction in global access to components [4]. As a result, global manufacturers and retailers who rely on raw materials from these plants, as well as intermediate products, were unable to obtain sufficient quantities for their operations. Medical protection products were plentiful in the US prior to the pandemic, but when the pandemic hit, there was a severe shortage, directly leading to an increased risk of contagion for frontline health care workers and indirectly affecting the entire country with the increased impact

of the pandemic. This is partly due to the massive outsourcing of manufacturing in the US, enabling cheap Asian labour, and when the outbreak hit, the outsourcing companies are producing medical protective gear for their own countries, leading to a disruption in supply to the US.

3.1.2 Food

COVID-19 had a negative impact on supply for many businesses [3, 20]. Lockdowns and highly unstable logistics in many parts of the world were caused by a number of government interventions, such as the suspension of public transport and the closure of airports, railway stations and highways. While these measures are necessary to prevent the further spread of disease, they have a detrimental effect on the distribution and overall transaction costs of the food supply chain, as they must source demand from domestic markets. And production and manufacturing industries like food and PPE cannot work from home due to their specific production, resulting in labour shortage. In addition, the restricted mobility of commodities has also had a huge impact on the supply chain. Regional closures and controls impede the efficient delivery of food (whether domestic or transoceanic) to consumers, reducing supply chain liquidity. Especially the impact on fresh food (food with a short shelf life) is huge. In addition, labour shortages due to pandemics, diseases, and physical distancing due to pandemic prevention and control have also negatively affected food production. These effects include reducing the delivery capacity of the supply chain, and putting pressure on the ability to provide a continuous supply to the market [15, 21].

3.2 Demand Shocks

3.2.1 PPE

The demand for PPE is also growing like never before due to the high demand for pandemic protection for the general population and medical staff.

For both food and PPE supply chains, for large companies, the short-term surge in demand may be highly profitable, but most small companies do not have the equipment, manpower and technology to cope with such an overwhelming change. Large companies are somewhat cushioned against supply chain vulnerability by having stockpiles and multiple supply chains, as vulnerability is also highly dependent on the size of the company and its raw materials stockpile.

3.2.2 Food

During the time of the COVID-19 pandemic, people around the world are stocking up and panic buying amid fears of food shortages. People's consumption behavior has also changed. More consumers would rather cook at home than eat in restaurants.

3.3 The Bullwhip Effect

The bullwhip effect refers to the increasing volatility of inventory as the supply chain moves upwards and as customer demand changes [22]. One of the main reasons for

the bullwhip effect is the lack of transparency in the supply chain, which increases the vulnerability of the supply chain to a certain extent. First, as far as the food industry is concerned, companies upstream in the supply chain cannot correctly determine supply when consumer demand increases dramatically in a short period of time. This can lead to unnecessary inventory, as well as costs and shipping costs for upstream businesses. During this pandemic, demand patterns become even more unpredictable. This is followed by production inputs for PPE, as a large increase in demand sees more companies flood in for immediate benefit, but the quality of the masks themselves, for example, may be at risk.

3.4 Transport Requirements/Costs

Reduced logistics frequency and increased costs have a particularly negative impact on products that require long-distance transportation. For example, some countries have closed their borders to prevent the spread of the pandemic. Henriksen and Selwyn point out that some occupations that are critical to the safety and continued operation of Global Supply Chains (GSC) have been disrupted by border closures and quarantine laws [23]. Sustaining GSC operations depends on the movement of these people on land and sea. Supply chain vulnerabilities are further exacerbated by individual country policy restrictions and potential contagion risks from transportation.

4 Measures to Address the Vulnerability

4.1 Automated Supply Chain Reform

Automation allows the entire supply chain to operate 25% more efficiently, with tasks such as loading and unloading and processing and packaging being done more quickly in terms of logistics and transportation [15]. Not only that, but robots and Cyber-physical systems (CFS) can perform services such as food processing and safety supervision [24]. It is therefore recommended that each country should be able to upgrade its industrial equipment as far as possible to automate supply chain operations.

4.2 Better Predictive Demand Models

Changes in demand have a huge impact on supply chain performance and require more accurate statistical models for forecasting. In particular, products that are critical to everyday life, such as PPE and food, gained more demand at the start of the crisis. And because of the relatively short shelf life of food products in the face of the pandemic shock, more accurate forecasting was particularly important and corresponding adjustments in production and processing distribution were made to cope with the disruptions in supply and demand due to the COVID-19 outbreak.

4.3 Decentralization of Manufacturing and a Decentralized Supply Chain Model to Cope with the Risks of Centralization

Bring down production and inventory costs for smaller producers. This will diversify suppliers to avoid over-reliance on one or a few trading partners. After receiving the impact of the Great East Japan Earthquake in response, Toyota organized a team of 100 executives to spend more than a year addressing companies in its extended supplier network. Although costly, the measures Toyota took to improve the resilience of its supply network helped it outperform some other carmakers during the COVID-19 crisis, until now [25].

4.4 Labour Security

In order to face the cross-border constraints of the pandemic and to prevent labour from encountering this situation from reoccurring supply problems, activation of the local workforce should be initiated and a reliable workforce for the future in the long term should be developed through training [19].

4.5 Shortening the Supply Chain (Mainly for the Food Supply Chain)

AN effective solution for food supply chains to mitigate the shocks caused by the pandemic was derived from Short Food Supply Chains (SFSC) [26]. SFSC is an emerging strategy for sustainable supply chain practices, specifically demonstrated as reducing intermediary nodes in complex supply chains, reducing transport costs and facilitating direct links between producers and consumers. The most common example of this is the direct link between local producers and consumers, giving customers access to fresh and natural products. This can be an effective solution to potential food shortages during the pandemic. Moreover, since the security of the delivery is guaranteed, both online and offline supply models can be adopted, matching buyers and sellers online to make the supply chain work more robust [26]. In addition, companies can invest in regional supply chains (or sourcing close to home) to increase logistics gains and strengthen relationships with local industries [6].

4.6 Coordinate Regulation and Financial Support from Financial Institutions

The government should coordinate the supply chain for safety regulation, while sharing information with the Chamber of Commerce or other stakeholders in a timely manner to increase the transparency of the supply chain. Financial institutions should provide financial support to maintain the stability of the supply chain and make corresponding investments.

4.7 Electronic Supply Chain Management

In the context of COVID-19, it is more important to increase transparency, achieve efficient and fast information exchange and quickly match the corresponding logistics. For example, matching platforms such as Shield-Net mainly focus on matching between

industrial suppliers/manufacturers and healthcare recipients [27]. Another example is the Get Us PPE, a Civil PPE platform, which is a good way to alleviate people's strained PPE supply and demand relationships and is very relevant for the food production and PPE manufacturing industries. An integrated analysis of supply and demand distances and shipment difficulties is adopted by it to strengthen supply and demand relationships, ensure supply chain mobility, reduce delivery times and costs, and consequently reduce logistics costs, increase the timeliness and make traditional supply chain structures and logistics more robust. Get Us PPE also found that collecting appropriate geospatial data is critical to achieving efficient supply chains and logistics in a pandemic [7]. E-commerce can facilitate the efficient flow of information and equitable distribution of supply and demand in the supply chain [28], which enables more coordinated and flexible collaboration at all stages of the supply chain. In addition, 'supply chain management (SCM) data science' can be used by governments and the private sector to address SCM issues by analyzing the results through statistical data, but ensuring that the data is timely and reliable. If the right techniques are used, the impact of uncertainty can be reduced and better decisions can be made [15].

5 Conclusion

This paper provides an overview of the specific vulnerabilities of PPE and food supply chains. It divides vulnerability analysis into supply-side and demand side, details the vulnerability factors affected by the pandemic, and proposes solutions for supply chain vulnerability under COVID-19.

The vulnerability of PPE supply chains is mainly reflected in external disaster shocks, geographical concentration and corporate reputation. Food supply chains have similar vulnerability factors to those of PPE supply chains, in addition to fluctuations in the prices of food raw material inputs, and additional processing costs. In the face of COVID-19 shocks, the paper presents specific manifestations of vulnerability in terms of supply and demand, and uses the bullwhip effect to explain cost fluctuations in specific periods, as well as the significant increase in transport costs due to the effects of regional isolation resulting from the pandemic. Finally, the paper reviews the literature on approaches to vulnerability and focuses on effective supply chain vulnerability mitigation, such as automated supply chain reforms, improved predictive demand models, decentralized supply chains, labour security, appropriate supply chain shortening, seeking external financial support, and e-supply chains, in order to theoretically prepare for possible future shocks. Especially for e-supply chains management such as supply chain management (SCM) data science, combines the latest computer technology to make supply chains more robust and efficient, which is an optimal direction for further development of supply chains.

However, this paper is only an overview refinement on the basis of previous work, and the implementation of specific solutions requires the collaboration and technical support of each node in the supply chain and external resources. Future research directions can be further developed in optimizing the electronic supply chain to further improve the robustness of the supply chain to prevent shocks from a similar pandemic.

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