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Pandemic Impact on Supply Chains: Strategies to Minimize Supply Chain Disruption

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Abstract

Covid-19 pandemic has challenged all the areas of living of people in the last year, supply chains were not excluded by it. Restriction measures, global health concerns and drastic-unreasonable demand changes were the main issues supply chains had and still have to face in the most globalized world ever seen. The aim of this work is to understand how the pandemic impacted in the supply chains, the first reactions of companies to minimize the disruption of the production, logistic and supply shock and finally the measures to be taken in order to prevent future problems. The question of this study is, in fact: how did supply chains react to pandemic and what can they do to be more resilient? To answer this question, in the first section we show the chronological development of the pandemic, starting from China's outbreak and its expansion to the rest of the world, keeping in mind the economical context in which the event takes place. In the second section we first review literature on natural disasters, since it are the most similar events to a pandemic in terms of their effects. Moreover, in the third section we depict the suggestions to move to a more resilient management of the supply chain and the possible measures to be taken by supply chain managers. The focus will be on the improvements and weaknesses of current supply chain management techniques, such as Just-In-Time methodology, in-shoring possibilities and demand management.
At this study publishing, supply chains are still struggling with uncertainty associated with the pandemic situation and need to change some of their features and strengthen others to prevent future disruptions. Future researches could take advantage of more specific and updated information on this topic.

Keywords: Pandemic impact, Supply chains resilience, Reshoring, Supplychain management, Uncertainty.

1. Introduction

Covid-19 pandemic has challenged all the areas of living of people in the last year, supply chains were not excluded by it. Restriction measures, global health concerns and drastic-unreasonable demand changes were the main issues supply chains had and still have to face in the most globalized world ever seen. The aim of this work is to understand how the Covid-19 pandemic impacted in the supply chains, the first reactions of companies to minimize the disruption of the production, logistic and supply shock and finally the measures to be taken in order to prevent future problems. The question of this study is, in fact: how did supply chains react to pandemic and what can they do to be more resilient? To answer the question, in the first section is shown the chronological development of the pandemic, starting from China's

outbreak and its expansion in the rest of the world, keeping in mind the economical context in which the event takes place. In the second section is first presented literature about natural disaster, since it is the most similar event to a pandemic in terms of effects. Moreover, are depicted the suggestions to move to a more resilient management of the supply chain and the possible measure to take for supply chain managers. The focus will be on the improvements and weaknesses of actual organization, such as Just in time methodology, in-shoring possibilities and demand management. Finally, in the third section, literature has been complemented by a case study of a real company which must face the pandemic impact and the measures the company itself could take to strengthen the supply chain, providing also the economic feasibility of the investments. On this basis, supply chains must still struggle with uncertainty connected to the pandemic situation and will have to change some of their features and strengthen others, to prevent future disruptions.

2. Covid-19 pandemic evolution and supply chains disruption

2.1. Background

Covid-19 pandemic is a world-wide infection that caused the lockdown of all economies, even if in varying degrees. A pandemic is, generally, an unpredictable event, so something that happens rarely, and, for this reason, most of companies were not prepared to manage it. For the magnitude of the event, all supply chains in the world have been highly affected and need to re-think about their needs and priorities.

In the background part, we try to describe on one hand the model of supply chain before the Covid-19 virus and on the other hand the different phases in chronological order of the spread of the virus, to understand the impact of these on the supply chains.

2.1.1. Supply chains state of the art

Covid-19 disruption on supply chains is connected to the global dimension of the supply chains themselves. It is important to understand how global chains changed during the last century and why a pandemic is such shocking for the model. There are mainly two models of global economies (Gereffi, 2020). One model, that can be called domestic economic model, reached the peak in 1960s. It was a model based on the distinction between advanced industrial countries and the others. The flow of international trade was mainly based on the movement of primary commodities and finished goods. Southern countries, so the less industrially developed ones, supplied primary commodities, while industrialized countries monopolized the production and so the export of finished goods. From 1960s/1970s, the international trade started to take the shape of a global factoring model. The offshoring strategy started with the lift of assembly operations to the closest and cheapest countries, with respect to the most industrialized ones. For instance, USA companies moved to Mexico, while Western European countries to Eastern European countries. In the 80s/90s, the process moved on, with the offshoring, not just of some production processes or parts, but with the complete production of goods to countries in which companies could reduce costs, especially to East Asia. In 2000s, China became the world biggest exporter. China’s dominant position was upheld by the entrance of the country into the World Trade Organization and the opening of the regime to western economies.

The second model is the so called Global factory model (Gereffi, 2020). There are several advantages in the global factory model that can explain why it imposed globally.

1. It is a flexible model: it allows the companies to
   a) Move production processed in the countries in which there are the natural resources needed,
   b) Exploit qualified workers, and
   c) Be close to emerging markets

2. It scales easily
   a) It is an export-oriented model that means that most of the production is not thought to be in the country in which the good is produced, but to export.
   b) It is a network-based model: even small economies can produce in large quantities, because they export to the rest of the World.

3. Highly specialized: factories in most cases produce a specific good or even a specific component. It affects the trade since
   a) International trade becomes trade in components rather than of final goods.
   b) International trade is coordinated by large firms, of which most are manufacturing producers.

In the global factory model there are some actors that exploit the efficiency of the model and others that are negatively affected by it. In particular, firms that coordinate the supply chains gain from this model, but also consumers that always have cheapest products at massive quantity. The negative side of the global factory model falls onto the workers in the industrialized countries, who are no more competitive, compared to Asian workers. So the efficiency of the supply chain is counterbalanced by the fragility of the same.

How to face a pandemic

Figure 1 is quite representative of the effects the virus spread caused in the three main actors of society and how it is then related to the disruption of the supply chains. On one hand, we have the consumers. As the virus threat becomes to be higher, the consumer is worried about being infected. This takes the person to take measures that are supported by the government behavior, such as increasing social distancing, maintaining staple purchase but reducing discretionary purchases. This is connected to the unstable working environment, and so uncertain income, but also to the need of dodging crowded and potentially contagious places. This is reflected to the companies' environment that can count on a reduced labor contribution and purchases. In addition, there are the governments. Governments are concerned about the epidemic and on the breaking point of the healthcare. The measures governments take, are the restrictions on people movements and transportation to reduce the propagation. At the same time, governments must be ready to implement offsets to actors' behavior, in order not to destroy the economy of the country. They are subsidies for consumers, to prevent the collapse of consumes, and government expenditures to avert bankruptcy of companies and collective redundancy. Finally, the last actors are the companies. Companies' main concern is about the impact on labor, supply and sales. Because of the consumers movement limitations, many companies are forced to reduce the business activity and so reduce sales and purchases. The sum of these behaviors takes to the disruption of the supply chain.

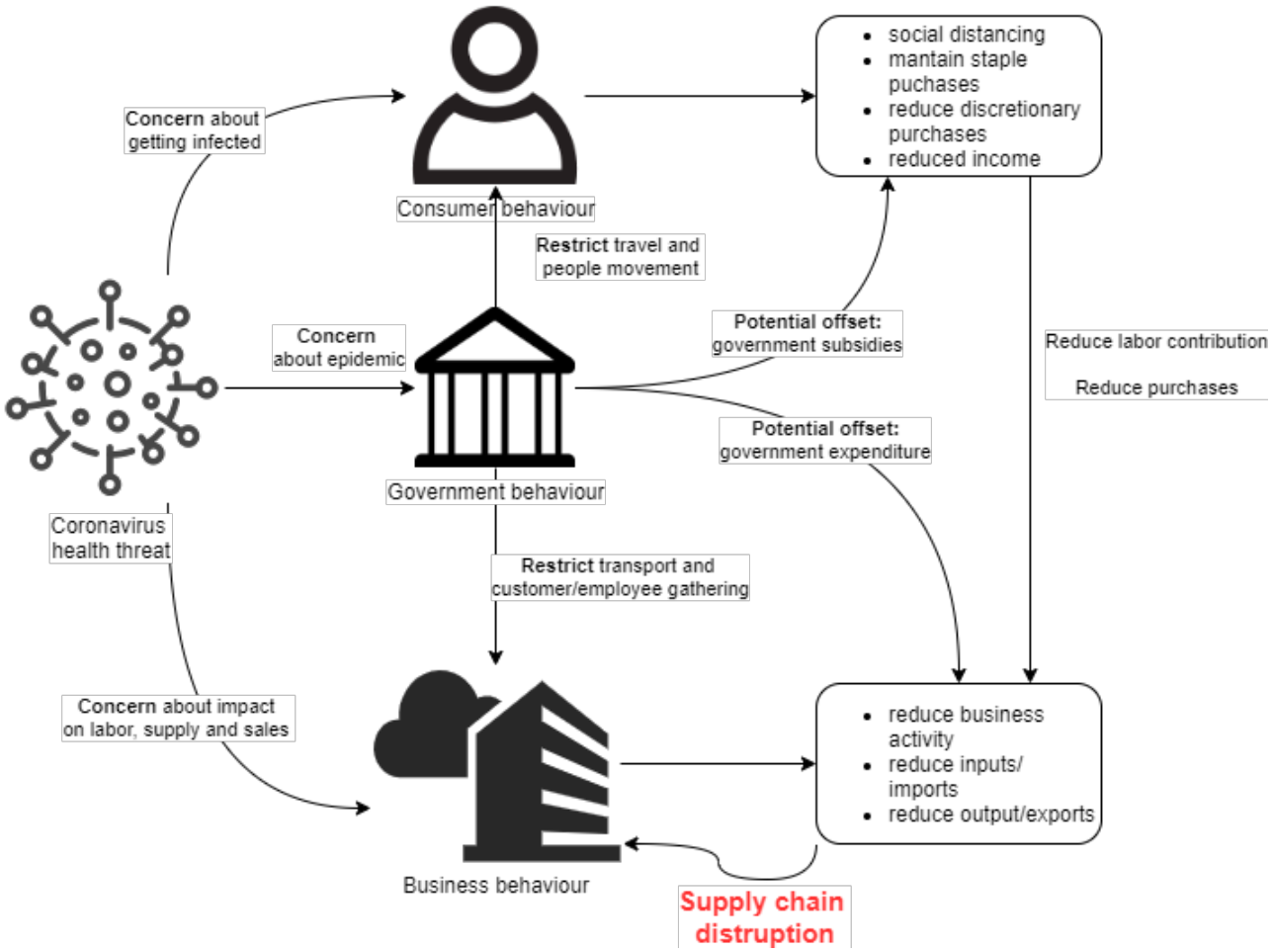

Figure 1. Actors' behavior and supply chain disruption

2.1.2. Chronological events

China's lockdown

From a chronological point of view, the first patient developing symptoms of Wuhan coronavirus appeared in December 8th, 2019. Some studies affirm that it is possible that some cases already existed in China in November, although these cases were not recognized and classified as Covid-19. Definitely, the initial unconsciousness enabled a wider spread of the infectious. In December 31st, China alerted WHO about several pneumonia cases that were then connected to a person who bought and consumed a bat in a market in the city of Wuhan. In the first week of January 2020, Wuhan's wholesale seafood market shutdown and the virus was identified.

In January 11th, the first death in China's province was recorded and Wuhan was placed under quarantine, with rail and air services suspended. Timeline is shown in Figure 2.

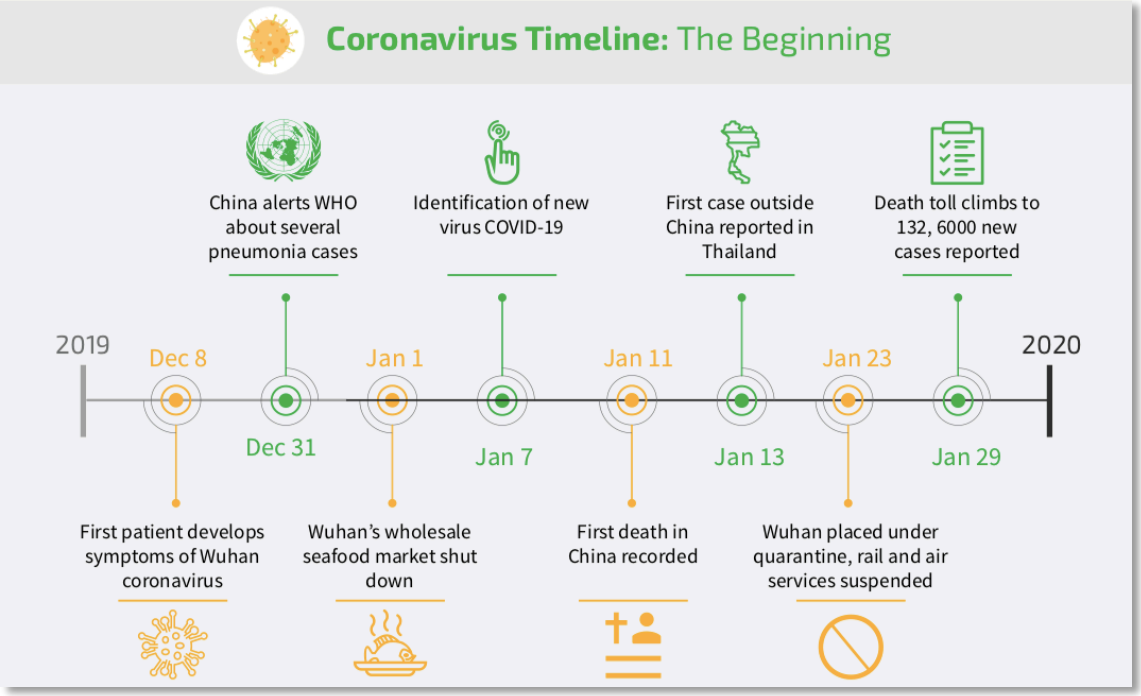

Figure 2. Coronavirus spread timeline

It was at this point that all other countries and companies started to understand the severity of Covid-19. China is the biggest and most growing market and economy of the world and it was clear that, although the virus was blocked in the country, the effects of the China's shut down would have been wide and worldwide.

As Deloitte (2020) reports, the spread of the virus (or at least the recognized moment of spread) in China corresponded with the Chinese Lunar Year, China's most important holiday, when every factory in the country shuts down for between two and four weeks to allow people to travel back home to spend time with their families. Companies that do significant business with China are aware of this shutdown and many placed large inventory orders in advance to ensure that they had supply to cover this period.

At the same time, the planned closure of factories enabled the government to mandate extended factory shutdowns in support of efforts to control the spread of the virus. Typically, the holiday starts January 24th with the expectation that plants are back up and running starting February 2nd. However, many factories were asked to remain closed for another week until February 9. Historically, most plants would have been up and running fully by mid-February, but given the extended closures and delays in getting workers back to the plants due to health quarantines and travel restrictions, production was restarting at a much slower pace, as shown in Figure 3.

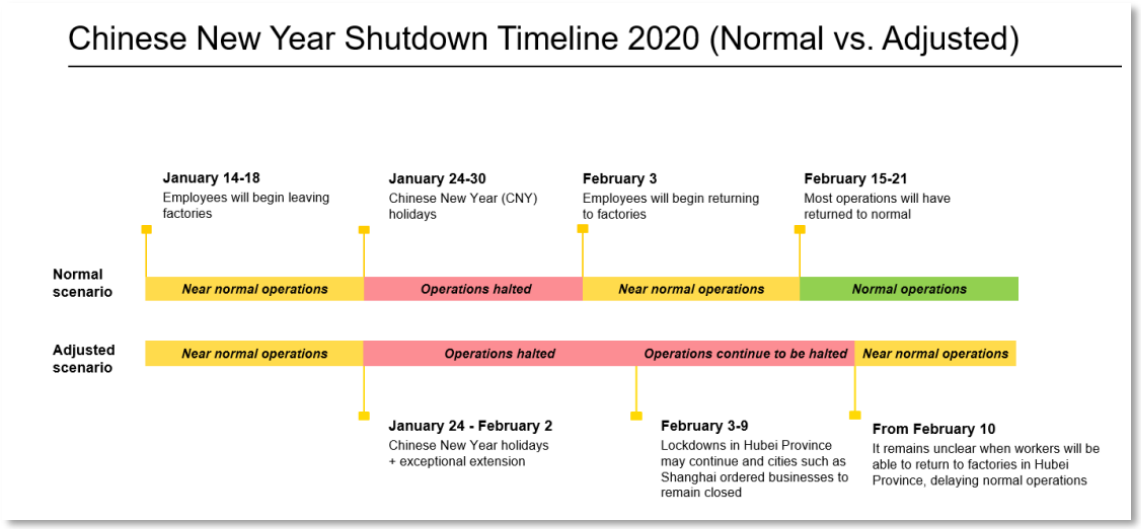

Figure 3. Chinese New Year shutdown timeline 2020

Already in the first weeks of the pandemic, it was clear that the productivity of the companies in the country would have decreased for an uncertain period. It was necessary to manage at that time not only the lack of materials, but also the containment of the virus among the people involved in operations and manufacturing.

The problem that this created for the worldwide supply chain was not just connected to the goods directly produced in the region firstly interested in the lockdown, since Hubei province and in particular Wuhan, is not just a production area but also an important hub.

A special briefing of Dun and Bradstreet (2020) took into consideration the relevant position of the Hubei province and the most affected zones of China, into the world commerce. In Figure 4 is shown the province with more than 100 cases confirmed in February 2020, before the pandemic became a problem for other countries outside the Asian nation.

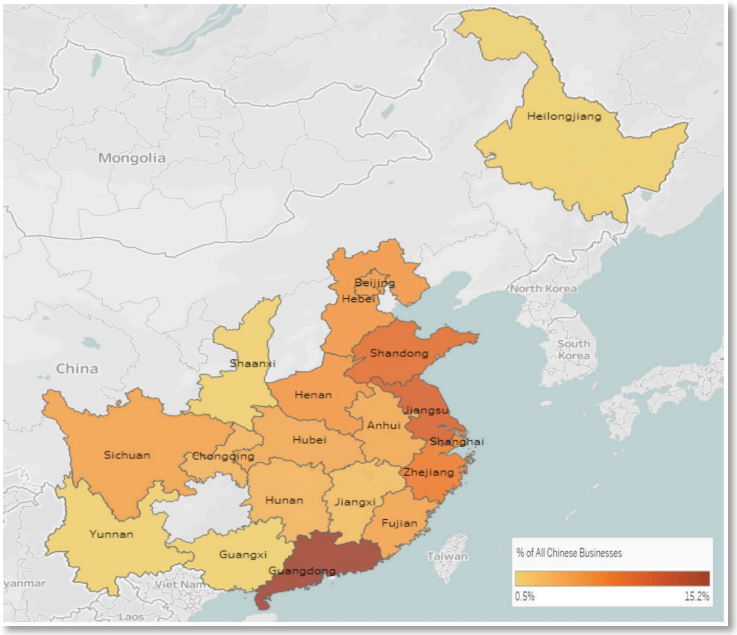

Figure 4. Provinces with 100+ Confirmed Cases and Percent of All Chinese Businesses Affected in February 2020

Global lockdown

At the end of January 2020, the western world started to be hit as well as China by Coronavirus. Figure 5 depicts the timeline of the first cases in Europe, with a focus on Italy, because it was the most impacted country in the initial phases and the one who take the most sever measures first.

The first case in Italy was in January 25th, followed by different cases in other countries in Europe. In February the virus was clearly circulating in all western countries, but the speed and the strength of the virus were not clear, until that time.

In Italy, on March 6th the most impacted region, Lombardia and, in particular, the province of Bergamo, were close to the collapse with a contagious rate that was already following an exponential trend, and so the deaths. For this reason, the area was shut down. In three days, all the country was under lockdown, with the block of circulation and movements in the country. Similar measures were undertaken in March by most of the countries of Europe, in order to avoid the collapse of the healthcare system.

Finally, on April 2020, 158 countries out of 181 required closing temporary or working from home for some sectors in some or all cities.

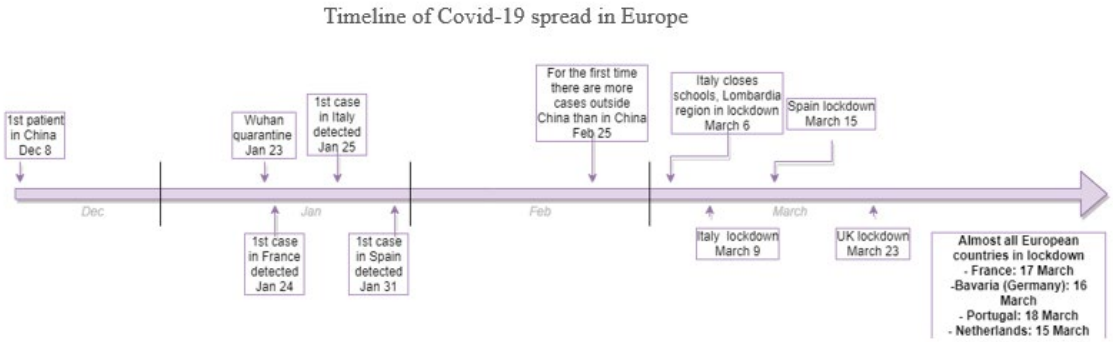

Figure 5. Timeline of Covid-19 spread in Europe

Anyway, not all the countries of the world reacted the same way to the spread of the virus. In Table 1 we can see some representative countries:

- China: because it is the source country of the epidemic
- South Korea: because it developed a different control, successful, based on massive tests but no lockdown
- Spain: it is representative of all the countries in which the health measures have been very strict, such as Italy, France, UK, USA, etc.
- Germany: it is representative of all the countries in which the measures have been less strict, such as Austria, Switzerland, etc.
- Tanzania: it is representative of the countries in which the measures have been almost inexistent.

As we will see later, if a country did not put in place strict measures to contain the virus spread, it did not mean that his supply chains have been less impacted. Anyway, in this part we will settle only the government measures undertaken by different countries and the effects on their supply chains.

Korea, Germany and Tanzania have not established settlement measures preventing a total shutdown of the economy. China has put in place settlement measures in the area affected mainly throughout the province of Hubei, but not in the rest of the country. Spain for its part, has opted for the total lockdown and, consequently, complete paralysis of the local economy.

Analyzing these implemented strategies by these countries and comparing them with results based on number of deaths it would seem that the results of Korea, without paralyze the economy, applying measures social distancing, performing tests mass, requiring the use of masks and geolocating the infected have been substantially improved measures with regard to of the number of deaths each 100,000 inhabitants. These strategies of governments had a disparate effect on economies and in the supply chains. The conflict measures and unemployment, imposed without any international coordination in some countries, improvised and with a significant delay in decision-making, has not had the expected result in health and has broken the CDS, in some cases an irreparable form (Leporati, Martul and Morales, 2020).

Of course, it is too reductive to charge exclusively the government reaction for the mortality and severity of the situation. There are many factors that influence the results, such as the local culture, the weather and so on that are not inherent to this analysis, but that have an important role in the spread of the virus.

Table 1. Countries reaction to restrain Covid-19 spread

	China	**South Korea**	**Spain**	**Germany**	**Tanzania**
Massive tests	yes	yes	no	No	no
Obligation to wear masks	yes	yes	no	No	no
Geolocalization	yes	yes	no	No	no
Lockdown	immediate in Hubei	no	late and general	No	no
Social distancing	yes	yes	yes	Yes	limited
Economy paralysis	partial	no	total	Partial	no
Inhabitants	1.395.261.000	51.843.000	46.791.000	83.082.000	55.082.000
Deaths (16/05)	4.636	236	20.852	8.123	21
Deaths each 100.000 inhabitans	0,33	0,5	44,56	9,78	0,038
Strategy	**very effective**	**very effective**	**non-effective**	**Effective**	**?**

In the following analysis, the focus will be mainly on the countries that put in place restrictive measures, including total lockdown and paralysis of the economy, to depict how it impacted on the supply chains.

2.2. Impact of pandemic on supply chains

China's commercial relationships with foreign countries

In the webinar "COVID19_Business and Supply Chain Impacts with Prof. Yossi Sheffi at Crossroads 2020", professor Sheffi underlines the importance of the China export for the global companies. In particular, he affirms that companies do not supply from China cheap products, since in the last years the trend for this kind of products is to move to other Asian

countries. China's export is now more focused on sophisticated product. Industries rely on Chinese suppliers' innovation, speed, capacity and responsiveness that is hard to match elsewhere. The effect of this link between high-tech industries and China's manufacturers is that the production of the companies in the sector is highly connected to the supply materials from the Asian country.

In terms of values, we can see in Figure 6 the most traded EU-China goods, expressed in million dollars in 2018.

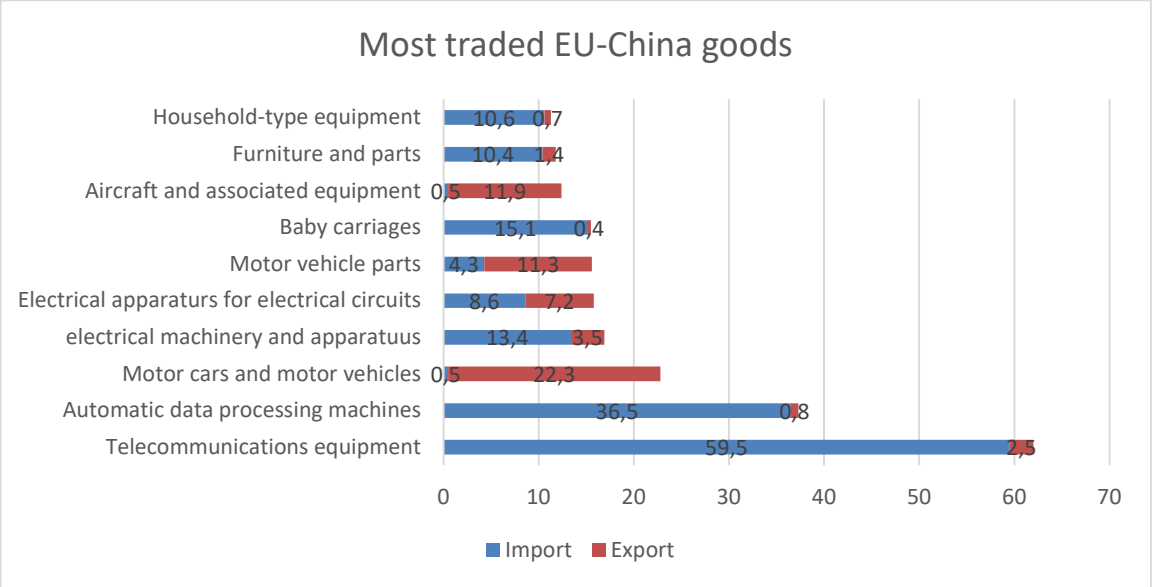

Figure 6. Most traded EU-China goods in million dollars in 2018, divided in import and export

Moreover, in Figure 7 is shown the Top 10 countries with the highest import value from China, and so the ones that could be higher affected by the China lockdown.

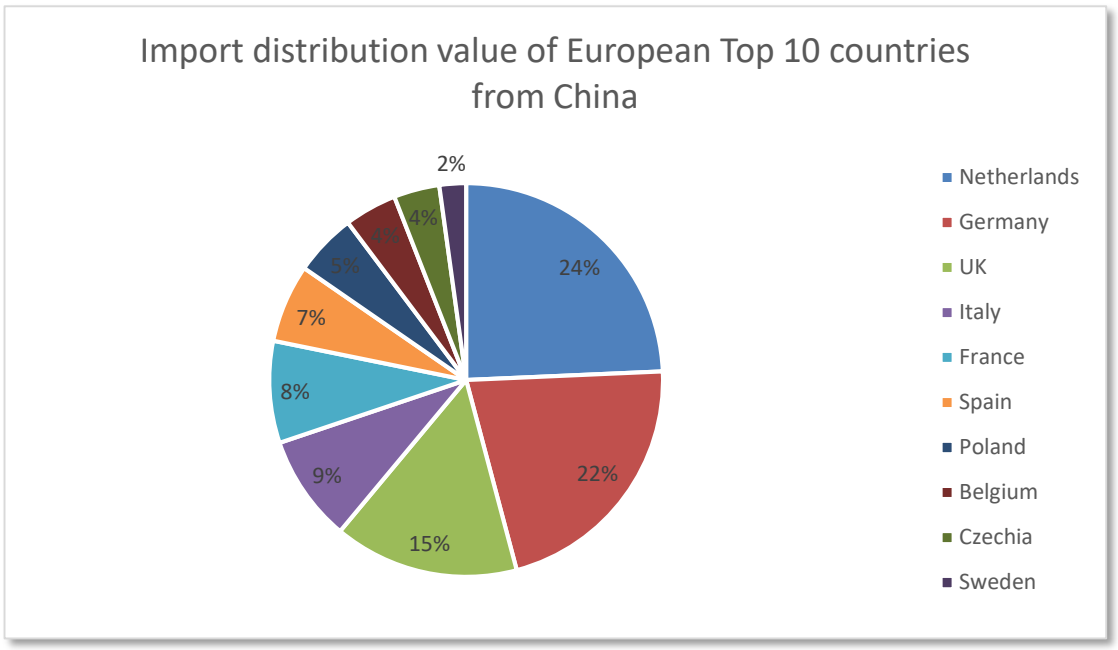

Figure 7. Classification of European country importing good from China, values in volume

Dun and Bradstreet (2020) data shows that close to 90 percent of all active businesses in China are located in the impacted region. Dun & Bradstreet (2020) data also shows that the impacted provinces command a majority of employment and sales volume – nearly 90 percent – of all businesses located in China. For what is concerned to Wuhan, in recent years, the city has developed into a hub for high-tech industries such as optoelectronics and semiconductors. Wuhan is known as China's "motor city" due to a significant manufacturing presence of domestic and foreign car makers, including Dongfeng Motors, Honda, and PSA Group. The city also hosts hundreds of production facilities of global autoparts suppliers, including Bosch, Valeo, Lear Corp, and Schaeffler.

In details, Figure 8 shows the ten most impacted businesses in the wedged provinces, of which services, wholesale and manufacturing account approximately 65% of the businesses in the regions.

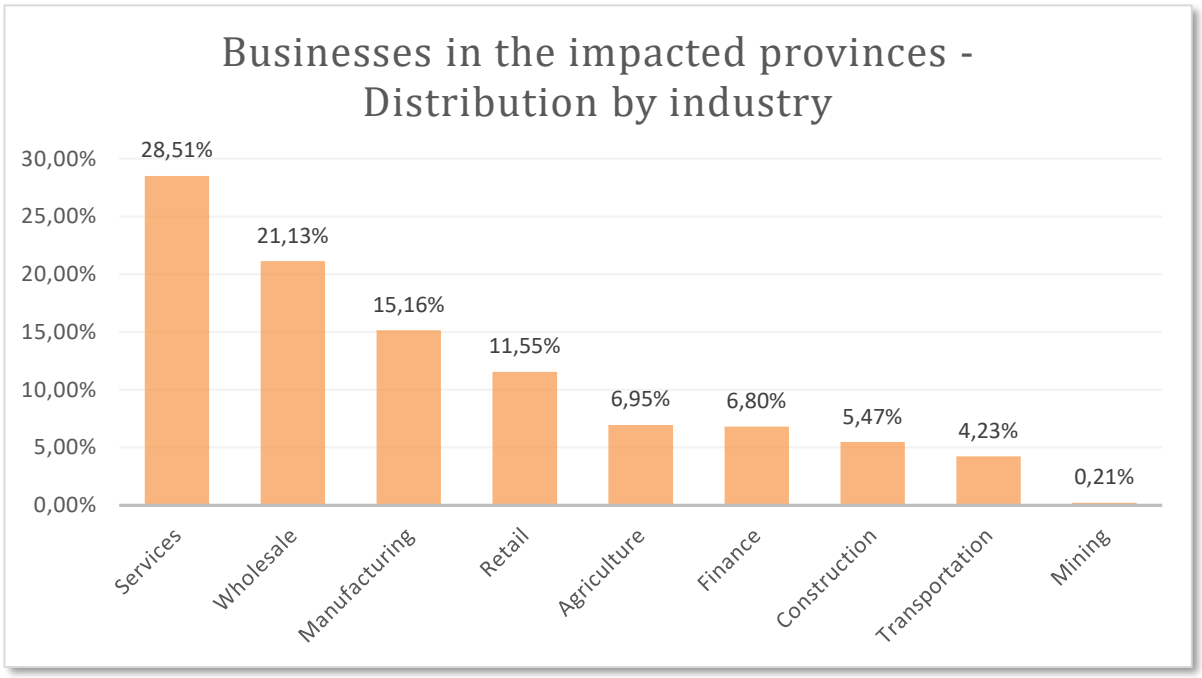

Figure 8. Ranking of businesses in the most impacted region

Because of the importance of Chinese market and, in particular, of the first impacted region, it is not surprisingly that this area has many international relationships and connections. As is shown in Figure 9 there are many companies from foreign countries that have headquarters in the impacted region, not only in the Asian area, such us Hong Kong and Japan, but also in Europe, such as Germany or UK.

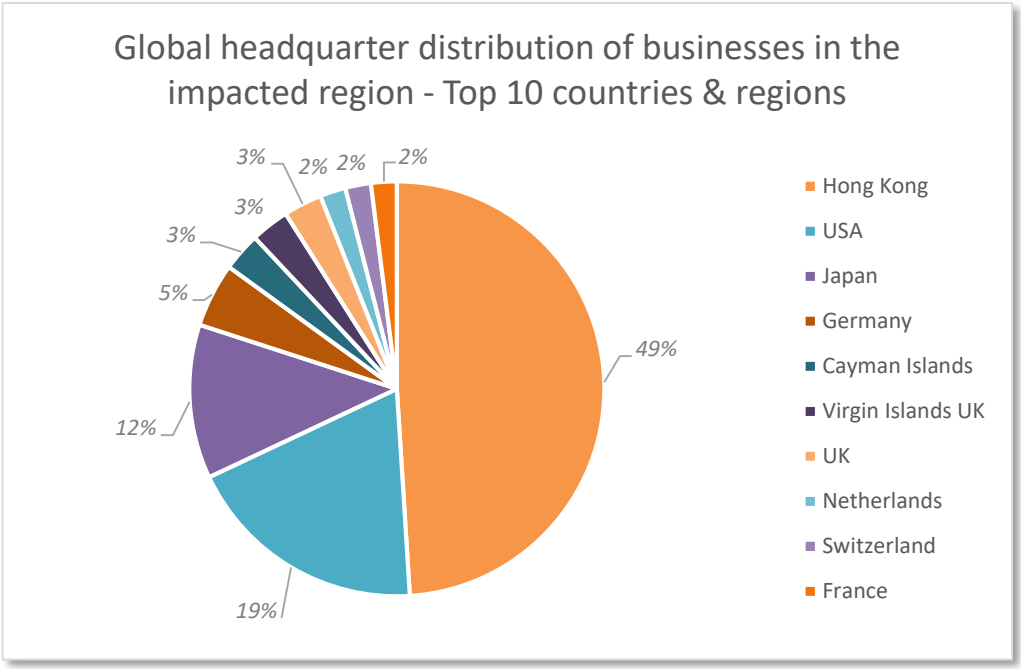

Figure 9. Nationality of companies that have the global head quarter in the impacted regions of China

On the other hand, Dun and Bradstreet (2020) report that "There are also several businesses on the other end of the spectrum whose corporate headquarters are located in the impacted region with branches and subsidiaries situated in other countries. Notwithstanding the fact that most of these branches are located in China, these Chinese origin companies have considerable presence globally with the biggest footprint in countries and regions including Hong Kong SAR, the USA, Spain, Germany, and the UK. Over 17,000 corporate headquarters are in the ground zero province of Hubei and may have experienced disruptions to business. […] These branches are linked to the impacted regions through their family trees and are projected to see some decline in their earnings due to operation disruptions."

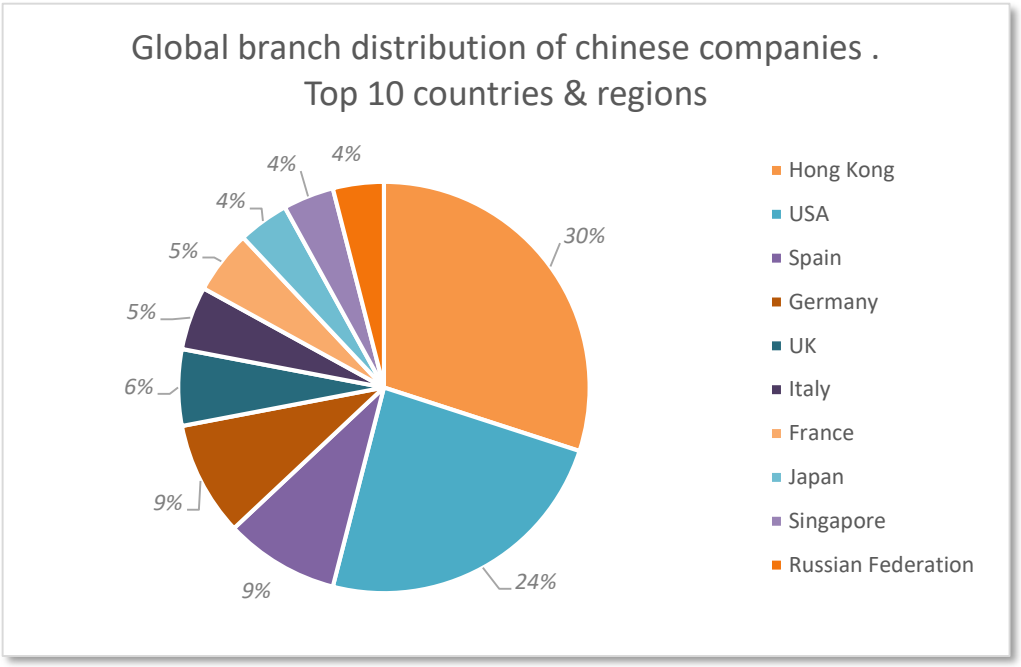

Figure 10. Global branch distribution of Chinese companies. Top 10 countries & regions

2.3. Covid-19 pandemic issues

2.3.1. Bullwhip effect

The effect of Covid-19 lockdown and its supply chain disruption was amplified by one of the biggest issues connected to supply chains: the bullwhip effect. The bullwhip effect happens when a small variation in demand is perceived as a large one, causing production to change. Bullwhip effects can happen when retail and manufacturing aren't talking to each other, but in this situation, they are caused by unpredictable demand. Both shortages and surpluses result in reduced income for manufacturers.

The first reaction we saw in demand was the stocking up of essential goods, leading to the shortage of these goods in retailers' shelves. The first response of retailers to the shortage was to place large orders to wholesalers. This triggered a domino effect from wholesalers to suppliers, from suppliers to manufacturers and so on.

Bullwhip effect creates two main effects: on one side consumers, so demand, that are the source of the outcome, are the responsible of the self-fulfilling prophecy, because, since they think there will be unavailability of some goods, they stock them and buy in excessive quantity, provoking the shortage itself. Secondly, the peak in demand does not represent a real increase in needs of the product, but it is the result of consumers' panic.

Since it is not a concrete shift in needs, the positive peak will be following by an as-big-as negative peak, because consumers will need time to consume the stored products and, consequently will not ask for it for quite a long time.

This last point generates a huge amount of inventory that will not decrease in short time. In order to better understand we will provide an example of the dynamic. The retailer or anyone in the supply chain, involved in the bullwhip effect who does not realize what is happening, place orders under the effect in the peak moment. Considering the lead times of production and logistics, he is not even sure to meet the demand in the peak period that, meanwhile, has burst. After the peak in demand supply chain actors face not only the dizzying decrease in demand, that does not even reach the levels pre-burst, but have to handle a huge inventory composed by orders placed under bullwhip effect circumstances, with a incommensurate forecast in demand. This example explains the need of companies to realize if the surge of demand, in any step of supply chain, is real or caused by non-concrete factors.

2.3.2. Liquidity problems

With the spread of the pandemic all over the world, more and more companies had to face liquidity problems due to the slowdown of economy. Most of the companies, in fact, must run fixed costs without revenues. Companies had to be aware to protect their business providing a financial base to the company.

There are many ways to protect business finance:

- Cost cutting: cost cutting usually entails cutting workers' pay, but also delaying investments and cutting discretionary spending. This last voice in strictly connected to the trend companies face in crisis times. They usually stop investing and also, in some

extreme cases, like the pandemic environment, they cut the production of some specific items, under certain conditions and do not launch new ones.

- A second measure to cost cutting is to change the Cash conversion cycle (Sheffi 2020), that is the cycle involving the timing of events related to suppliers, customers and inventory.
- Companies can conserve cash by delaying the speed at which the pay their suppliers / on the other side it takes to damaging financially suppliers, leading to supply disruption.
- Inventories ties up cash that can be released by selling off that inventory and reducing the time parts and products spend sitting or travelling in the supply chain / it improves cash levels but increase also level-of-service risk if supplies disrupted or if demand surges.
- Reducing the time lag payment. If company can reduce days dales outstanding below days payable outstanding (suppliers) effectively fund money for suppliers from customers (Sheffi 2020).

This approach has, anyway some downsides:

- Delaying the speed at which the pay their suppliers takes to damaging financially suppliers, leading to supply disruption.
- Fast inventory movement increases level-of-service risk if supplies disrupted or if demand surges.

2.3.3. Demand and supply shock

Disruption in supply chain means disruption of tangible (physical) and/or intangible flows. In Figure 11 we can see the representation of how these flows move along of the supply chain.

Tangible (physical) flows: the supply chain normally consists of two main flows:

- The flow of goods and services company, from the company to distributors and finally to retailers to reach consumers.
- Cash or financial flow, which starts with customer payments for goods and services received; and terminates payments to trading partners for supplies and all other resources used along the chain.

Intangible flows: these are four other main flows, which circulate in both directions. They are critical to understanding the end-to-end management process:

- The information flow, how to manage the big data volume continuously in the chain.
- Exchange of risk level, how to manage and transfer the existing risks among the agents of the supply chain.
- Personal relationship.
- Exchange of ideas and innovations inside the company and among the company and external agents.

The disruption in the supply chains produced by the COVID-19 has two fundamental pillars. On the one hand, risk management by the physical flows of the supply chains, that is the supply shock and on the other hand, the management of intangible flows and so the shock in demand.

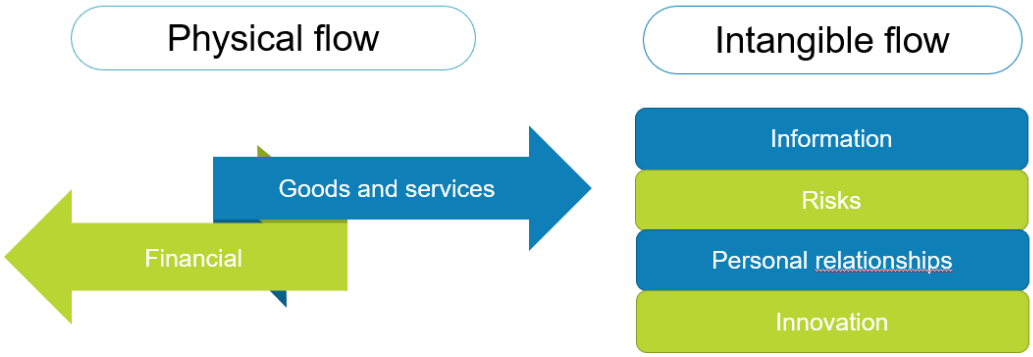

Figure 11. Flows in supply chain

Supply shock

As COVID-19 was taking its toll on China, experts were focusing on 'supply shocks'. Supply shock is connected to the unavailability of goods sourced from China; both finished goods for sale and products used in factories in developed markets (Seifert and Markoff, 2020). The lockdown of many countries from March worsted the situation of the supply chains. Closing workplaces shrinks the economic output of locked down regions.

It is fundamental to underline that in a highly connected context of supply chains, the shutdown of one country, one region or even one company, could have an effect not just at local, but at global level, depending on the structure and linking of the entity itself. In other words, the economic effect of a lockdown in a region depends on whether other regions connected through supply chains are similarly locked down. For example, Sweden did not impose a strict lockdown, unlike other European countries. However, it still expected a 4.5% reduction in gross domestic product (GDP) in 2020, a decline comparable to those in neighboring countries that did lock down, possibly because of its close economic ties with its neighbors (Seifert and Markoff, 2020). Moreover, the negative economic effect of a lockdown in one region may diffuse through supply chains, i.e., supplier-client relationships of firms, to other regions that are not necessarily locked down. When a firm is closed by a lockdown strategy, its client firms located anywhere should suffer decreased production because of the lack of supply of intermediate goods and services. Suppliers of the closed firm should also see reduced production because of a shortage of demand, as it is reported visually in Figure 12.

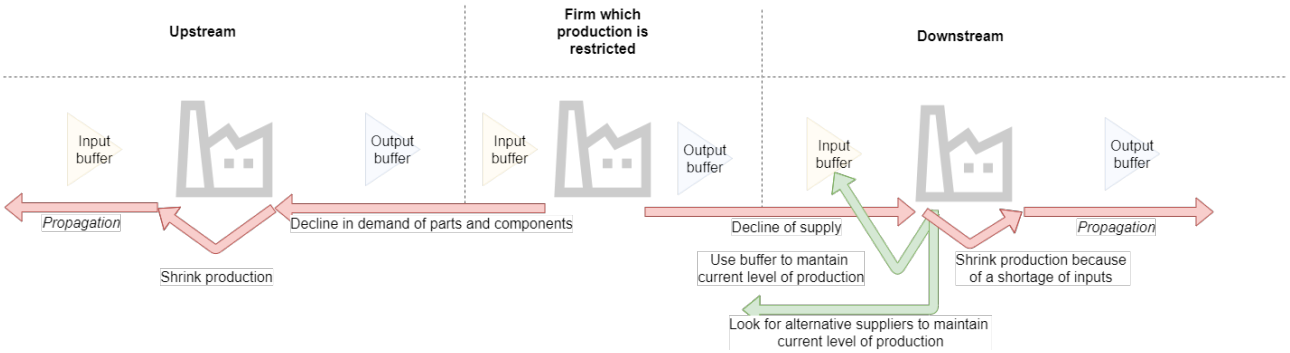

Figure 12. Ripple effect of one firm disruption in its supply chain

The effect of China's lockdown was the impact on intermediate goods to Western countries. We can see the relevance of China exports in Figure 13. The figure shows the amount of intermediate products coming from China to the rest of the world, as percentage of the total volume of intermediate products used in the countries. As we can see, the most connected countries are USA and South-Asian countries, but also Europe and South America are highly reliant on China's production.

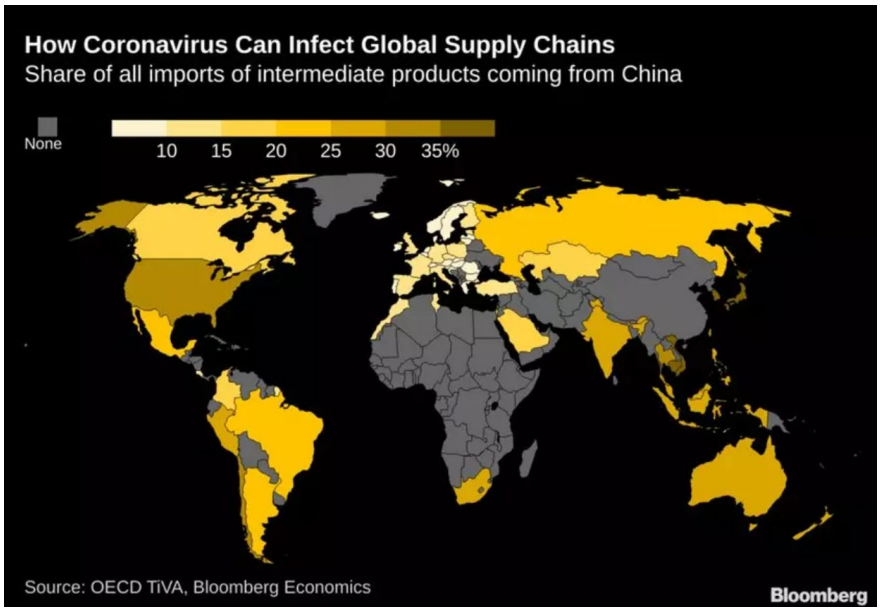

Figure 13. Impact of global spread of Covid-19 in countries

In Figure 14, instead, is shown how the volumes completely changed from the end of 2019 to the first months of 2020 in percentage terms. The graph underlines the trend for different countries, such as USA, Germany, Italy and Spain. In February 2020, for instance, German export drop to more than 20% compared to the previous two months and what is relevant, is that Germany is one of the most important commercial partners of China. The same for USA, which fall was close to 30%.

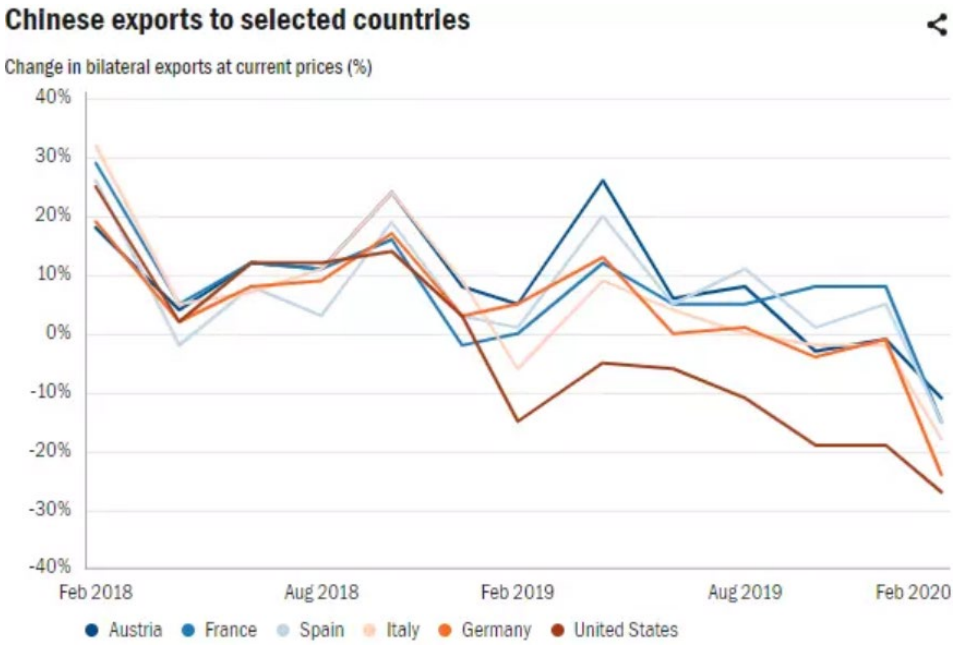

Figure 14. Bilateral exports at current prices, Year-on-year changes of two-month data from January/February 2018 to January/February 2020

The most reliant sectors on Chinese export are electronics, televisions, phones, PC, automotive but also pharmaceutical products. Regarding this last type of products, European countries were extremely in danger because most of the active substances come from China. Moreover, they are protected by patent and they come to the continent with airliners that were highly reduced, when the pandemic started in China. The high level of finished goods inventory premised European medical companies to avoid the lack of pharmaceutical products (Brusini, 2020).

Early disruptions were felt in the automotive sector with Fiat-Chrysler, Toyota, Nissan and Tata and others having to cut production. The automotive sector is more exposed than other sectors due to the just-in-time nature of corporate supply chains. The concurrent rise in "force majeure" support from the Chinese government – effectively indemnifying suppliers from the consequences of shutdowns – will reduce the ability of buyers to offset higher costs or lost profits (Panjiva Research, 2020).

In the case of electronics, the impact on its supply chain was due to the length of the chain and the importance of the industry in the initial outbreak region of Hubei. Since it was hard to elaborate a generic argumentation on the impacts of Covid-19 on supply chains in the phase of Chinese lockdown, we explore in more depth one of the most impacted sectors: automotive. We explain how it is worldwide connected and how it reacted in the first phase of the pandemic.

Fiat-Chrysler and Seat

The most hit area in Italy from the 21st of February to the 9th of March, was the one of the North-Centre, precisely in the provinces of Bergamo mainly, and Brescia. This is a strategic area, both from industrial and logistic point of view. In fact, the biggest logistic hubs in Italy are in the area of Pavia, Lodi and Piacenza. In Figure 15 it is possible to understand the closeness of the zones.

Figure 15. Map of Italy with first affected areas and biggest logistic hub

The red area in Figure 15 was the first one to be completed locked down at the beginning of March 2020. When the cities were isolated, also the production processes were blocked. In this area is placed the major supplier for FCA of electric components. FCA is the biggest automotive producer of Italy, with production plants in all the country. It does not only produce cars but groups many other goods, for instance luxury cars, trucks and agricultural machines. The establishments risked being closed because of the shortage in the products coming from the quarantined area, in which the production was reduced to 10%, because of lack in personnel and to respect safety measures.

A similar situation happened in the Seat establishment in Martorell (Barcelona), belonging to Volkswagen group, that was forced to stop the production of Seat Leon, in March. The plant was not able to receive components first from China, then from Italy and finally from the closest producers in Igualada, that was the outbreak of Catalunya region of the pandemic in Spain, for which the area was posed under lockdown on March 12th.

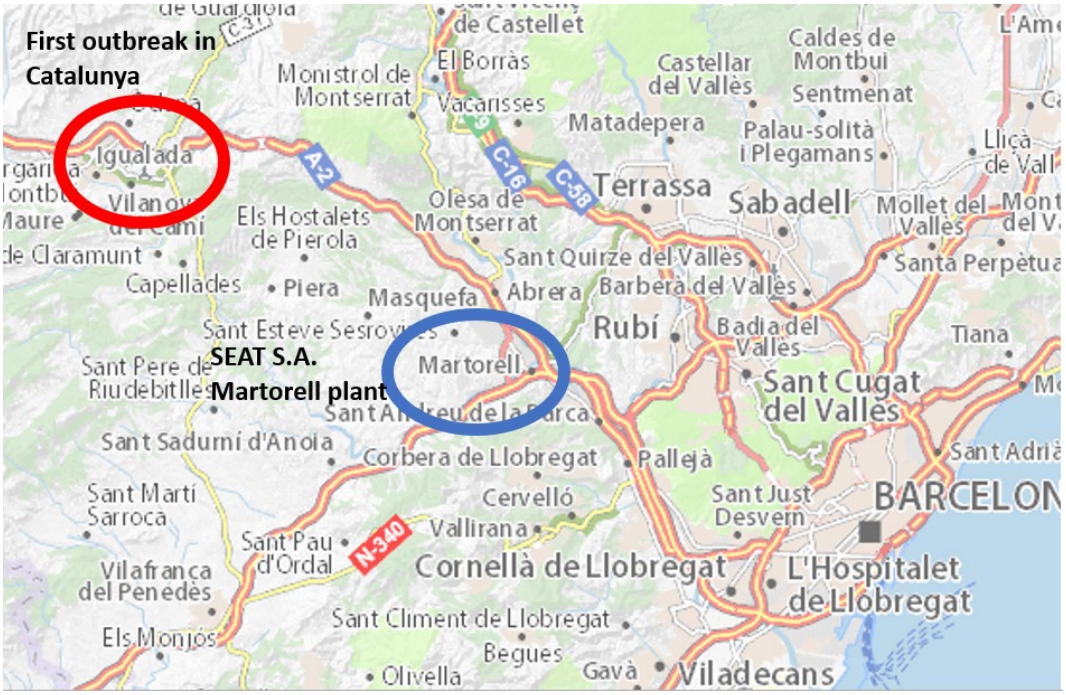

Figure 16. Seat Martorell plant and first outbreak area in Catalunya

The most important consequence of supply shock was, anyway, the lack of supply of some essential items during pandemic: personal protective equipment (PPE). The usage of PPE pushed by the need of safe work environment, outlined in the first weeks of pandemic and then stabilized but with much more volume than in the pre-Covid period, especially in countries such as European ones or USA, where it was not usual before, unlike some Asian countries, as shown in Figure 17.

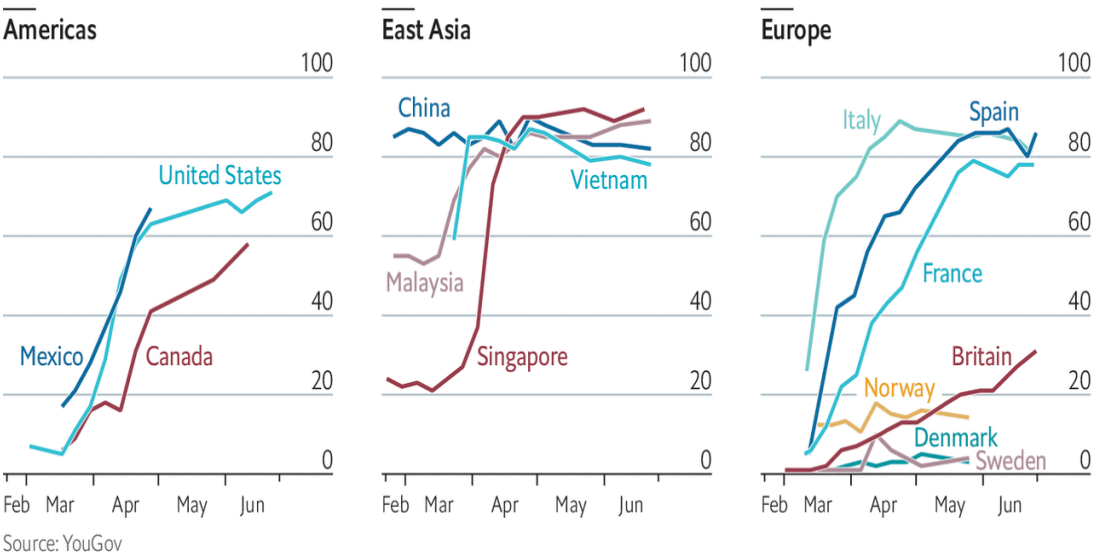

Figure 17. Share of population wearing mask in public

It meant that the supply chain of PPE was not ready for such a peak in demand, and many companies risk to have to stop production because they could not be able to provide a safe work place to workers. Finally, supply shock was worsened by the Just-In-Time system, already applied by most of production businesses. We will speak in deeper about the doubts evoking JIT during Covid-19 pandemic. In this section we just want to underline that this

methodology, based on the small batches and small inventory, created tensions in the first weeks of pandemic, since usually inventories levels were not enough to cover the unforeseeable peak of demand of some goods and, combined with exasperated pull flow chains, generated stockouts.

China's block of production lasted just one or two weeks later than the normal period of shut down because of the Chinese New Year. It means that by the end of February, 95.9% of workers were back to work. Despite of the recovery of production, so even where factories were back in operation, one of the biggest obstacles lied in the country's half-paralyzed logistics industry. The supply chain problems were mainly due to the public transport restriction, since only 47.8% of urban transportation was available (Coletta, 2020).

Chinese authorities imposed a city-wide quarantine and severe transport restrictions on January 23 in response to a deadly novel coronavirus outbreak, the notice suspended all flights in and out of the city and barred all non-emergency vehicles from entering or leaving the city (DHL report, 2020). A total of 13 cities have since been put under full or partial lockdown through similar transport bans. Thousands of flight cancellations to and from Wuhan have been announced by domestic and international carriers, while port congestion and delays have been reported on the Yangtze River as authorities attempt to control the outbreak.

Wuhan hosts China's largest inland river port on the Yangtze River that connects Shanghai to the country's hinterland for a third of the costs incurred by road transportation. Since January 23, China has reportedly held back ships, including gas carriers, from calling in Wuhan as authorities ordered terminals to stop their operations in order to slow down the outbreak of the virus.

The lockdown of the region caused problems not just in the outbound logistics, but also in the inbound since many companies were not able to receive already shipped orders, because of the restriction of traffic in the area. In some cases, shipments were left in Hong Kong harbor or in other cities of the country, generating high delays in production and logistics.

The docks situation was one of the most dramatic, since many docks were clogged in China with arriving shipping containers. Moreover, "warehouses overflow with goods that cannot be exported for lack of trucks. And many factories are idle because components are not reaching them. […] Some factories still have goods that they produced and never shipped in January, before the Lunar New Year holiday that turned into a month long nationwide shutdown. "There is a backlog of factory production to be shipped once factories reopen, and there is insufficient trucking capacity," says Brian Wu, the chairman of the Hong Kong Association of Freight Forwarding and Logistics" (Bradsher and Chokshi, 2020). The problem in some cases were not the operations in the docks that proceeded as usual, but the lack of trucks to move the materials from and to there.

From a technical perspective there were also challenges caused by a lack of empty containers in the foreign countries to allow for exports back to China (Panjiva Research, 2020). In order to contain the effects of the delays that were on average of 8 to 10 days, the Chinese government stated that they would have used the "*force majeaur*" clause of the contracts in order for the supplier/customer, not to have to pay for the products that were not able to be delivered (Bertozzi, 2020).

Like in the case of China's lockdown, once the spread took hold in other countries, logistic problems arise. They were mainly: unavailability of some transportation means used for delivering products, from raw materials to finished goods. Analyzing the different transportation means, they suffered different shocks. From the point of view of the trucks, used in terrestrial movements, there was a different fluctuation depending on the area to be reached. In the case study we will see in deeper how the different areas to be supplied and the kind of products affected the offer of trucks' transportation. Anyway, this kind of mean was the least touched because they are used only for the movements of goods. On the other hand, sea transportation and air transport were strongly damaged by the restrictions in passenger travels. In fact, usually companies use commercial lines, both air and sea transportation, to decrease their costs. In the case of sea transportation mainly for short range journeys (e.g. ro-pax ships). Due to the travelling ban, many companies had to face a steep decrease in offer of transportation. A for air travels, was to convert commercial flights into cargos, not permanently, in order not to lose flexibility for airlines, removing seats and reinforcing floor with rollers allowing to load and unload pallets (Sheffi, 2020).

Demand shock

As the pandemic crisis deepened and nations have begun instituting lockdowns, supply chains have been experiencing something completely new: systemic demand shocks, where people are stocking up on consumer staples in order to comply with restrictions on movements, in some cases buying months' worth of goods in a single day. The most talked-about example, toilet paper, is ironically usually the go-to example of a perfectly forecastable product, since the end consumption is usually rather stable. There seemed to be a fear that food supply chains would be unable to respond to this unprecedented, massive spike in demand (Seifert and Markoff, 2020).

The demand shock was mainly pushed by the information flow to the consumers. The flow of information has a disruptive impact of the supply chains. The excess of information can lead to a change in consumer habits, causing disruption in the supply chains. In the Covid-19 crisis disruption in the supply chains has not been produced by an infrastructural problem; it has been produced by the management of the intangible flows.

70% of global population was exposed to news about Covid-19, in some countries, like Italy, Korea and Japan, the percentage reached 90%. It was a scenario of interruption in the supply chain, because consumers reacted buying an excessive amount of primary goods, generating the shortage of multiple categories of products and potentially generating the bullwhip effect. In other words, there has been a change in behaviors and habits of the customer in a non-rational way, mainly caused by the saturation of information and panic effect.

The most sold products during lockdown period were closely related to the country, they were in fact the most used products used in the food sector. What did not depend on the region, was instead the spread use of sanitizer products and for personal hygiene: the case of the shortage of towel paper was common in almost every country. For instance, in Italy the most sold products are reported in Figure 18.

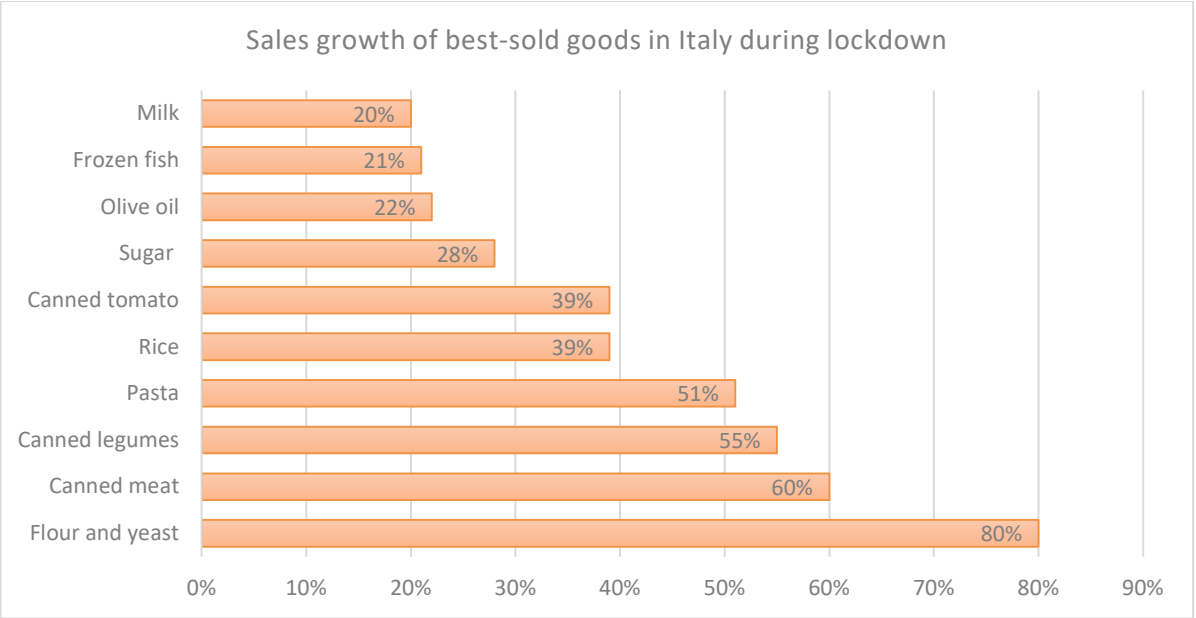

Figure 18. Sales growth of best-sold goods in Italy during lockdown compared to pre-lockdown period

Figure 19 shows instead the most sold products in one of the most important retailer chains in Spain during lockdown.

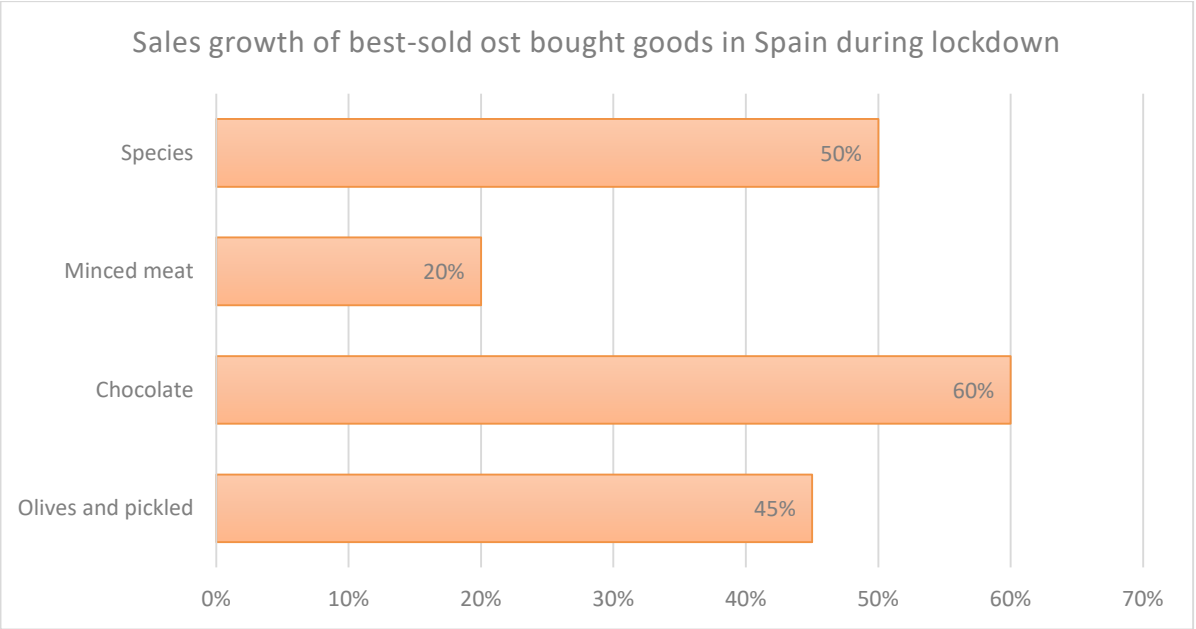

Figure 19. Sales growth of best-sold bought goods in Spain during lockdown compared with pre-lockdown period

The demand of some goods grew up of 40% in this phase and no supply chain, anywhere in the world and in sectors that are relatively stable historically from the point of view of the demand, is prepared to absorb a 40% change in overnight demand in the morning as there is no availability labor, equipment, machinery, materials premiums, productive capacity, etc. for a sector quickly absorbs this change abrupt.

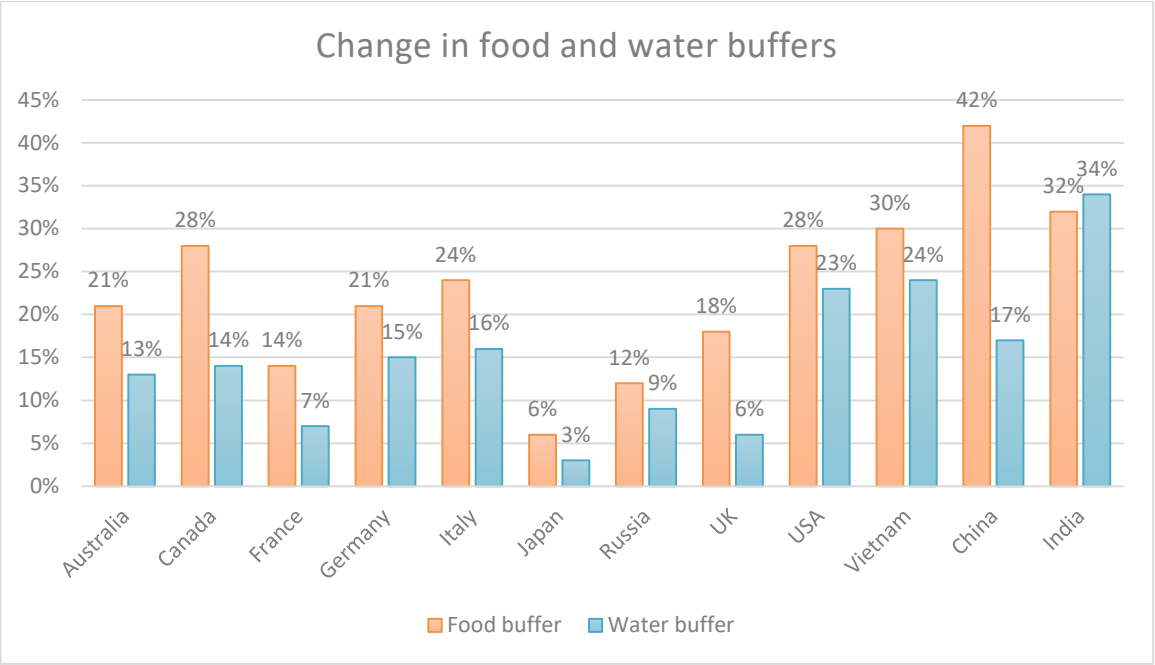

Figure 20. Change in food and water buffer in different countries, compared to pre-lockdown period

Manufacturers of these essential products should bear in mind that when the crisis reverts completely to normal, this over-storage that have household consumption will start, reducing consumer demand levels on supermarket shelves. This can generate high levels of inventory in manufacturers or intermediate agents in the supply chains with the consequent reduction in production levels and therefore a potential reduction of employment (Leporati, Martul, Morales, 2020). Moreover, the manufacturers must understand which are the changes in habits that the crisis is causing, but more important is to try to identify which of them will remain in the scenario of the new normality.

Not all the goods suffered an increase in demand. Some products, such as cars, luxury goods, fashion and goods sold in Horeca channel, suffered a demand breakdown. In this channel, the effect of demand disruption was the creation and handling of huge inventory levels that could not be sold because of the opening restrictions of the channels in which they were usually sold. The shock of demand is not only connected to finished goods but also raw materials, especially when the demand of China and Eastern countries drop. These materials are, obviously, necessary to build the intermediate goods, most of Eastern countries supply from the nation.

The most impacted sector, regarding the drop of demand of China because of the lockdown was the one of the oil. “China is the world’s largest oil importer, after surpassing the U.S. in 2016, so any change in consumption has an outsize impact on the global energy market. The country consumes about 14 million barrels a day -- equivalent to the combined needs of France, Germany, Italy, Spain, the U.K., Japan and South Korea. […] Chinese oil demand has dropped by about 3 million barrels a day, or 20% of total consumption, as the coronavirus squeezes the economy, according to people with inside knowledge of the country’s energy industry” (Cang, Blas, and Cho, 2020). The main suppliers of Chinese market of crude oil, Latin America, West Africa and Russia saw a big drop in the demand of the product. Moreover, exports of commodities from Brazil including soybeans and iron ore were already in decline before the shock. Similarly, Mexican steel output has started to decline and had already fallen by 8.4% year over year in January (Panjiva Research, 2020).

3. Approach and decision on possible solutions

3.1. Covid-19 and natural disaster parallelism

The aim of this section is to take advantage of the literature related to natural disaster management, since it is the most similar event compared, in terms of disruption on supply chains, to pandemic.

All disruptions proceed from one or more of these losses:

- Capacity to acquire materials (supply)
- Capacity to ship / transport
- Capacity to communicate
- Capacity to convert (internal operations)
- Availability of human resources
- Financial flows (ex. Demand) (Cai, Goh and de Souza, 2013)

These losses are generated in the case of a natural disaster, think about an hurricane that destroys the logistic infrastructure and hits the purchasing ability of the consumers. In the case of the pandemic, we could say that all these losses that place.

With a natural disaster is indicated a natural event such as a flood, earthquake, or hurricane that causes great damage or loss of life. The reason why the effects of these events have been studied is that in the last decades many countries faced this kind of disasters, some of which are repetitive or with high risk of reappearance. It means that it is necessary, for companies operating in high-risk territories, to know how to manage a natural disaster. Studies have been done regarding Hurricane Sandy that hit the United States in 2012 or Fukushima earthquake and many others. It is a linked phenomenon to the pandemic because the probability of occurrence is low but the effects, when it happens, are huge.

In order to better understand the effects on a pandemic in a larger time horizon, we can depict the lesson learned from known natural disasters. The primary impact of the disaster is the damage of local operations, personnel and communication lost. In a second moment, downstream customers suffer losses of supply from primary impacts causing shutdowns. Finally, critical dependencies emerge, and also it is clear how niche suppliers in lower tiers influence the production.

Companies hit by the effects of natural disasters, realize that they have short time to identify the impact on the business. Hence it is not completely clear the core operations, each supplier and each customer in the chain. In addition, they have to execute fast the business continuity plan, that, sometimes, is not even well implemented and, finally, they need to identify sources and secure the remaining capacity (Cai et al., 2013).

The primary consequence of a natural disaster, in the last years, was questioning the effectiveness of Just in Time methodology and Lean principles, since the low inventory levels and the low peace of production do not help the recovery from a disaster. There must be a trade-off between remaining agile and mitigating risks, always with a focus on the cutting of costs on daily supply chain operations.

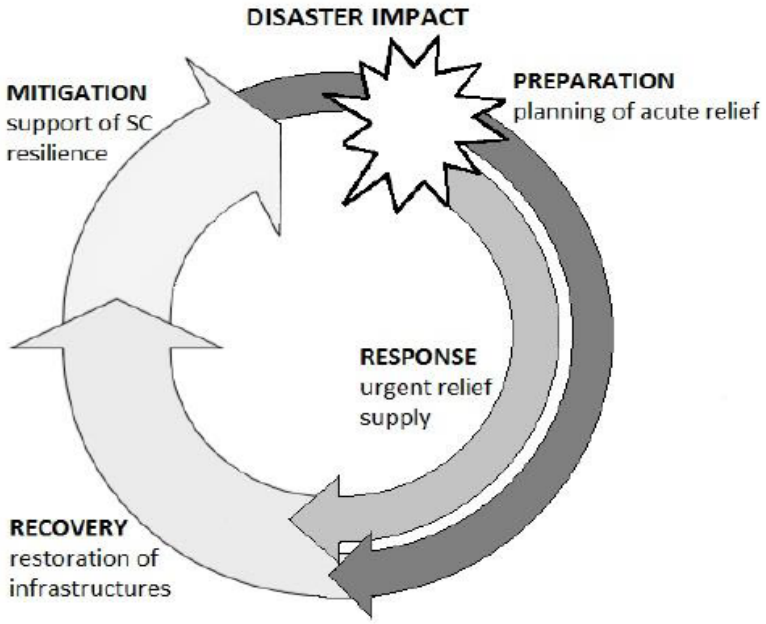

Figure 21. Disaster management cycle based on Howdes (2009)

Figure 21 represents the most important phases a supply chain faces, after a disaster. Soon after the catastrophe, the business must focus on the planning to manage the effect and start to depict the measures for recovery. Once the measures are clear, the company must respond to the challenges. The recovery includes all the steps to restore infrastructures, intended as logistic ones, personnel, capacity and so on. Finally, the most important and less deployed step is the mitigation, i.e. the measures to consolidate the supply chain and to make it more resilient, also in case of future events.

The main core of the mitigation is usually a risk mitigation strategy that is part of the enterprise risk management. Risk Management (RM) is broader area and a systematic process which helps organizations to understand what the risks are, who is at risk, what current controls are for those risks, and then making a judgement about whether the current controls are adequate or not (Freeman, 2013). In particular Enterprise risk management plan is a new branch of risk management that eliminates the boundaries among divisions, departments or cultures, focusing instead on the risk associated to the different assets of the company, such as health and safety, financial, technology, reputation and so on.

The risk mitigation strategy can improve efficiency, flexibility and responsiveness of the supply chain. Especially, companies must find a balance in the usage of resources to mitigate the most common and low effect risks with bigger risks such as a natural disaster and a pandemic, that are usually classified as low probability and high impact risks.

Some steps have been identified in order to develop a risk mitigation strategy, exploiting the past natural disasters' impacts on the chains:

- Postponement: reducing the number of items produced, so move the specialization and customization of the final product in the last stages of production, in order to have the lowest number of goods in production and stored.
- Strategic stocks: placing shared inventory stock at a certain strategic location to be shared by multiple supply chain partners.
- Rebalancing the supply chain: have more than one supplier to immediately switch, in case it is unable to fulfill the service.

- Make and out-source: mix the production sourcing, some goods will be produced in-house and others will be outsourced, to decrease the risk of lockdown.
- Networked economic supply incentives: governments may offer incentives to entice suppliers to enter the market if the number of suppliers is low. This is especially important in the economies and sectors in which the level of specialization of companies is really high. For instance, in Japan, the specialization trend was really hard in the last years, so that there could be only one supplier available for a type of material or part.
- Flexible modal choices: having flexible and diverse logistic strategy that relies on multiple nodes of transportation, multiple carriers and multiple routes.
- Use dynamic pricing to shape and manage demand: supply chain is not just about production and transportation; everything starts with the demand. It is fundamental to have control over the demand and it is possible thank to the market rule of demand/offer. The lower is the price, the highest is the demand. So, when the demand and the offer do not match, because the production capacity is not enough or too high, companies must use this leverage to correspond (Cai et al., 2013).

Taleb (2007) coined Black Swan as low probability, high-risk events. With increasing global interconnectivity, complexity of networks, and speed of activities, today's worldwide conditions are favorable for the occurrence of Black Swans. Due to the unpredictable nature of Black Swans, preparing a business continuity plan to handle them can be extremely challenging. The best plan that most companies can venture to have includes conducting a business impact analysis and determining the minimum level of services and products that is acceptable to the organization to achieve its business objectives in the case of an emergency or a disaster. Moreover, building flexibility into the business will help the organization to better respond when something actually goes wrong. While it is not possible to rely on past data to predict less-commonly occurring future events, it is beneficial to identify which critical paths could be affected by a disruption, assess and identify the worst-case scenarios on project and portfolio success, create a defined process of response, identify key decision makers that need to be involved, and know what are the critical functions of the business. These details are typically well defined in any business continuity plan.

Related to the types of losses explained at the beginning of the chapter, Covid-19 caused both a shock in demand and in supply (Sheffi, 2020). For this reason, the effects of the shock were incredibly big and the recovery more difficult. The biggest difference in the case of the pandemic, for which it is hard to relate the studies in natural disasters with the actual situation, is that the pandemic became a worldwide problem and so it becomes difficult for companies to take in place some of the recommended actions. For instance, look for other supply sources was difficult not just for the lack of diversification but also because almost everything was shutdown. It was even more difficult, because of the restrictions in movements, as measures to contain the virus propagation. Unlike natural disaster are usually correlated with a block in supply and logistic means, because of geographic and infrastructural damages, countries decided willingly to close the border, not because of a physical impossibility in transport, but in order to avoid an excessive propagation of the virus. Anyway, despite the causes are different in the case of pandemic and in the one of natural disaster, the result is the same: a restriction in movement for logistic operators.

3.2. Building resilience

This section has the aim to identify the biggest issues that emerged from the Covid-19 situation and some possible solutions. Deploy the solutions by a company would lead to a change in the

supply chain management, in order to make it more resilient in a future perspective.

Resilience means the ability of a pre-existing network of demand and supply to deploy surviving capacity, and/or introduce new capacity, under severe duress. It is the ability of a network, or portion of a network, to continue moving (directing, redirecting, flowing) goods and services even when important elements of the network are no longer operating (US department of Homeland Security, 2020).

On the following paragraphs, it will be provided some measures that can be useful to create a more resilient supply chain. The first focus will be on the supply chain network management and the need of visibility among all the tiers of the chain. The second point will be the risk management and the need of developing a risk management plan, ready in case of supply destruction. Later, the study will focus on the suppliers' management and choice and the winning strategy of differentiation and the impact geographical distribution has on resilience. Finally, it will be provided a reflection about the risks of Just in Time supply chain system.

3.3. Problems and possible solutions in supply chain network

3.3.1. Managing multi-tier supply chain

The supply chain network is a complex system of interdependence among multiple firms, each one with a number of links to specific partners. The supply chain network is composed firstly by tier-1 suppliers, which are the ones directly connected to the main company. They then rely on other suppliers that, for the original firm, represent tier-2. The depth of a supply chain refers to the number of tiers in the network, which is determined by the number of steps it takes to transform primary inputs into a finished good. Another aspect of supply chain network is the number of tiers-1. The highest is the number of suppliers, the hardest is the challenge in terms of procurement and operations, unless the downstream company actively shapes a coordinated and cohesive core group into which all others feed. This aspect, could mean that it is better to have a few number of suppliers, but on the other side, relying on a narrow supply chain may cede strategic leverage to key suppliers and create the possibility that one player going down can snarl the entire network. Each company will have to determine the balance that suits its management capabilities and its risk tolerance. Often the result of cascading outsourcing decisions, deeper supply chains with many tiers may be more opaque and harder to trace.

One way to react to the uncertainty generating from supply chain network, is to deploy a scale-free topology. This network is characterized by the existence of few large hub firms with many connections combined with many small peripherical firms with few connections. It is seen as the most efficient topology on supply chains and the most suitable structure to respond against disturbance and disruptions. This type of structure provides big agility to the supply chain, so the ability to respond quickly to sudden changes in supply and demand. The agility is highly connected to the number of intermediate agents through which the flow of materials or information needs to pass between the initial supplier and the final customer.

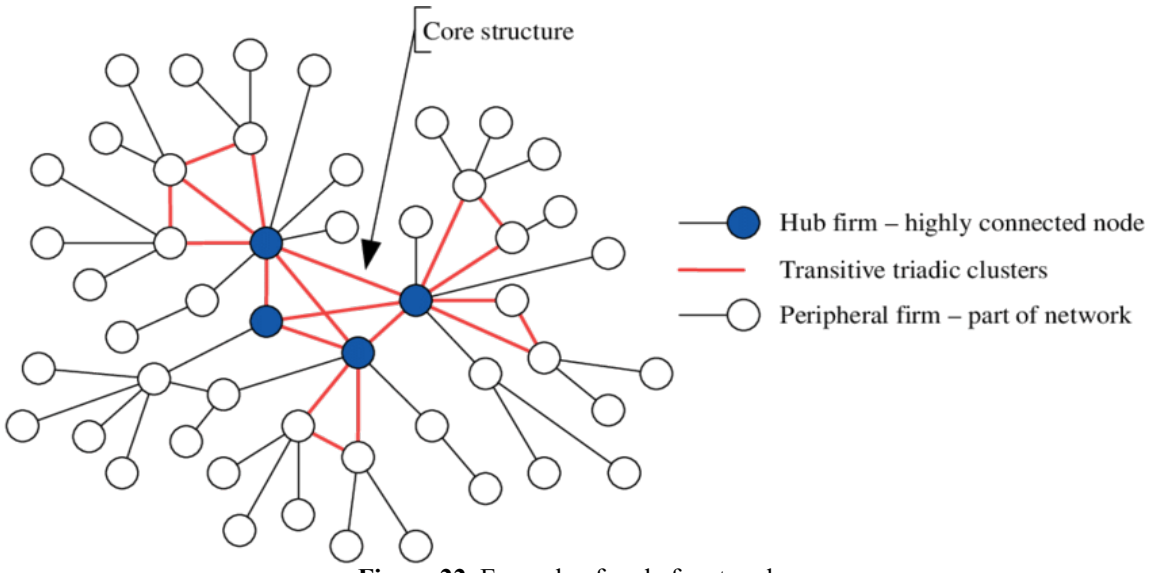

Figure 22. Example of scale free topology

Agility generates two positive effects: on one hand more visibility, so the ability to see all entities, production and distribution capacity of the connected suppliers, on the other hand, velocity, i.e. the speed of the response when the change in demand and supply chain is produced (Hernández, 2020).

If it is not possible to develop a scale-free topology, companies must, at least mitigate the risk. Risk mitigation connected to multi-tier supply chain is possible through the mapping and definition of all the suppliers in Tier-n the company has. For instance, although companies think to rely on a set of suppliers, they may rely on a single at Tier-n supplier, since their supply chain has a diamond structure (Sheffi, 2020), as the one represented in Figure 23.

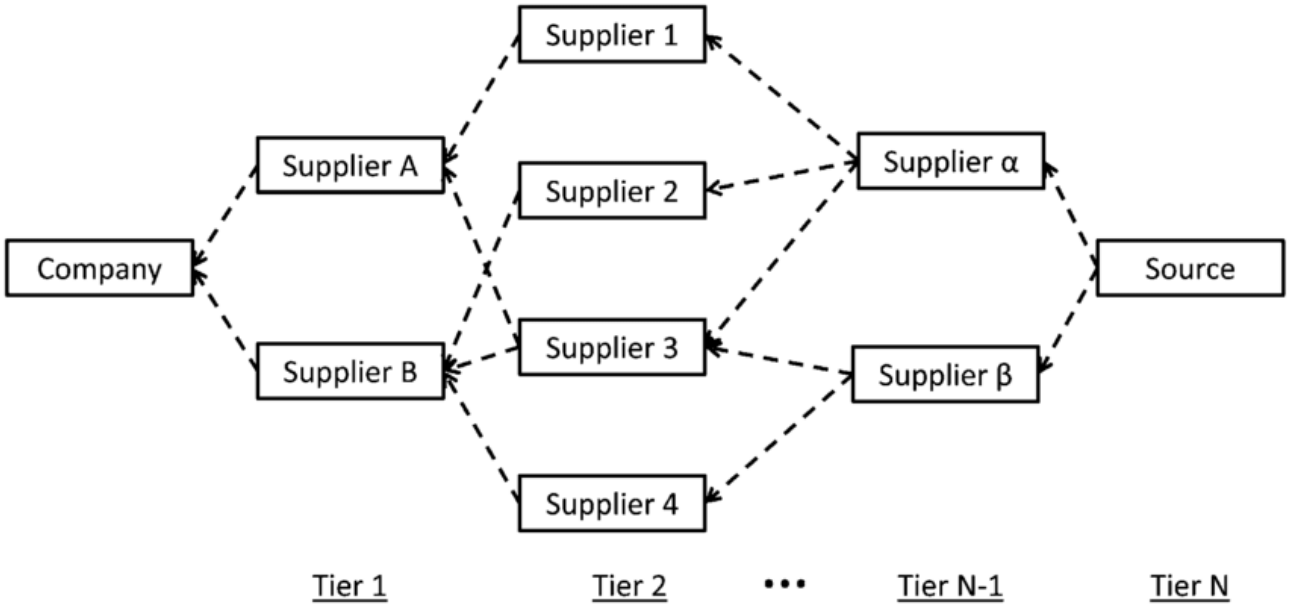

Figure 23. Example of diamond structure in supply chains

If the company belongs to this supply chain structure, although it is convinced to mitigate the risk, it incurs in the risk, as long as Tier-n supplier suffers a disruption. For this reason, it is important for companies to map the supply chain and know exactly how its supply chain is

organized. Likewise mapping the supply chain structure is important also the accuracy of the Bill of Material is essential. In fact, companies could ignore that a material necessary for the production is inside the Bill of Material and do not expect a disruption when its production is under stress.

Visibility

Apart from the supply chain structure, companies had to face during the emergency the lack of information about the parts involved in their supply chain. It is necessary for each business to identify all the players in its supply chain (McKinsey Global Institute, 2020). Most have some view of the potential risks in their direct tier-one suppliers but are flying blind when it comes to the sub-tiers of the supplier network (McKinsey Global Institute, 2020). Not having visibility on sub-tiers means that the companies did not have idea of the impact of the pandemic on their supply chains (Tang, 2020). This leads to the impossibility to carry out some strategic and preventive actions in order to anticipate the possible effects of the pandemic on their supply chains. In addition to this, there is a misunderstanding of the information companies own. As Tang (2020) depicts, firms assume to have a clear information flow. This could be true in good times, but not during extraordinary events: in these moments, in fact, information flow is not following material flow. As a result, companies lose a big part of their visibility.

Data represent a competitive advantage for companies both in good periods but more in bad ones. In the first moments of pandemic, it was necessary for people to understand what was really happening and what, instead, was just the effect of panic. Technology enables in this way the visibility necessary for firms. The issue is that all businesses involved in the supply chain must, firstly track their movements and secondly adapt a compatible technology, agreeing on a set of standards so they can all share and use others data (Sheffi 2020). In this way, supply chain managers can know as soon as possible, what the problem is and where is it, in order to plan solutions. In this context, visibility is not enough, since it must be flanked by transparency (Sheffi 2020). Transparency means sharing downstream inventory and sales patterns so the supplier can plan production. This plenty of data allows preventing the Bullwhip effect we spoke about in the previous chapters.

3.3.2. Developing risk management plans

The crisis in which many supply chains find was mainly due to the inexistence of a risk management plan. In the last years, many academics underlined the need of a developed and ready risk management plan, especially since the supply chains became more and more globalized and complex.

Some factors influence deeply the level of development of the plan. In fact, firms that are settled in areas that, with high probability already face geographical and natural struggles are more prepared to deal with the effects of extraordinary events. At the same time, companies that produce essential items, are not allowed to stop the production and, for this reason, are strongly recommended to own a plan.

The risk management plan drafting starts with the risk identification. There are mainly three types of risk (Tang, 2020). The supply risk is the first one. This specifies which are the risks directly connected to the supply. It is necessary to understand in this stage also if the flow in local or global. The second type of risk is the process risk that includes the likelihood of suppliers' closures, export bans, import bans, logistic delays, factory closures and so on.

Finally, the demand risk that considers the unexpected changes in demand.

After developing the risk identification, the company must switch to the risk assessment, considering different groups of the society, such as the risk for the health sector, the business sector, the citizens and so on, defining the likelihood and the impact. It is important to identify the link among these actors because of the domino effect. For instance, when shops closed during the lockdown, they were the first ones to tackle this shock, but then it reflected on the retailers that did not have any demand from the downstream level and finally to the suppliers.

The third step is the risk mitigation and so the contingency plan. It is needed to assess the capability of the company, understanding the local and global sourcing capacity and finally develop the contingency plan, composed by stress tests and scenario planning (Tang, 2020). McKinsey report, underlined, for instance, that all the banks, after the 2008 financial crisis, understood the importance of carrying on a stress test every year, to be prepared for any case of events that could highly impact the company. It is probable that, after the pandemic, also production companies will put in place this kind of risk management tool.

One of the main objectives of the risk management plan is to improve the visibility in the stages of the supply chain. Companies must put in place measures to track and control all the parts of the chain. It would be necessary to develop a tool, like a risk index for each component and commodities, based on the uniqueness and location of suppliers (McKinsey Global Institute, 2020). After mapping upstream suppliers, companies need to understand the production footprint and financial stability of each participant in the supply chain. The second important tool companies must implement is digitalization. It is necessary to have a centralized control system, like some companies already have. It can help in case a problem occurs; the system can run scenarios to identify the most effective solution. In fact, one of the biggest issues during the pandemic was the lack of accurate and timely information about supply and demand.

Apart from the risk management plan, companies must do investments to be resilient in the future and minimize the financial impact of disruptions and speed time to recovery from a disaster. Resilience typically requires investment or even accepting higher current operating costs today to minimize potential losses in the future. Companies can conduct their own stress tests to quantify their financial risk from disruptions. Key parameters to explore could include measures of shock exposure and measures of supply chain vulnerability and resilience. Such an exercise helps companies to identify the most effective preventive measure at their disposal and conduct a cost-benefit analysis of the required investment. Since the cost of disruptions is high and highly probable, it is time to rethink the returns from investing in value chain resilience, which may pay off both today and over time. McKinsey analysis indicates that an average large company could invest up to 40 percent of one year's EBITA in resilience measures and still have a positive return on investment when viewed over a decade (McKinsey Global Institute, 2020).

In addition to these measures, companies must develop the so called "Scenario planning". This tool is useful to think about what-if features and how to operate within them. The scenario planning offers two strengths to businesses: on one hand it helps to develop the stress test, on the other hand it helps to create alerts or sensors to identify early signals of a coming disruption, in order for managers to be prepared for it. The adoption of scenario planning and stress test is fundamental for companies that can take advantage of this, improving the solidity of the business. For instance, high-tech companies usually use them to stress the infrastructure

and know where to improve it, providing the best version of the platform itself, just by putting to the test on their own.

3.3.3. Suppliers' choice and in-shoring possibility

As was explained in the previous chapters, the magnitude of Covid-19 effects was even bigger because of the globalized network of the supply chains. For this reason, one of the measures on the table, to improve the resilience of the chains is the better suppliers' management and, extremely, the in-shoring of production. But it is not so immediate or easy.

Since we deeply spoke about China in the work, considering that Covid-19 started from it and it is a commercial power, it is interesting to start defining the in-shoring possibility of businesses based in China. The role of China in the globalized supply chain is far different from the one "popularly" recognized.

On one hand, the common belief is that China is chosen for the production of low-cost products. This is not true, because in the last few years, the labor cost has increased in the country, making labor-intensive production, basic training and capital-intensive businesses move to other countries in South-East Asia, where labor conditions are cheaper. Moreover, the movement of companies away from China had already started in the past years, because of the commercial tensions with the United States.

On the other hand, China is a strategic position for companies, especially in some sectors such as pharma and high-tech. The development of this market led in the years to a strong supply base that cannot be replaced easily. Chinese customers, in addition, have more and more purchasing power, China's GDP is the second highest in the world and the nation consumes 20% of global output, and the population is growing faster. For this reason, for some businesses moving away from China would mean going far from customers and not closer.

Geographical concentration

Geographical concentration of the suppliers represents a source of vulnerability. This is a big issue, since manufacturing of some products has become highly concentrated, creating the potential for bottlenecks. For instance, just five regions (mainland China, Taiwan, South Korea, Singapore, and the United States) account for three-quarters of global exports in semiconductors. China, Vietnam, the United States, the Netherlands, and South Korea account for three-quarters of exports in telecommunication equipment. Overall, we find 180 traded products, worth $134 billion in 2018 that were overwhelmingly produced in just one country. (McKinsey Global Institute, 2020). The concentration and co-location of many companies and suppliers is called an industrial cluster. It is positive for economic development and for attracting investments. It creates a competitive advantage for companies but at the same time creates a concentration of supply chain risks.

Sourcing from multiple or lower-risk geographies can minimize the odds that an isolated natural disaster in one place can bottleneck the entire value chain. When most suppliers are concentrated in a single geography, a natural disaster or localized conflict in that part of the world can cause critical shortages that snarl the entire network. The risk of concentration affects both downstream customers, whose inputs could dry up, and upstream suppliers if those customers stop ordering. When a country is heavily reliant on one major export industry, a sharp downturn in customer markets can have devastating effects (McKinsey Global Institute,

2020). Another issue in the case of in-shoring is the fact that some activities have already optimized a global portfolio of locations (Sheffi,2020). To handle disruption, it is enough to have a distribution chain in which the available nodes, not touched by disruption, can serve the areas hit by disruption, sharing capacity and resources. Having a multi-shore network of locations provides on one hand, local presence to serve rapidly customers, on the other hand resilience in case of breakdown of some nodes.

In addition to this point, it is necessary for companies not to rely on a single supplier, to minimize the risk. Some companies cannot supply from other suppliers because of the shortage in that product, especially when we are speaking about raw materials. Others do it intentionally, to save money or for proximity. It creates a vulnerable environment, in which the company is exposed to high risk of bottlenecks in case of a reduction in provisions.

Short vs. long term decision making

Looking at the long term (within the next 5 years), we can foresee different types of relocation initiatives triggered by Covid-19. First, a relocation guided by the need to reduce the risk exposure (Barbieri, Boffelli et al., 2020). Second, one can foresee decisions from entire supply chains that may be driven by the actors of the supply chain itself or by policy interventions to attract strategic productions. On the short-term, we do not find evidence of such joint actions. A possible explanation is a need for preparation, as evidenced in the literature, that is much more complicated to be assured in a joint reshoring initiative. Instead, examples of multi-firm collective production shifts and supply chain restructuring may be found even in the short-term, enabled by policies pushing manufacturing towards critical supplies.

In the end, two elements appeared to be critical in differentiating the type of responses, namely the time (short term vs. long term) and the decision-maker (single firm vs. supply chain), as reported in Figure 24.

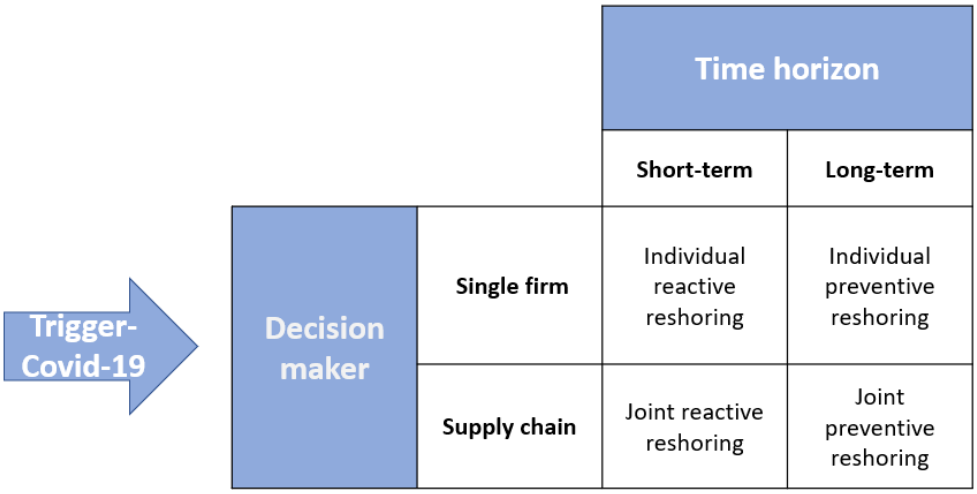

Figure 24. Definition of the type of response, looking at the decision maker and the time horizon

Figure 24 suggests decisions will be developed within two different time frames: the short term and the long term. In the short term, companies and governments will react simply to the current situation using reshoring to revise their current operations with potentially no substantial change in their future strategy. In this perspective, reshoring will be simply a way to cope with the current conditions, where companies and supply chains may either face a transitory condition before coming back to normality or adapt to a new normality. Other

organizations will consider the current situation in a long-term perspective revising drastically their strategy. We do not argue that this is due to a radical change in the environment, but the current situation has accelerated already developing processes, that probably in different modes and times would have eventually happened. In this scenario, a new normality will settle. In the long-term, we expect to see two different approaches to reshoring, according to the level at which decision making is processed: single firm or supply chain. From a policymaker perspective, we expect to see actions at both levels. Policies at the single-firm level are easier to be implemented, more popular in a strictly political sense, but potentially not solving the problems that several industries faced during the Covid-19 emergency breakdowns. Focusing on a supply chain perspective can be critical to cope with sudden variations and to increase its resilience, responsiveness and restoration capabilities. Moreover, it may become difficult to attract an entire supply chain within one single country's boundaries; for this reason, proper cooperation with countries in close macro-regions could become a turning point to favor near-shoring initiatives (Barbieri et al., 2020).

Sharing goals among supply chain

In addition, the relationship with the suppliers must be strictly controlled, since companies must assure that also their suppliers and in general, businesses that are connected with them, develop and care for resilience. Large companies may consider investing to develop their suppliers' capabilities or collaborate alongside them on key components. Apple, for example, has invested $450 million in Corning to support the development of glass used in its iPhones. The money comes from the company's $5 billion advanced manufacturing fund, which provides suppliers with capital for R&D and upgrades; in return, Apple locks in supplies and favorable prices. Vertical integration is the ultimate way to ensure continuity of a key input. In 2018, the iconic British fashion brand Burberry acquired a major Italian supplier, CF&P, to ensure the delivery and quality of leather goods. In the automotive industry, demand is growing for electric vehicles, but automakers have faced difficulties in securing sufficient supplies of batteries. This has led Volkswagen to invest €1 billion into its own state-of-the-art battery-making plant in Germany and to acquire a 20 percent stake in Chinese battery maker Guoxuan. The make versus-buy question is a complicated trade-off but one worth exploring, particularly in cases where companies depend on scarce or unique inputs (McKinsey Global Institute, 2020).

During tough times, like pandemic, arises the relevance of trust among suppliers and customers in all the steps of the supply chain. Trust means that all actors in the supply chain share the goal of not reaching stockouts and provide the best service possible. Increasing the trust can be achieved putting incentives for a good expected output by suppliers, on one hand, by increasing payments, penalize underperformance, promising potential for growing future volumes of business, on the other hand it is worth to decrease the vulnerability, by managing multiple sources of supply or redundant inventory (Sheffi, 2020). In order to have a high level of trust it would be necessary for companies also to share their sensitive data, so that anyone in the supply chain knows what others have on hand. The trust issue is extremely impacting in the last steps of the supply chain, among suppliers and final customers. For instance, the pictures of empty shelves saw during the first weeks of lockdown, were connected to the lack of trust by the demand side that suppliers were not able to provide the products for all the people. Of course empty shelves represent a stockout of products, but it was not due to real disruption in supply, rather than an unjustified stock race. In fact, no more stockout of primary products was seen in the following weeks.

Diversification of suppliers

Most of the supply chain managers, after Covid-19 effects, decided to take actions to diversify their supplier network by qualifying more vendors and building in redundancies. Others think it is important to hold more inventory of critical inputs. Others plan to nearshore their supply base, others to regionalize their supply network, both these last strategies enable to build a more collaborative production network and spot bottlenecks in production more quickly.

Considering, for instance, businesses really reliant on China's companies, the solution taken into account, is the "China+1" strategy. In this way, companies can diversify their facilities and suppliers to at least one other country. It is not a strategy based on the complete relocation of plants but a way to consider the next capital investment project, looking at nearby Asian countries instead of China. Rather than re-shoring in this case, we would speak about near-shoring to balance risk (Sheffi, 2020).

In Figure 25 we show the most used strategies, companies put in place or plan to, to make the supply chain more resilient. The results show how managers feel the need of a change at a chain level, to avoid, in the future such disruptive effects.

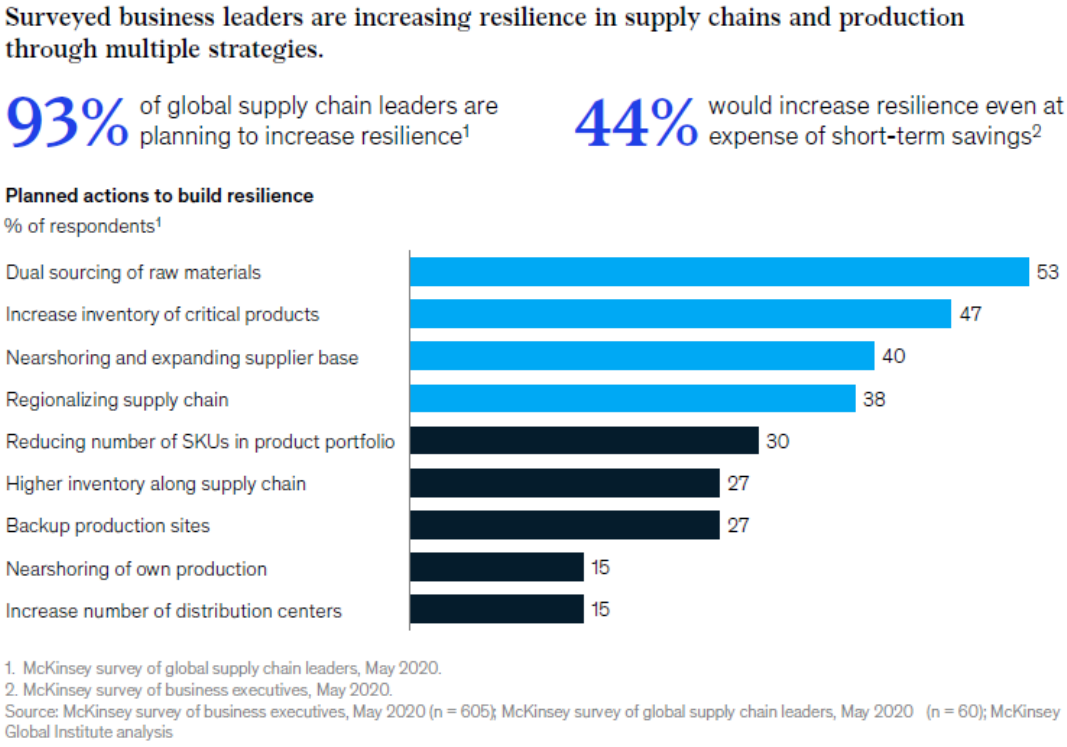

Figure 25. Planning actions to build resilience by business leaders

As shown in Figure 26 the strategies do depend on the sector and on the industry of the firm. For instance, for the consumer packaged goods and food industry, the most important measures to take are dual sourcing of raw materials, regionalization of supply chains and reducing the number of SKUs in product portfolio, while increasing inventory of critical products is not a big issue.

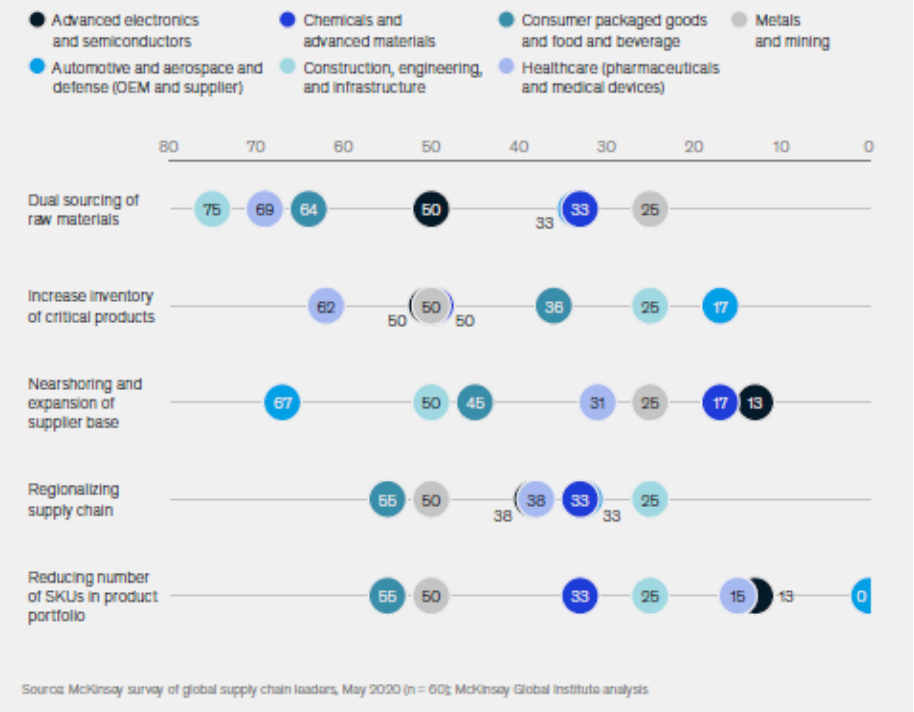

Figure 26. Resilience strategies by sector

Multisourcing is an element of redundancy. The faster is a company in understanding the need of multi-sourcing, the easier is for it to find additional resources, such as inventory or transportation capacity, since all the businesses in the same sector will need extra resources when a disruption occurs.

3.3.4. Balancing Just-In-Time and Just-In-Case

Covid-19 spread generated an unpredictable awareness in the supply chain managers: that maybe Just-In-Time methodology is not the best one, if applied alone. Just-In-Time methodology was developed and put in place with the aim of creating an extremely efficient organization, but efficiency is often the opposite of resilient. The shift to just-in-time and lean production systems first engineered by Toyota in the 1980s has helped companies improve efficiency and reduce their need for working capital, raising profitability along the way. The main goal of JIT is to try to eliminate some inventory by coordinating the processes rather than allow each process run at its optimal race. It means that some processes may operate at less than optimal rates but overall, the costs are lower due to the savings in inventory levels. This structure makes companies very efficient and with low levels of unnecessary inventory, such and safety stock. But a supply chain built for maximum efficiency may be more fragile. The irony is that Toyota moved to JIT to avoid part shortage (Sheffi 2020), because some parts were supplied in different moments and in completely different volumes, making it impossible to produce continuously. They learned what is needed, when and which amount.

Many companies—including Toyota—are now striking a new balance between Just-In-Time and "Just-In-Case" (McKinsey Global Institute, 2020). Just-in-Case (JIC) is an inventory management philosophy that prioritizes risk management, often in the form of larger standing inventories. The main difference between Just-in-Time and Just-in-Case is that JIT operations receive inventory only as it is needed for production, whereas JIC stocks up inventories ahead of time. The pandemic has underlined the need for suppliers and customers to work together. Afterwards, it will be up to larger survivors, in particular, to help support the smaller and

weaker components of their supply chains, rather than pursuing a beggar-thy-neighbor approach that destroys the chain altogether. Models show that having enough backup inventories of key parts and safety stock is a critical buffer that can minimize the financial impact of disrupted supplies. It can also position companies to meet sudden spikes in demand.

One of the potential solutions to prevent the supply-chain disruption might be a hybrid model of JIT and JIC. JIC would provide sufficient response times for companies to reconfigure their production processes, while the JICT would allow companies to operate under lean manufacturing practices. However, this hybrid model would vary in its mix across industries, needs, existing production capabilities, and the supply chain (J. Koo, 2020). On one hand, JIT improves resilience, since its strength relies on the small quantities managed that permits detecting and solve problems fast and makes the production more flexible, thanks to the easy switch among products and demand changes (Sheffi,2020), apart from drastically decreasing costs. Finally, it is necessary for companies to add safety stock to prevent disruption to Just in Time methodology.

3.3.5. Reshaping demand

As said in the previous sections, one of the main issues during Covid-19 pandemic was the sudden and irrational change in demand that led to shortages of some products, especially in the "house-products". First of all, companies must be receptive to signals, and quickly detect the changes in demand. Once the disruption comes and capacity is not enough for customers, companies must decide where to allocate products and choose who to serve or try to reshape demand. In order to reshape demand, businesses can apply the oldest market mechanism: change price. If the demand is higher than the expected one and shortages are not enough, price must get higher, to decrease the number of customers interested in the product. On the contrary, if the demand is lower than the expected, the product must be sold at a lower price, to foment purchases. Another way to reshape demand is through the stretching of supply, re-thinking of the product design. More and more companies in the last years moved to the use of the same assembly parts for different final products, in order to reduce the SKUs produced. It is an efficient choice not just in terms of inventory, since its volume will probably consistently decrease, but also in terms of resilience of the chain. The most resilient companies design products with common components and cut down on the use of custom parts for different product offerings. Makers of consumer-packaged goods in particular have accelerated effort during the pandemic. Some of the companies decided to focus on best sellers, although there is no proof that this will continue in the future. Moreover, the trend of companies is towards modularity of the products, i.e. designing a product based on well-defined interfaces and architecture that fosters the organization of complex designs and process operations more efficiently by decomposing complex systems into simpler subsystems.

The combination of modularity, reduction of SKUs and demand management can highly improve the resilience of a supply chain, just revising the final demand and the product design. Companies will have to understand how to manage better demand. In particular, the up and down effects of demand will be higher and higher for at least some months. The best way to react it is to shorten the demand forecast as much as possible. This is for instance one of the measures deployed by the company presented in the case study.

3.4. Other measures to improve supply chains

3.4.1. E-commerce and other retail channels

Pandemic did not only change consumers' preferences but also the way they provide goods. For this reason, one of the main channel clients deploy during lockdown and post it is e-commerce.

The raise of this channel is due to two main factors: on one hand the fear of the contagion that pushed many people to avoid going out to shop, preferring the indirect channel, on the other hand, the unavailability of some products in the retail industry, since many countries decided to close those non-necessary shops. In Figure 27 we can see the growth of some sectors in Italy, for instance.

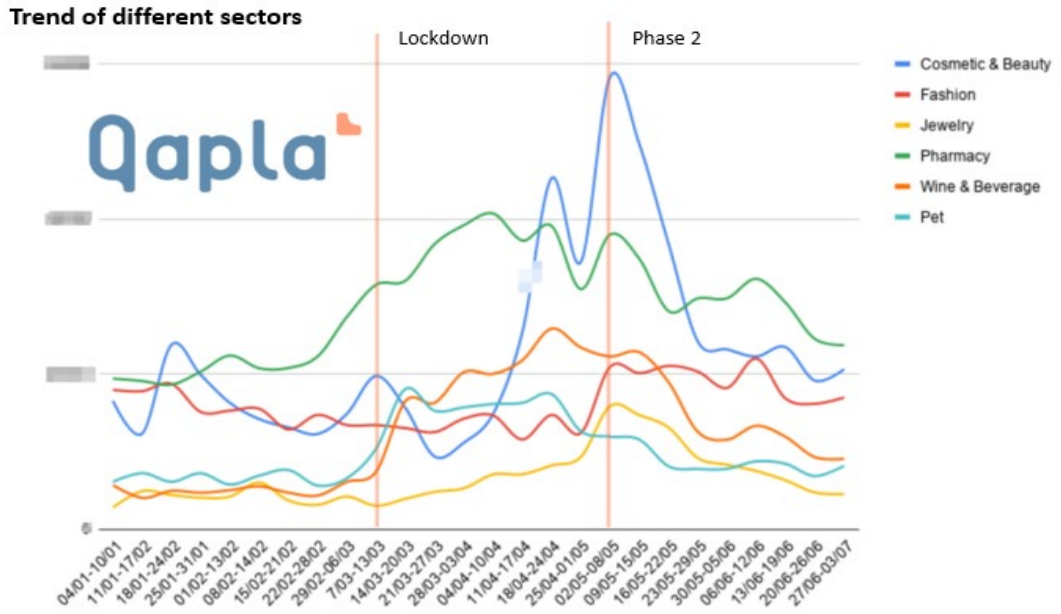

Figure 27. Growth in Italy before and during Covid-19 by sector

A study reflected that, after using e-commerce channel, many consumers will permanently change their behaviors, addressing more and more to this purchase method. This means that, from a supply chain point of view, lockdown caused a permanent change in the way consumers look for and find the products.

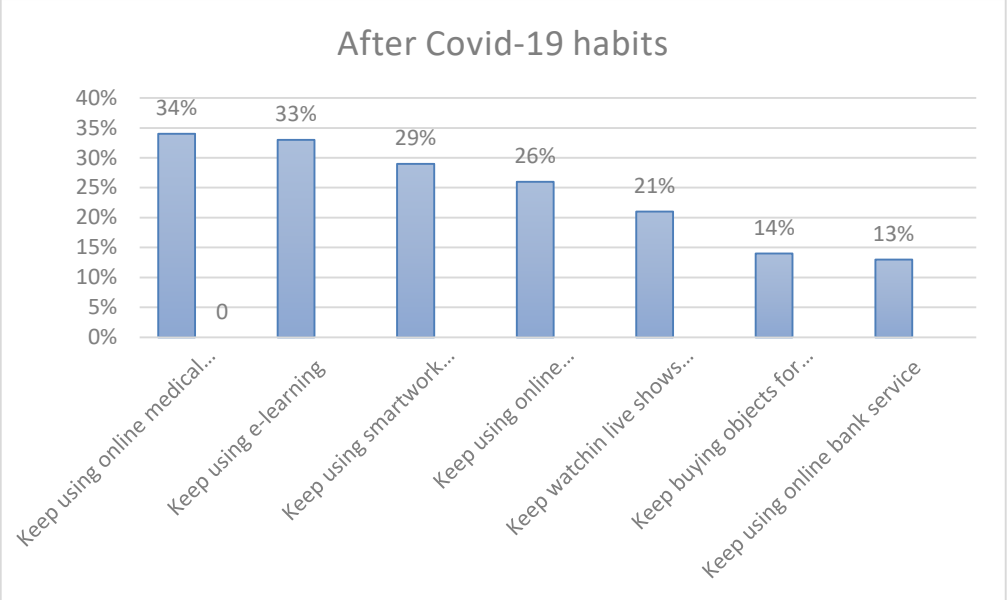

Figure 28. After Covid-19 purchasing habits

Figure 28 shows how the trend through e-commerce would be, also after the lockdown, from a sampling of consumers. If the distribution of purchase methods, traditional and e-commerce, will change so deeply, companies, especially small ones that are not usually used to imply those means, will have to adapt to the new reality.

Not only e-commerce raised in these conditions. Other retail modes became more and more important, because of the needs of not losing sales and to face restrictions. Brick and mortar shops had to face high debts and low cash levels. They needed to quick invest in more online sales or other measures. There are some hybrid channels that can permit retailers to take advantage of their physical assets, despite the situation: omnichannel retail. Omnichannel is an integrated commercial and fulfillment strategy in which customers can interact with the retailer via any physical or electronic channel and buy products via any physical channel (Sheffi, 2020). One example of omnichannel is the so called Buy Online Pick in Store (BOPIS) that allows the customer to choose in the online shop the product and pick it in the store. This kind of channel raised 300% during lockdown and 200% after lockdown. From the perspective of the consumer it combines the best aspects of physical and online stores but it is really hard for the retailer to handle. In fact, retailer must own a perfect visibility, in terms of inventory level and time, in order to provide the best service possible. Moreover, the more the order is complex, the higher are the processing costs because of the need of an algorithm that provides the best combination of product availability- warehouse location-final customer position.

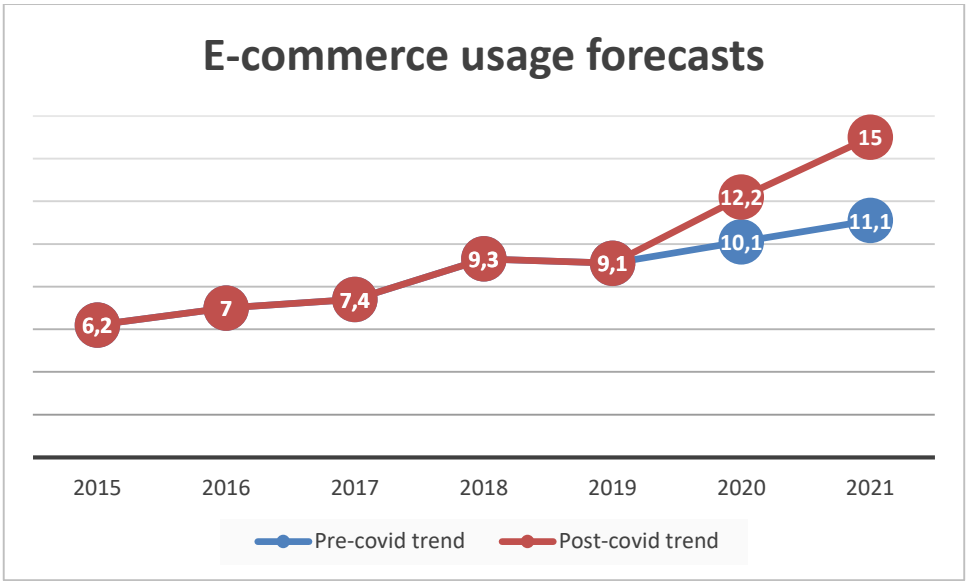

Figure 29. E-commerce usage forecast pre-Covid-19 trend vs. post-Covid-19 trend

Figure 29 shows the trend of the companies to use e-commerce channels, comparing pre-Covid forecasts and post-Covid.

Another trend connected to different retail channels is the "go direct to consumer" channel. Many companies, from the smallest to the largest, are focusing on going direct to the consumer. It is possible thank to the advanced technology and platforms that do not only provide a direct link between producer/retailer and consumers, but increase the visibility of products for the retailer, enables the retailer to have reliable forecasts and strengthen the relationship among consumer and provider. This last point is strictly dependent on the visibility the consumer himself has on his shipment: more and more companies realized that the higher is the visibility degree the consumer has on his shipments status, the biggest is the patience and the reliance he/she has on the provider.

3.4.2. Switch to additive manufacturing

A big chance for companies that want to make their supply chains more resilient and solve some problems taken by pandemic is to deploy additive manufacturing. Additive manufacturing is a specific 3D printing process. This process builds parts layer by layer by depositing material according to digital 3D design data. The term "3D printing" is increasingly used as a synonym for additive manufacturing. However, "additive manufacturing" better reflects the professional manufacturing process that differs significantly from conventional, subtractive manufacturing methods. Additive manufacturing takes to many advantages: it can potentially produce any kind of products for any industry. 3D printing enables the decrease of setup times and the decrease of inventory levels, since products can be built exactly just in time. Moreover, companies can stop relying on suppliers, decrease their inventory levels and consequently, costs. In this sense, 3D printing is useful to achieve in-shoring goals of companies or at least, approach production sites. On the other hand, disadvantages of additive manufacturing are the low speed rate of production and some limits, still imposed by the material use.

4. Conclusions

The objective of this study was to understand the impact of Covid-19 pandemic on the supply chains, especially of consumers' goods and how to make supply chains more resilient to this kind of disruptions.

In order to better understand how pandemic impacted on supply chains, we have introduced how supply chains changed in the last century, connecting this topic with the outsourcing trend and the split of the production steps in different countries and areas, depending on the kind of goods produced and the infrastructure of the country. We have explained later how each supply chain's disruption contributed to the disruption of the other ones and the role of the various actors inside the country and in a global environment, depicting how the measures and actions undertaken by each one impacted on the supply chain disruption. We have also described the historical background of the pandemic underlying the economic importance of the area initially impacted by the spread of the virus at global level. The last introductive part was a first sight at the issues generated by the spread of the pandemic on global supply chains. Issues were categorized in three main blocks: bullwhip effect, liquidity problems and supply and demand shock. In this section one can find a deeper explanation of the mentioned issues, especially in the first months of pandemic.

The second part of our study focuses on the measures companies should take to face Covid-19 pandemic. One can find an initial part about the literature regarding natural disaster since it is the most similar event to a pandemic. A part from the measures to handle a natural disaster, such as postponement, strategic stocks or rebuild the supply chains, one can see the main differences between natural disaster effects and a pandemic, that can be reconducted to the magnitude of the event: natural disaster is often confined in the region/country in which it takes place, while pandemic is a worldwide event. This distinction makes Covid-19 effects more difficult to handle than a natural disaster.

The final section of our study focuses on the most reasonable actions to reach resilience inside the supply chains. The first measure is the assessment of the type of supply chain companies find themselves: it involves the identification of the structure of the supply chain, to be able to understand the effects a negative occurrence can generate and the recommendation of the most agile and respondent type of structure to disruptive events. Secondly, the is the need of visibility among all the tiers implied in the supply chain, not just connected to the belonging actors but also to the transparency of information among the tiers, in terms of inventory and sales patterns. The third point is the need of implementation of a risk management plan and scenario planning, useful to companies to assess and mitigate risks. The fourth point is the suppliers' choice and the in-shoring possibilities: in this part is presented the reason why supply chains had become more and more geographical concentrated and the reason why the concentration make the chain, on one hand optimized but, on the other hand, weaker, and how companies could decrease the level of fragility. In this part is also presented a big issue, that is the questioning of the Just-In-Time methodology, of which, one of the main pillar, is the reduction of wastes and so of inventory levels. In the work is presented, as a possible solution, a hybrid model that combine Just-In-Time and Just-In-Case methodologies. The last part of the section refers to the need of reshape demand in this situation, when the demand presents a high level of uncertainty, with some specific actions, such as the reduction of SKUs and modularity. Finally, are presented some additional actions, companies could consider to keep working in a fast-changing environment, such as move to e-commerce and other retail channels and turn to the additive manufacturing as a way to better control inventory.

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