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The future of globalization: Building resilient and sustainable supply chains

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Conscious of their responsibility in the face of the unprecedented challenges confronting society, the University of Lausanne through its Faculty of Business and Economics (UNIL-HEC), the Institute for Management Development (IMD) and the EPFL under the stewardship of the College of Management of Technology, have joined forces in Enterprise for Society (E4S). E4S aims to be the laboratory where its founding institutions jointly explore new ways of fulfilling their mission in the fields of economics and management.

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Executive Summary

English

The Covid crisis made obvious how vulnerable globalization has become to systemic risks and prompted discussions about its end. The lockdown measures to fight Covid-19 and the drop in demand hit production, first in China where the virus originated, with ripple effects that affected supply chains all over the world. It is apparent that globalization needs to be redesigned so that it becomes more resilient and does not compromise people’s safety and welfare in the future. Besides the lack of resilience, globalization faces another challenge: sustainability. Global value chains have an enormous ecological footprint that contribute to climate change and biodiversity loss.

In this report we analyze the resilience and sustainability challenge of globalization. Building on recent advances in the economics and business literature, we discuss in particular two possible avenues to reach this goal: the re-localization of production and the use of blockchain technologies in supply chains. We argue that reshoring may not be the panacea. Rolling back globalization and reshoring production would imply losing out on the economic benefits of international specialization that are consensual among economists, without clear benefits in terms of resilience and sustainability. In contrast, technology and more intensive international cooperation between governments are needed to to make globalization in the future more resilient to external shocks, while being compliant with the planetary boundaries.

Français

La crise du Covid a montré à quel point la mondialisation est devenue vulnérable aux risques systémiques et a suscité des discussions sur sa fin. Les mesures de confinement pour lutter contre le Covid-19 et la baisse de la demande ont frappé la production, d'abord en Chine où le virus est apparu, avec des effets d'entraînement qui ont affecté les chaînes d'approvisionnement du monde entier. Il est évident que la mondialisation doit être repensée afin de devenir plus résiliente et de ne pas compromettre la sécurité et le bien-être des personnes à l'avenir. Outre le manque de résilience, la mondialisation est confrontée à un autre défi : la durabilité. Les chaînes de valeur mondiales ont une énorme empreinte écologique qui contribue au changement climatique et à la perte de biodiversité.

Dans ce rapport, nous analysons le défi de la résilience et de la durabilité de la mondialisation. En nous appuyant sur les avancées récentes de la littérature économique, nous discutons en particulier de deux pistes possibles pour atteindre cet objectif : la relocalisation de la production et l'utilisation des technologies blockchain dans les chaînes d'approvisionnement. Nous soutenons que la relocalisation pourrait ne pas être la panacée. Faire reculer la mondialisation et relocaliser la production impliquerait la perte des

gains économiques résultant de la spécialisation international, lesquels font consensus parmi les économistes, sans avantages clairs en termes de résilience et de durabilité. En revanche, la technologie et une coopération internationale plus intensive entre les gouvernements sont nécessaires pour rendre la mondialisation de demain plus résistante aux chocs externes, tout en respectant les limites planétaires.

Deutsch

Die Covid-Krise hat deutlich gemacht, wie anfällig die Globalisierung für systemische Risiken geworden ist, und hat Diskussionen über ihr Ende ausgelöst. Die Maßnahmen zur Bekämpfung von Covid-19 und der Nachfragerückgang haben die Produktion zunächst in China, dem Ursprungsland des Virus, beeinträchtigt, was sich auf die Lieferketten in der ganzen Welt auswirkte. Es ist offensichtlich, dass die Globalisierung umgestaltet werden muss, damit sie widerstandsfähiger wird und die Sicherheit und das Wohlergehen der Menschen in Zukunft nicht gefährdet. Neben der mangelnden Resilienz steht die Globalisierung vor einer weiteren Herausforderung: Nachhaltigkeit. Globale Wertschöpfungsketten haben einen enormen ökologischen Fußabdruck, der zum Klimawandel und zum Verlust der ökologischen Vielfalt beiträgt.

In diesem Report analysieren wir die Herausforderungen der Globalisierung in Bezug auf Resilienz und Nachhaltigkeit. Basierend auf den jüngsten Erkenntnissen in der volks- und betriebswirtschaftlichen Literatur erörtern wir insbesondere zwei mögliche Wege, um dieses Ziel zu erreichen: die Rückverlagerung der Produktion ("reshoring") und den Einsatz von Blockchain-Technologien in Lieferketten. Wir argumentieren, dass Reshoring möglicherweise nicht das Allheilmittel ist. Die Globalisierung zurückzudrehen und die Produktion zu verlagern, würde bedeuten, dass die wirtschaftlichen Vorteile der internationalen Spezialisierung, die unter Ökonomen Konsens sind, verloren gehen, ohne dass es klare Vorteile in Bezug auf Resilienz und Nachhaltigkeit gibt. Im Gegensatz dazu sind Technologie und eine intensivere internationale Zusammenarbeit zwischen den Regierungen erforderlich, um die Globalisierung in Zukunft widerstandsfähiger gegen externe Schocks zu machen und gleichzeitig die planetarischen Grenzen einzuhalten.

1 Introduction

The COVID-19 global pandemic exposed the fault lines of globalization. The spread of the virus induced most governments around the world to impose total or partial lockdowns, causing a decrease in overall consumption (between 11 to 26% in the first months of the pandemic)[1] and a dramatic reduction in international mobility and national transport (air travel dropped by 60% in 2020)[2] The lockdown measures to fight Covid-19 and the drop in demand hit production, first in China where the virus originated, with ripple effects that affected supply chains all over the world. As a result, international trade dropped by a staggering 15% in the second quarter of 2020.[3] The pandemic also led to a spike in demand for some particular goods such as medical products (e.g., masks and hand sanitizers) that quickly became short in supply all over the globe. In desperate need to supply hospitals with essential equipment, some countries went so far to divert shipments destined for others for their own use.

We are living in an age of ``hyperglobalization" characterized by highly interconnected economies and by global supply chains that link high tech with low wage regions of the world and that span multiple continents. The Covid crisis made obvious how vulnerable globalization has become to systemic risks, and prompted discussions about its end. Carmen Reinhart, chief-economist of the Worldbank, was quoted in May 2020 saying that *"Without being melodramatic,Covid-19 is like the last nail in the coffin of globalization"*. Resistance against globalization was already on the rise prior to Covid-19 fueling the election of nationalist and populist governments in many parts of the world. The pandemic gave further impulse to the idea of reshoring production and regaining control over supply chains so as to make them less sensitive to future global disruptions.

It is apparent that globalization needs to be redesigned so that it becomes more resilient and does not compromise people's safety and welfare in the future. Reshoring may not be the panacea, however. Rolling back globalization and reshoring production would imply losing out on the economic benefits of international specialization that are consensual among economists, without clear benefits in terms of resilience and sustainability. Exploiting the power of technological solutions, in particular blockchain technologies, might be a better way to go without giving up on international specialization.

Besides the lack of resilience, globalization faces another challenge: sustainability. Global value chains have an enormous ecological footprint that

[1] Data for China, the US, and Western Europe relate to the period from Q4 2019 to Q2 2020 (Q1 in China) and are taken from McKinsey.

[2] Information relates to the year 2020 and is taken from the International Civil Aviation Organization.

[3] Numbers, from the WTO, relate to global merchandise trade.

contribute to climate change and biodiversity loss. This challenge is also an opportunity, as decarbonizing supply chains can significantly contribute towards the goal of making our economies climate neutral. Hence supply chains should be in the focus of climate policy, so that the future of globalization is not only resilient, but also compliant with the planetary boundaries.

In this report we analyze the resilience and sustainability challenge of globalization. We focus in particular on two possible avenues to reach this goal: the re-localization of production and the use of blockchain technologies in supply chains. Our report builds on recent advances in the economics and business literatures. In section 2 we describe the emergence of "globalization 3.0" characterized by global supply chains. Section 3 discusses the resilience issue of globalization, while section 4 looks at its environmental footprint. In section 5 we discuss whether re-localization of production and blockchain technologies will make supply chains more resilient and sustainable, and which role governments can play in shaping the future of globalization.

2 Globalization 3.0 and the rise of global supply chains

Due to the development of more cost-efficient modes of transport, the reduction in barriers to international mobility of people and merchandise, and the lower communication and transmission costs prompted by the development of ICT technologies, economies have become increasingly global.[4] Baldwin (2018) distinguishes between several phases of globalization. "Globalization 1.0", the first phase of globalization in the modern age, was driven by industrialization and the development of the steam engine that enabled trade of goods over long-distances, but which lacked regulation and institutional oversight. Institutions promoting free trade such as the GATT (the predecessor of the WTO) were established after the end of WW2 that set off the phase of "globalization 2.0" in which the international trade of goods intensified.

The second phase of globalization was followed in the 1990s by "globalization 3.0" characterized by the establishment of global supply and value chains. Unlike earlier waves of globalization in which mainly resources, and final goods were traded internationally, intermediate goods and production processes started to cross borders. During this phase of "hyperglobalization", networks between high tech and low wage regions of the world were established (Baldwin and López-González 2014). Many companies cut costs by

[4] A report from the OECD (2010) shows the increasing trends of trade-to-GDP ratios in goods and services, foreign direct and international R&D investments, movement of labor, prevalence of multinational firms and the growth of global value chains. Worldwide, the volume of merchandise exports has grown by 185% between 1990 and 2010 and its value by 342%, whereas the value of exported services has grown by 369% over the same time period (WTO statistics).

operating internationally or outsourcing part of their supply chains to external providers in regions of the world characterized by low wage labor.[5] Supply chains have become increasingly fragmented and often span multiple continents. Firms are now using a multitude of suppliers of parts and components located in diverse places to produce final goods. The third wave of globalization drastically increased the linkages between economies and came with opportunities for workers in low-wage economies, and disruptions for workers in high-wage economies facing competition, causing the pushback against globalization mentioned earlier. The location of global economic activity shifted markedly, impacting manufacturing activities in particular and making China "the factory of the world".

Currently, we are seeing the beginning of the most recent wave of globalization, "globalization 4.0", in which artificial intelligence is expected to make it possible to outsource specific tasks rather than jobs or the production of specific goods (Baldwin, 2019). While previous technological revolution already reduced the distance between locations drastically, artificial intelligence will likely tear down the last barriers to trade and interpersonal communication, such as those related to language that can be overcome with intelligent text and speech translators. As a consequence of this trend gaining traction and the importance of the service sector in GDP increasing, the share of international merchandise trade will most likely decrease in the future.[6]

3 Global supply chains: the resilience issue

The third wave of globalization changed economies substantially. In their desire to increase efficiency, firms sought to outsource parts of their production to external firms that supply them at lower costs (Farrel, Newmann 2020). Offshoring did not only increase the interdependence between firms along the value chain and regions of the world, but it also fostered the concentration of economic activity in some areas, increased the dependency on a limited number of highly specialized suppliers, and led to the dissolution of buffer stocks in favor of just-in-time and lean management. The "hyperconnectivity" that marks the third wave of globalization increased substantially the vulnerability of global supply chains to systemic risks (Goldin, 2020).

Several risks that were **internal** to the firm, ranging from holding inventory stocks, responding to product defects and managing long product life cycles, to high labor costs or the inability to scale up or down quickly in reaction to market

[5] Fillat et al (2015) show that multinational firms exhibit higher stock returns and earnings than non-multinational firms and that among these latter, exporters do better than non-exporters.

[6] According to data from the World Trade Organization and World Bank GDP estimates, the share of merchandise trade to global GDP reached its peak in 2008, at around 51%.

movements, have become **external** to the firm as a consequence of outsourcing and unbundling of production. Firms focus their efforts on design and marketing, deferring the risks of production to external suppliers (Manners-Bell, 2018). Of course, new risks arise from the delocalization of production and firms usually face a **trade-off** between minimizing internal and external risks.

From the point of view of the firm, external threats to value chains can arise from the environment (natural disasters, climate change, pandemics), economic conditions (demand and supply shocks, oil price volatility, trade barriers, work stoppages), social transformations (demand for more corporate social responsibility), security (geo-political tensions, piracy, customs corruption) and technology (system failures, cyber-attacks, data fraud, digital misinformation).

Shifting supply chains from the local to the global level made them more vulnerable to some of these external threats: i) longer lead times depending on the distance and timeframe to place orders (which entails a less agile response to market conditions); ii) the difficulty of controlling quality of the suppliers; iii) exchange rate fluctuations; and iv) in many locations, institutional failure and political turmoil such as labor disputes, corruption, theft, and political instability[7]. Moreover, the specialization of some low-wage regions in manufacturing and the continued importance of spatial distance between the different stakeholders led to the geographic concentration of production networks in a few big regional blocks (Baldwin and López-González 2014; Gamberoni et al. 2010, Li et al. 2019). The dependence on a few key regions increases the risk that regional shocks propagate globally.

Over the past years, **global value chains (GVC)** have seen a surge in subcontracting. That is, an external supplier outsources part of its own production to another supplier, who in turn does the same. In the end, the downstream firm often does not know who are its suppliers and lacks the necessary information to properly manage its risks (Shih, 2020). With supply chains becoming global multistage production networks, it becomes even more difficult to respond quickly to market conditions or to control quality. In section 4 we discuss how blockchain technology could address these threats by increasing the transparency of the network.

From a macroeconomic perspective, risks to GVC can be understood as the probability of a **network** failure. As discussed, supply chains are a complex network composed of interlinked local and global networks. These networks are of many kinds and are vulnerable to idiosyncratic and global risks: energy (vulnerable to power cuts), human (vulnerable to pandemics as the one we are facing today, and also to labor disputes), information and communication (vulnerable to cyberattacks, system failures but also power cuts), transport (bottlenecks, but also failures in the human network due to strikes, pandemic-related lockdowns, etc.). A disruption to one node in one of these networks can quickly entail failures in

[7] In 2012, the World Economic Forum conducted a survey in the context of their Supply Chain Risk Radar initiative and identified the top five disruption triggers. According to survey respondents, these were: 1) natural disasters, 2) extreme weather, 3) conflict and political unrest, 4) terrorism, 5) sudden demand shocks. Naturally, these sources of concern are tied to the most recent world events at the time (the 9-11 terrorist attack, Japan earthquake, Thailand floods) (WEF, 2013). In 2021, pandemics would probably rank first as a disruption trigger.

others (Manners-Bell, 2018). For example, the lockdowns imposed after the COVID outbreak disrupted the human network. With the sudden global transition to remote work and distance education, internet outages rose to unprecedented levels. Transport was substantially affected, too, with the air fleet grounded due to restrictions to international personal mobility.

Based on network theory, Acemoglu et al. (2012) model how sector-specific shocks are transmitted to the whole economy when there are « inter-sectoral input-output linkages », showing the substantial aggregate **volatility** that can arise depending on the structure of connections between the different agents. Given that supply chains are increasingly global, local disruptions can quickly expand to other countries and generate economic volatility beyond the originating country.[8] Barrot and Sauvagnat (2016), Boehm et al. (2019), and Carvalho at al. (2021) document how local shocks caused by natural disasters such as the 2011 Tōhoku earthquake in Japan propagate along supply chains within and across countries. Huo et al. (2020) show theoretically and quantitatively how GVC play a role in GDP synchronization ("co-movement") across countries.

The first COVID-19 outbreak exposed some of the main vulnerabilities of global supply chains: a lack of inventories resulting from lean "just-in-time" production optimized for efficiency, the reliance on few very specialized suppliers and regions such as China that produce almost half of the world's supply of face masks, etc. Chinese exports plummeted by about 20% as a result of the initial outbreak of COVID-19 in 2020. Due to the dependence of many firms on Chinese suppliers of intermediate inputs and manufactured consumer goods, the shock quickly disrupted global value chains and spread globally.[9] Already by March 2020, the total costs to global value chains caused by reduced exports amounted to $50 billion according to UNCTAD. Moreover, the disruption of supply chains caused immediate shortages of protective gear and first-necessity products such as facial masks or hand sanitizers to fight the spread of the Corona virus. These disruptions could have been prevented by building surplus inventories that would have paid off because the low probability event did occur, and by diversifying supply chains among a greater number of suppliers located in different regions, points we will return to when discussing possible solutions. Striking the right balance, ex-ante, between inventory management and just-in-time "efficient" production, as well as the optimal level of spatial diversification, is challenging because:

[8] In this context, one can easily imagine how little disruptions can magnify into potentially catastrophic global crisis. Can two or three butterflies flapping their wings metamorphose in a black swan? Edward Lorenz (1969) used the metaphor of a tornado being originated by the flapping wings of a butterfly elsewhere to explain the instability of the planet's atmosphere. His work was the building stone of chaos theories. Black swan events are not just «small probability-high impact» events; they are also unforeseen. For example, the probability of a COVID-19 outbreak was small, and its impact is huge, but pandemics can be modelled and appear in all risk-management textbooks. Moreover, epidemiologists sent warnings of a pandemic arising from "emerging viruses" decades ago (Maranz Henig, 1994; Morse, 1996). See Robin Maranz Henig's article in National Geographic published in spring 2020, at the outbreak of the COVID-19 pandemic, for an interesting critique of the general ignorance of those warnings.

[9] According to UNCTAD (2020), about 20% of all intermediate goods traded globally are exported from China.

- It is difficult to estimate the nature of all future disruptions and even more their probability of occurrence.

- Multistage production networks add uncertainty about the exact structure of the supply chain.

- Arguably, the tenure of decision makers is shorter than the timeframe they need to consider for a truly resilient strategy to pay off in the context of low frequency events. By focusing on quarterly revenue data, accounting practices in general do not favor resilient strategies that have positive expected value in the long-run.

The last point is reminiscent of a traditional business model designed to maximize immediate shareholder value at the expense of the firm's long-term viability. Building resilient supply chains requires rethinking this objective in terms of multiple stakeholders and longer time horizons.[10]

One possibility to solve the pervasive problem of robust risk management for first-necessity products and key inputs is to establish a centralized inventory management mechanism. A drawback of such a system is that it would require strong multilateral cooperation between governments and suppliers, making it costly to implement. Another option is to build a decentralized inventory management system by writing smart contracts on strategic supply chains. We discuss these options in section 5.

4 The environmental footprint of global supply chains

According to a recent report by the World Economic Forum (WEF, 2021), eight GVC's account for more than 50% of global carbon emissions. Of these, food is by far the most carbon intensive (25% of global greenhouse gas emissions), followed by construction (10%), fashion (5%), fast-moving consumer goods (5%), electronics, automotive production, professional services, and freight.

Despite their huge carbon footprint, the discussion of supply chains and climate change focuses usually on the risks caused by climate change and mitigation efforts. First, there is the risk of extreme climate events that can disrupt the chain links. Second, climate mitigation is considered a "risk", both on the supply-side due to mitigation policies and regulation, but also from the demand-side as consumers are increasingly conscious of the environment and demand more environmental and social responsibility (ESR) of

[10] A good example of why focusing on shareholder value can lead managers to harm the firm in the long run has been exposed by the GameStop rebellion early 2021 (see Project Syndicate's article about the corporate governance takeaways of this affair).

firms. Less attention is, however, placed on the responsibility of businesses in addressing climate change through a reduction in the carbon footprint of the entire chain.

In most sectors, emissions arising from own operations and energy consumption of a firm are rather low, whereas the emissions stemming from the production of the raw materials entering their supply chains are enormous. This is particularly problematic since many carbon-intensive activities such as manufacturing have been outsourced to countries with very little environmental regulation. Therefore, efforts to reduce emissions from own operations have little impact in reducing global emissions if they are not complemented by upstream mitigation. Of course, "on-site" mitigation is what consumers see and if the firm only cares about marketing its green practices to its consumers, it will have little incentive to trace its carbon footprint along the entire supply chain.

For these reasons, regulation at the level of the firm producing the final good can have positive effects through the entire supply chain. If firms are demanded to use recycled materials or design products for easy recycling and replacement of parts, for instance, positive environmental effects could spread throughout the supply chain, in particular if suppliers are located in countries with less environmental regulation and in sectors that are traditionally very difficult to decarbonize.[11]

5 Possible solutions to increase resilience and sustainability of supply chains

The Cambridge dictionary definition of **resilience** is *"the ability of a substance to return to its usual shape after being bent, stretched or pressed"*. In this definition, resilience of a system is simply its ability to go "back-to-normal" following a shock.

For an economy, resilience is the ability to cope with external shocks and to recover to the pre-crisis growth path or level of welfare after a large-scale disruption. The concept of resilience is distinct from **sustainability** but it is not unrelated. The Brundtland Report of 1987 defined sustainability as the availability of a society to meet the needs of current generations without compromising the needs of future generations. While resilience concerns the short-term stability of systems, sustainability strategies are more directed towards the long run. Indeed, short-run resilience strategies do not need to be sustainable. Switching to coal energy after a nuclear catastrophe such as Fukushima in 2011 might increase resilience but not sustainability.

[11] Buggle et al (2021b) describe avenues to transition toward a circular economy and that are particularly relevant for GVC.

However, links exist between the concepts. Making economies more sustainable by moving towards circular economic systems can increase their resilience against natural resource shocks. On the other hand, unsustainable behavior can challenge resilience: emitting CO2 leads to climate change and more extreme weather that societies must cope with. Moreover, if a society is constantly unable to bounce back after shocks, the welfare of future generations and hence long-term sustainable development will be compromised.

At the company level, resilience implies the ability to maintain output, reorganize to continue to deliver, or bounce back after a disruption (WEF, 2013). While there is some consensus in the definition, there are no reliable metrics to measure the resilience of a company's supply chain. At the level of the entire economy, we rarely expect business-as-usual in the aftermath of a shock, as the business landscape tends to be significantly reshaped. The COVID-19 pandemic, for instance, is driving technological and behavioral changes that are likely to become permanent - such as prevalence of e-commerce, remote working, local shopping - giving rise to new business models while terminating others.

How do firms design their supply chains to bounce back after a disruption? Typical strategies involve inventory management (accumulating safety stocks to a level that allows replenishment) and sourcing (contingency strategies with alternative suppliers allowing to switch quickly). They can also decide to do nothing, if the costs of mitigating a disruption out-weigh the estimated benefits (Manners-Bell, 2018).[12] Building sufficient stocks is costly and computing the right level that would insure against different types of disruption is complicated. Over the past decades, most firms instituted a business model of "just-in-time" production, as discussed in section 3, minimizing the level of inventory at all stages of production. The pandemic is acting as a wake-up call suggesting that the excessive amount of risk was tolerated.

Naturally, supply chain design goes beyond cost and risk management, if firms pursue ESR goals. Indeed, concerns about responsible sourcing, carbon mitigation, decent working conditions and fair trade are growing. Designing a supply chain compatible with all these objectives is a titanic challenge.

In the next sub-sections, we focus on the merits and drawbacks of two options highly advertised in the media and among academic circles to make supply chains more resilient *while* reducing their environmental footprint: re-localization of production networks and blockchain technologies. In addition, we discuss how governments intervention can help the transition towards a more resilient and sustainable globalization.

5.1 Re-localization of production

As a response to the Covid-19 trade disruptions, the idea of re-localizing production to increase supply chain resilience greatly gained importance. The movement towards reshoring and more local supply chains was, however, already on the rise

[12] None of these strategies are designed to manage unforeseeable risks though, because by definition those risks cannot be quantified, leaving open the question of whether firms should aim for resilience to black-swan events, and if so how.

prior to the pandemic[13]. It was partly a result of the hardship it brought to the lives of workers in parts of the developed world. The concomitant (and causally related) emergence of nationalism and populism that entered the political center stage notably through the election of Donald Trump and the Brexit vote reinforced a move towards protectionism, trade wars (US – China), and attempts at reshoring manufacturing.

Does re-localization of production increase ***resilience*** *of supply chains?*

By producing locally, companies can reduce lead times and become more agile to respond to market movements. They can also better monitor the quality of suppliers, more closely observe the institutional landscape and avoid exchange rate fluctuations and geo-political tensions abroad. However, a fully domestic supply chain puts all eggs in the same basket: a local disruption can stop production altogether as firms have little margin for contingency sourcing, particularly in highly specialized countries.

In general, the fragility of supply chains increases with the distance as it becomes more difficult to monitor suppliers. The cost of distance needs to be weighed against the nature of shocks that are expected to occur. Supply chains in which nodes are in greater spatial distance are more valuable if the expected shocks are more local. Regarding aggregate shocks that affect entire regions or even the entire globe at the same time, extending the distance between suppliers brings lower gains in terms of the capacity to insure against the shock, but larger costs in terms of monitoring.

In the case of a pandemic like COVID-19, re-nationalizing production is unlikely to increase resilience because local suppliers are as likely to be disrupted as external ones (Bonadio et al, 2020). Indeed, most countries around the globe implemented partial or global lockdowns that significantly disrupted manufacturing, shipping, as well as on-site production worldwide.

Importantly, re-localizing production entirely may **reduce competition**. The consequences of concentration are the inability to implement contingency strategies in case of disruptions, but also the increase in domestic prices which are detrimental for consumers.

A survey by Allianz from December 2020 of 1,181 companies located in Italy, France, Germany, the UK, and US revealed that almost all firms were affected by supply chain disruptions during the Covid-19 pandemic. However, less than 15% of firms respond by reshoring production to increase resilience, while about one third of companies consider nearshoring. An earlier survey conducted by McKinsey of 60 senior supply-chain executives conducted in the first half of 2020 paints a largely similar picture: A majority of firms encountered supply chain disruptions and, as a consequence, 93% of them are planning on making their supply chains more resilient against future crisis. Near-shoring was mentioned as strategy to increase resilience by 43% of respondents and regionalizing supply chains by 38%. These strategies were

[13] The share of global GDP attributable to global value chains (GVC)-related production has grown until the financial crisis of 2008, while the share of purely domestic production decreased. The trend reverted as a consequence of the crisis showing an immediate re-localization effect (Li et al, 2019).

considered less important than increasing inventory stocks (mentioned by 47%), or dual sourcing of materials (mentioned by 53%) that diversify supply chains. These survey results suggest that while re-localizing production is not top of the agenda, there is some concern about the geographic distribution of suppliers. Near-shoring especially could lead to a future increase in "intra-regional" trade within core regions such as the EU or Asia. However, loosening the dependence on dominant supplier regions like China is neither easy nor cheap (Simchi-Levi and Simchi-Levi, 2020). Whether the movement towards near shoring is a brief trend or will persist in the future even when the world has overcome the Covid pandemic is an open question.

*Does re-localization make supply chains more **sustainable**?*

A major advantage of re-localizing the supply chain to increase sustainability is the ability of firms to easily identify their suppliers and closely monitor their environmental and social compliance. Moreover, if suppliers and manufactures are in greater spatial proximity the implementation of circular economy strategies, such as repair, refurbishment or recycling, that reduce emissions and waste creation is facilitated. In fact, the move towards a sustainable circular economy might itself put pressure on shifting supply chains towards more local production to close material and energy loops (Buggle et al. 2021).

In a meta-study on green supply chain network design, Waltho et al. (2019) identify the following major sources of carbon emissions within the supply chain: transportation (contributing about one third), power-intensive processes such as manufacturing, storage and warehousing, raw material extraction and sourcing, facility construction and operation, and disposal. However, the more recent WEF report cited earlier (WEF, 2021) finds that the majority of emissions within supply chains are driven by raw material inputs from land use and heavy industries, while emissions from manufacturing and transport are relatively smaller. Therefore, the gain in terms of reduced emissions from **transport** obtained by re-localizing would be relatively small.

Whether producing locally would increase emissions related to **manufacturing, storage and warehousing**, depends on the widespread availability of renewable energy, green technology and the degree of environmental regulation. If, for example, production is moved from countries with little environmental regulation to countries where climate mitigation policies are in place (e.g., towards the EU), CO2 emissions will likely sink. If it is reshored from locations in which green energy is available and affordable towards countries in which green energy is expensive or unavailable, emissions will increase. In regions where cheap renewable sources of energy like hydropower are not abundant, investing in green energy abroad may be easier or more cost-effective. As for **raw material extraction**, which is the main contributor to emissions within GVC, it is unlikely that re-localization of this part of the supply chain is actually feasible, in particular if it concerns specific natural resources that are geographically concentrated.

There is evidence that other strategies which are not necessarily costly can have substantial impact in reducing the carbon footprint of supply chains, ranging from small operational adjustments in procurement, production, and inventory management, to increased coordination and cooperation between the chain stakeholders (Benjaafar et al, 2012; Zhao, 2021).[14] Concretely, WEF 2021 estimate that around 40% of GVC emissions can be abated at virtually no cost, by increasing recycling and circularity[15], improving material and process efficiency and increasing the share of renewable power generation (WEF 2021).

We have discussed the impact of re-localization on resilience and sustainability, but that strategy would have a major impact on the developing economies that see these companies fly away.

*What is the impact of re-localization on global **inclusiveness** and economic development?*

Supply chain trade between developed and developing countries ("north-south") gained importance towards the end of the 1980's. Countries like China, Korea, India and Indonesia saw their share of global manufacturing output increase significantly between 1970 to 2010 (Baldwin and Lopez-Gonzalez, 2014). Many emerging markets managed to industrialize very fast by joining global supply chains rather than by developing all stages of production in-house.

What would happen to developing countries if a large number of firms were to re-localize their supply chains? Countries that industrialized in specific sectors by joining GCV could see unemployment rise and income decrease if the lost markets cannot be replaced by local production, either because the local market is too small or because technology and infrastructure are too specialized.

A development opportunity may exist, however, to skip the industrialization stage facilitated by global supply chain trade, if firms were to re-localize production entirely. That is what Baldwin (2019) calls globalization 4.0: to trade what we *do* and not what we *make*. If developing nations get prepared to compete as suppliers of services and specific tasks over the internet (notably taking advantage of the disappearance of language barriers made possibly by instant translation tools), they may compensate the exode of manufacturing jobs. In terms of development policy, this is challenging because it involves ensuring that the labor force has the competences needed for performing the required tasks. If training is insufficient for these nations to reap the benefits of globalization 4.0, chances are that the development gap between the north and the south will widen.

[14] Whalo et al (2019) find that carbon mitigation policies (caps, offset, cap-and-trade and taxes) succeed to achieve substantial emission reductions with a slight increase in total cost; mostly by configuring the supply chain to use lower-emitting resources. They also signal the inexistent consideration of demand in the literature. It may be the case that the slight increase in total cost is compensated by an increased demand from environmentally conscious consumers.
Zhou (2021) analyses research around supply chain management under carbon taxes and concludes that carbon taxes /low carbon objectives promote supply chain member coordination to achieve not only environmental improvements but also economic and societal, using different types of contracts, such as carbon-cost-sharing or revenue-sharing. Comas et al (2015), Saberi (2018) and Das and Jharkharia (2018), discuss models for supply chain network design under different carbon policies and taxes on pollution.

[15] In Buggle et al (2021) we discuss the notion of the circular economy. Recycling raw materials such as glass, paper, aluminum reduces the "length" of the GVC because the first link is used only once (at least until the recycling potential of a material is exhausted).

5.2 Increasing visibility with blockchain and smart contracts

One of the biggest challenges to risk management is to quickly trace the source of a disruption, identifying affected suppliers and taking quick countermeasures. In global value chains, interactions are complex and involve multiple stakeholders with higher order connections outside the radar of any particular firm.

Blockchain is a data storage technology increasingly used to better trace all steps of the supply chain, from primary resources to consumers. In the current COVID-19 global crisis that exposed the vulnerabilities of global value chains, the promise of blockchain is to create a tool for **assessing risk** and helping mitigate disruptions, while regaining consumer **trust**, essential for the recovery of economic activity. The distinctive feature of this storage technology,

BOX 1: Some use cases of blockchain in supply chains.

In the food industry, IBM's Food Trust blockchain traces each step a food item makes, from the extraction of the raw material to the consumer's table. It offers traceability for supply chain efficiency, brand trust, food safety, freshness, fraud and waste, and also sustainability indicators and responsible sourcing. Big firms such as Nestlé, Carrefour, Walmart, and smaller ones like Raw Seafoods or Farmer Connect, focused on coffee.

Targeted to consumers, Provenance offers a blockchain platform to companies to communicate the origin, the journey and the impact of their products to consumers. Their value proposition includes the user-friendly visualization of a wide range of information to the general public, from sustainability indicators (carbon footprint, preservation of biodiversity, vegan composition), inclusiveness (respect of local communities, gender equity) to sourcing information (materials used, place of origin).

Origin trail is an open source blockchain used by the Swiss National Rail Company (SBB) to trace information for individual parts involved in their systems. It is also used in the garment industry to show consumers the garment's journey all the way from the factory to the point-of-sale. Daimler pilots the use of blockchain technology to track emissions and material flows in the cobalt supply chain.

compared to traditional ones, is that no single actor controls the infrastructure: control is distributed among a peer-to-peer (P2P) network of stakeholders (or "nodes") that keep separate records of the blockchain and that validate data additions by rules of consensus.

How does blockchain work? Data related to a transaction is recorded in a "block", together with a timestamp and a cryptographic hash of any previous block recorded on the merchandise involved in the transaction. The addition of new blocks never overrides previous blocks, ensuring that the data is not alterable (in principle). Crucially, each new block needs to be validated by the entire P2P network that controls the blockchain. If one single block is hacked, the network will not validate the transaction as it will not match their own copies of the records.

Consider, for example, a blockchain to store data about the garment industry. The first ("genesis") block is created when a first transaction takes place, for instance, when the cotton producer sells a ton of cotton to a yarn producer. The block will record the time of the transaction, the seller and buyer identities, the amount transferred. When the yarn producer sells its merchandise to a fabric producer, a second block is added to the blockchain containing the same type of information (timestamp, identities seller and buyer, etc.) and, in addition, a unique hash of all the information contained in block one. A new block will be added when the fabric is sold to the garment factory, containing all information about the transaction as well as all information about the previous ones involving the intermediary products and raw materials. Therefore, each block subsequently added to the blockchain contains information about all previous blocks, allowing users to trace back the entire supply chain of a piece of garment. Box 1 presents some use cases of the use of blockchain in supply chains.

Is blockchain technology keeping up its promises? Gaur and Gaiha (2020) present empirical evidence from seven large U.S. corporations that are exploring how blockchain might improve their supply chain operations. Their early initiatives show that the technology can enable faster and more cost-efficient product delivery, make products more traceable, streamline the financing process, and enhance coordination among buyers, suppliers, and banks.

In Europe, the EU parliament commissioned an analysis of the potential impact of the development of blockchains in international trade, economic development, social perspective, technical and security maturity, environmental impact, data protection and transparency (European Parliament, 2020). By empirically analyzing a series of use cases, the report identifies several **advantages** for supply chains:

- Establishing trust in environments where the single participating entities are not intrinsically trusted. This allows extending business to new horizons that the lack of trust was refraining or were establishing a central authority to monitor trustworthiness is technically or economically difficult.
- Establishing accountability and security in terms of data integrity in distributed peer-

to-peer environments, as data is publicly available.[16]

- Decentralizing control, which can facilitate the integration of new participants.
- Facilitating the scalability of digital solutions.
- The capability of automating transactions through the use of smart contracts, which we describe further below.

More recent developments of blockchain technology -blockchain 2.0 -, involve the use of "living" algorithms within the blockchain that can execute contracts. These **smart contracts** stipulate the conditions under which an action is triggered. For example, when the product arrives to the port in time, the payment to the shipping company is transferred. The algorithms verify the conditions and then execute the terms of the contract automatically, without a third party or "notary" screening.

One advantage of smart contracts is that they increase trust and reduce potential frictions and moral hazards between the parties (IMF, 2016), while reducing time and transaction costs. However, their potential disadvantages are still significant and perhaps the reason why they have not yet gained more popularity. They include their blurry legal status and jurisdiction, the risk to financial stability by propagating adverse events fast, and technical difficulties such as how to "observe" and measure external events.

*Can blockchain help supply chains become more **sustainable**?*

Blockchain can record carbon emissions, biodiversity depletion, sourcing practices and many other sustainability indicators in the supply chain and make them publicly available. If companies have targets set intrinsically, by regulation, or determined by consumer demand for sustainable products, blockchain can allow them to easily identify stages of production that need to be improved. Moreover, blockchain technologies can help to increase circularity by tracing information on product use to calculate resale and recovered material values. The sustainability gains due to the adjustments made in the critical stages of the production process could however be offset by the environmental impact of the blockchain technology itself. Indeed, the latter requires massive amounts of energy to run the mining algorithms that create blocks and that underlies the proof-of-work concept.[17] However, there are several possible avenues to reduce the energy consumption of blockchain platforms.

First, since the early days of blockchain, the rule of consensus used to validate the addition of new blocks was based on the so-called *proof-of-work.*

[16] If the data is in compliance with the data protection regulation as defined in the General Data Protection Regulation.

[17] Krause & Toloymat (2018) show that the Bitcoin blockchain network consumes as much energy per year as countries like Ireland or Hong Kong. The authors compare energy consumption of mining cryptocurrencies (Bitcoin, Ethereum, Monero and Litecoin) that use the proof-of-work consensus method to that of mining traditional metal. To calculate the energy demand of bitcoins they employ data on the number of calculations a network is performing. The authors find that in order to produce a similar market value of 1 USD, cryptomining consumed more energy than mining of minerals, except in the case of aluminum. De Vires (2019) presents estimations from the "Bitcoin Energy Consumption Index" that show that Bitcoin's energy use in 2018 translates to a carbon footprint of 19.0 to 29.6 million metric tons of CO_2 (475 g CO_2 / kWh).

A new block can be created if a complex cryptographic puzzle is solved by a miner and the other nodes acknowledge and validate the work done. As the network and the blockchain itself grow, the computations become more complex and more computational power is needed to solve them. In the case of cryptocurrencies, miners compete to solve the puzzle (and earn coins for it). Therefore, a lot of the energy is wasted and crucially only a restricted number of transactions can be processed daily.[18] In the case of applications of blockchain technology for firms and supply chains however, this consensus rule to add new blocks is less of a problem. As a decentralized mechanism, blockchain platforms can be *permissionless* or *permissioned*. In the first case, there is no restriction on the number of nodes that can enter as "peers" in the validation network. More nodes imply that more complex algorithms are to be run to create new blocks and thus more energy is consumed. Permissioned platforms, which are more common in supply chains, restrict the possibility to validate transactions to authorized nodes, typically stakeholders directly concerned by the business. Since less nodes are involved in the validation process, less energy is consumed. The blockchain can nevertheless remain public so that all stakeholders can read and submit transactions (see Table 1).

According to Arman Sarhaddar, CEO of the Swiss Vault Security Systems AG, many permissioned and private blockchains designed for applications in firms and supply chains do not need the proof of work method and can work with alternative, significantly less energy-intensive consensus methods. For example, some blockchains allocate proof-of-work validation privilege to nodes based on the number of coins they have (prove-of-stake), or to only few authorized and trustworthy nodes (proof-of-authority), while others select at random the node that will validate the transaction. Another validation method is *round-robin protocol* where the right to add blocks rotates among participants in a predetermined order (Gaur & Gaiha, 2020). These simplified validation procedures reduce computation efforts, require less energy, and allow substantially more transactions to be processed daily.

Table 1: Types of blockchain

	Access to transaction validation	
Access to transactions	**Permissioned**	**Permissionless**
Public	All nodes can read and submit transactions. Only authorised nodes can validate transactions—e.g. Ripple	All nodes can read, submit and validate transactions—e.g. Bitcoin
Private	Only authorised nodes can read, submit and validate transactions—e.g. R3 Corda	Not applicable

Source: Rosati & Čuk (2018)

A second avenue is, of course, technological innovation. The competition between miners created by cryptocurrencies has led to the development of more efficient machines that can perform a greater number of calculations per unit of electricity consumed (de Vries, 2019).

Last, the availability of renewable energy sources could be beneficial if the grid infrastructure allows distributing this type of energy efficiently (de Vries, 2019). Since blockchains work thanks to the internet, there is in principle no restriction on the

[18] Other rules of consensus are being advocated as more energy savvy alternatives, such as *proof-of-stake* or *proof of authority.* Examples of blockchains that are turning to these consensus rules are some cryptocurrencies such as Ethereum, the second most important cryptocurrency after Bitcoin, and NEO.

location of the computers around the world. Currently, a lot of the mining takes place in China where non-renewable energy is dominant (Le Sève et al., 2018). If electricity generated with fossil-fuels becomes relatively more expensive (due to CO2 taxes for example) than green sources (such as hydro, wind or solar), blockchain nodes will have incentives to move to locations where renewable resources are more abundant. Still, at least in the transition period, the massive amounts of energy used by proof-of-work methods is hardly reconcilable with sustainability goals.

An important aspect besides data storage is the quality of the data that enters the blockchain in the first place. The blockchain technology does not

BOX 2. Can smart contracts bring peace to the "war" around strategic inputs?

In an opinion column published on March 25th 2020 in The New York Times, when coronavirus became a global threat, Farhad Manjoo wondered "Why is the United States running out of face masks for medical workers? How does the world's wealthiest country find itself in such a tragic and avoidable mess? And how long will it take to get enough protective gear, if that's even possible now?". Soon after, we observed shortages in many other first-necessity products, such as oxygen and some medicines, and even consumer goods, such as toilet paper, aluminium cans, bikes or yeast. These shortages where mostly triggered by sudden (partly irrational) increases in demand, and exacerbated by disruptions in the transportation network and the labor supply at the factories. However, the fundamental problem remained the insufficient safety stocks and the inability to quickly apply contingency strategies.

Smart contracts (SC) can increase resilience of strategic supply chains, by stipulating immediate responses to early warning signs of shortages. Could smart contracts prevent hold-ups? For example, as demand for face masks explodes and inventories decrease to critical levels, SC could automatically place orders from suppliers that hold stocks, sign off new distribution channels, etc. While SC can significantly reduce the duration of shortages, they would be unable to prevent them altogether if these shortages arise from a global shock. The reason is simple, if hospitals worldwide implement SC for protective gear, a global pandemic will trigger their execution at the same time reducing their ability to leverage on existing inventories.

guarantee that data inputs are accurate. Suppliers might have incentives to manipulate records, for example the amount of carbon emissions, to appear more sustainable than they are to downstream firms. Automated record keeping with the use of hardware connected to the blockchain via the internet (``internet of things”), such as smart meters to measure energy consumption in real-time, are necessary to improve the reliability of data inputs (Le Sève et al., 2018).

*Can blockchain increase the **resilience** of supply chains?*

As discussed in part 1, one of the biggest challenges in risk management of supply chains is the lack of visibility of many stages in the production process faced by global multistage production networks. By allowing to track each and every element in this process, blockchains give firms the information they need to quickly respond to disruptions and to develop better contingency strategies.

Moreover, the possibility of establishing smart contracts on the blockchain further enhances the ability to instantly react to disruptions.[19]

On the downside, some concern has been expressed about the vulnerability of blockchains to cyberattacks, as they are global networks of interconnected computers exchanging information over the internet. However, if the blockchain is distributed (based on P2P), the probability of an attack disrupting a supply chain is small because many different machines and servers keep separate copies of the same records. If an attack to the ITC network disrupts part of the blockchain, it would still be operational. This is another argument in favor of decentralized or distributed blockchains.

Besides the ones discussed above, some remaining **challenges** need to be surmounted for blockchain to fully scale-up: data localization and privacy issues, identification of the applicable law and the allocation of liability, legal recognition and validity of blockchain-based information, and interoperability and standardization across economic operators and regulatory frameworks (European Parliament, 2020).

5.3 Government involvement and renewed multilateralism

Besides re-localization and the use of new technologies, the pandemic also triggered discussions about the role of national governments and international institutions in taming the forces of globalization to ensure that it leads to improvement in the welfare of humans rather than threatening it. Many states have realized that they need to do more to foster resilience and protect people’s safety and well-being against future global risks (Farrell and Newmann, 2020). The lockdown and its positive environmental effects, for example on water and air pollution, have also made visible that change towards a more environmentally responsible society is possible if the political will for (drastic) measures exists.

[19] Lohmer et al (2020) show in simulations that *blockchain smart-contracting prompts an increase in resilience* if the underlying collaboration is based on time-efficient processes. The propagation of disruptions, the network recovery time, and total costs can be substantially reduced. However, depending on the duration of the disruption, negative effects can occur if process efficiency is insufficient.

There is an economic argument for government intervention to increase resilience, in particular in critical or strategic supply chains such as food, pharmaceuticals and medical gear. Stockpiling of these essential goods, creates positive externalities in times of crisis for the society at large, which are not considered in the decisions of individual firms. Therefore, the level of stock holding provided by the market is below the socially optimal level, making a case for governments to step in. Indeed, countries such as Germany are piling up on essential medical equipment such as masks in response to the shortages they encountered in the first wave of the pandemic. Switzerland dissolved its stock of ethanol, which is crucial for disinfectants, only two years prior to Covid-19, largely responding to the requests of private companies. In March 2021, the Swiss government decided to rebuild its stock of ethanol.

Another idea how government intervention can increase resilience put forward by Simchi-Levi and Simchi-Levi (2020) is requiring critical supply chains to pass stress tests. A stress test for supply chains maps out the network linkages, simulates different risk scenarios, such as shocks to demand, shortages of inputs, or the shutdown of firms, transportation paths or entire regions, and identifies the impact of these disruptions. The results of the stress test enable firms to identify weak spots in their supply chains and to design strategies that make them more resilient.[20] Similar to stress tests of financial institutions, governments c0uld demand critical supply chains to pass stress tests on a regular basis, thereby guaranteeing that they withstand shocks.

Finally, the pandemic made apparent that international cooperation has not kept track with the increase in interconnections between economies and in their heightened vulnerability to systemic risks (Farrell and Newmann, 2020). On the contrary, the appearance of populist and nationalist governments that emphasize self-interest over cooperation undermines global institutions. Addressing global challenges and making globalization sustainable and resilient against global disruptions crucially demands multilateral solutions. Investing in prevention against global risks, designing early warning systems and cooperating in the creation of regional stocks of essential medical and pharmaceutical materials are all multilateral endeavors that would prepare societies better for future pandemics (Derviş, 2020). Environmental problems, such as climate change, are global in nature; they require multilateral solutions such as worldwide emission targets and multilateral financing of protections of the global commons. A diplomatic challenge?

[20] Researchers from MIT are currently building a stress test for commercial use together with Accenture.

6 Conclusions

Re-localization of production is unlikely to increase resilience of supply chains, in particular against external risks such as the current pandemic, because those risks are also present in local economies. However, one advantage of this strategy is to allow firms to identify disruptions earlier. In terms of sustainability, the impact of re-localization depends on the country and its availability of cheap renewable inputs, but overall, the gains would be mild. At the same time, the social and economic impact of re-localizing supply chains could be substantial for developing countries, unless strong development policies are in place. While the hypothesis that the current pandemic will lead to re-localization might go too far, there is some tendency for more near-shoring and a greater regionalization of supply chains in the future. In essence the main lesson may be the importance of diversification of the key nodes of a supply chain which goes against simple re-shoring since it goes together with regional concentration but at the same time a move away from an excessive reliance on a single region of the world especially if it is far away and is accompanied by more fragile monitoring.

Blockchains can help supply chains become more sustainable because they provide instant, reliable information about all products and stages in the production of a merchandise. This allows firms to quickly locate where the bigger environmental issues are in the supply chain and act accordingly, by strengthening standards, enforcing compliance and eventually switching suppliers. However, the sustainability gains of this increased visibility could be offset by the energy needed to run blockchains. Several avenues can reduce the electricity consumed, such as a restriction in the number of nodes that validate transactions (permissioned networks), a change in the consensus method, technological innovation that make computers more efficient, and the widespread availability of relatively cheap renewable energy sources.

Blockchain, and smart contracts in particular, can make supply chains more resilient by allowing firms to quickly trace the source of a disruption and automatically implement contingency strategies, such as placing orders, signing-off new suppliers and distribution channels. However, these gains will only be real if the contracts themselves are well designed, processes are efficient, and the information verified by the algorithms is reliable.

Governments can help to make globalization more resilient and sustainable by regulating and coordinating mandatory stockholding, by demanding stress tests of critical supply chains, and by cooperating internationally to minimize the risk of identified systemic threats and their global cost if they materialize.

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