OECD Trade Policy Papers No. 286

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https://dx.doi.org/10.1787/be692d01-en

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This Paper has been approved for publication by Marion Jansen, Director, Trade and Agriculture Directorate.

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Promoting Resilience and Preparedness in Supply Chains

Bublu Thakur-Weigold (ETH Zürich) and Sébastien Miroudot (OECD)

This working paper contributes to the debate on effective solutions for assuring the resilience of critical global supply chains by undertaking a review of both the supply chain management literature and recent actions by firms and governments. The report highlights that when pursuing the resilience of global supply chains, policy should focus on the performance of the system as a whole and not target a single objective, such as security of supply. In addition, resilience strategies should be segmented to address two distinct categories of risks: business-as-usual disruptions that can be mitigated by standard risk management practices of firms and unforeseen extreme disruptions where the role of governments is crucial as facilitators and providers of emergency resources. Effective interventions include reducing logistics frictions, regulatory co-operation and flexibility, and fostering an industrial commons for emergency preparedness. Regular preparedness conferences would enable public-private stakeholders to co-ordinate responses to future crises.

Keywords: Global supply chains, risk management

JEL codes: D81, F23, F63, H12, L23

Acknowledgments

The authors would like to thank John Drummond, Alexander Jaax, Julia Nielson, Silvia Sorescu, Ari Van Assche, Frank Van Tongeren, and Luk Van Wassenhove for helpful discussions and comments. The paper also benefitted from exchanges with and comments from the OECD's Working Party of the Trade Committee and Business at OECD. Finally, the authors would like to thank Laëtitia Christophe and Michèle Patterson for preparing the report for publication.

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Key messages

- **Role of governments:** Governments play an important role in supply chain resilience as facilitators, integrators, and providers of infrastructure and emergency resources, in co-operation with the private sector.
- **Proportionality and accountability:** Not every disruption or delay is a market failure requiring government intervention. Dealing with occasional stockouts at any node is part of every firm's routine risk management. Government should actively support supply chain resilience in cases of major risks or disruptions.
- **Strategic segmentation:** Resilience strategies should be segmented to address two distinct categories of risks: uncertainties which emerge during business-as-usual and extreme 'black swan' events. Applying the instruments of routine risk management (like stockpiles) to major disruptions results in waste, environmental burden, and underperformance.
- **Evidence-based decisions:** To avoid unintended consequences, policy makers should become knowledgeable in the complex adaptive systems which are today's global supply chains. Policy should ensure the improvement of system performance and not target a single objective (like assurance of supply). Decisions should be based on evidence, following analyses of the inherent trade-offs of the system: material availability comes at a cost.
- **Realistic assessment:** Visibility of complex systems does not guarantee meaningful insights into causality. The detail and dynamic complexity of global supply chains increase the challenges for monitoring and assessment. Without timely, complete, and accurate data, there is a risk of choices based on outdated or partial understandings of the system.
- **Alignment of competing interests:** In a complex adaptive system, a central authority (no matter how powerful or knowledgeable), cannot control outcomes. Superior supply chain performance is achieved through an alignment of stakeholder interests, calculated trade-offs, and coordinated action.
- **Appropriate policies:** Four types of policy interventions can have a high impact on the resilience of supply chains: the reduction of logistics friction, the promotion of regulatory convergence and flexibility, and the creation of an industrial commons (i.e. an integrated form of emergency preparedness comprised of inventory, backup production capacity and standby capabilities), followed by regular preparedness conferences with public and private stakeholders to stress test the industrial commons. While these resilience strategies can be implemented at the country level, they are more efficient if coordinated internationally.

Executive Summary

The COVID-19 crisis created awareness of how supply chain disruptions can trigger shortages of essential goods. Resilience of global supply chains was therefore elevated to a new priority in policymaking. Resilience means that the next crisis should be managed to minimise losses to society, while ensuring a rapid return to normal. This report contributes to the debate on effective solutions for, and the appropriate role of government in, assuring the resilience of critical global supply chains by undertaking a review of both the supply chain management literature and recent actions by firms and governments to strengthen the resilience of supply chains.

The global supply chains that produce most goods today incorporate inputs from globally diverse sources. These linkages enable participation in a system of enhanced productivity, quality, and innovation. The same linkages can also represent a country's exposure to international risks, which include disruptions to supply, demand, transport and infrastructure, regulation and policy, as well as catastrophic events like wars and public health emergencies (risks that equally occur domestically). Both firms and governments have come under pressure to minimise the impact of these risks on collective wealth and well-being.

The structure and behaviour of the global systems of production and trade have implications for their governance. When devising policy, the traditional focus on domestic firms should be expanded to include the supply chains in which these firms participate. Policy interventions in complex adaptive systems such as supply chains should also be based on evidence and supported by expert analysis. Modelling and scenario testing can help decision-makers to become more knowledgeable about the system prior to intervening. The detail and dynamic complexity of global supply chains increase the challenges for monitoring and assessment. But without timely, complete, and accurate data, there is a risk of making choices based on outdated or partial understandings of the system.

When pursuing the resilience of global supply chains, policy should focus on the performance of the system as a whole, and not target a single objective (such as ensuring supply), without calculating the possible trade-offs (i.e. with economic efficiency, sustainability, or costs of implementation). And finally, in complex adaptive systems such as supply chains, the literature confirms that a central authority (no matter how powerful or knowledgeable) cannot control outcomes. Superior supply chain performance is achieved through an alignment of stakeholder interests, calculated trade-offs, information sharing, and coordinated action.

There are material differences in the severity of disruptive events. Not every stockout or delay is a market failure requiring government intervention. Resilience strategies should therefore be segmented to address two distinct categories of risks. The first concerns the uncertainties (described as 'ergodic') which emerge during business-as-usual and for which firms apply regular risk management practices to mitigate the impact. These practices include backup suppliers or close partnerships with reliable single sources, redundancy, business continuity insurance, safety stocks of inventory, organisational flexibility and a culture of responsiveness. Of these routine measures, the literature confirms that flexibility and the culture of responsiveness are the most important, because they yield the most economically sustainable results.

The second category of risks is the much rarer, more extreme type of disruption triggered by non-ergodic uncertainty. These "black swan" events include a public health emergency, war or natural disaster. In these cases, disaster management practices in the form of a lifecycle of four activities can achieve resilience: preparedness, response, recovery, and mitigation. Learnings from each phase are reviewed to continuously improve the next phases of activity. In this way, active preparedness can achieve remarkable results by enabling a better emergency response, before transitioning to faster recovery and mitigation.

In both regular (ergodic) risk management and disaster (non-ergodic) response, risk management is not free. Decision-makers need to professionally manage the return on these investments. In particular, the waste produced by applying regular ergodic risk management tools to an extreme non-ergodic event should be avoided. For example, the literature indicates that firms do not maintain safety stocks for the demand spikes of black swan events because they are unaffordable, ineffective to prevent shortages, and divert resources from other business priorities. Evidence also indicates that efforts to "de-risk" global supply chains through the widely debated reshoring or "friend-shoring" strategies have focused on relocating

production facilities, without recreating a domestic supply base. Because they shift, rather than mitigate, risk, the impact of these initiatives is expected to be low.

To ensure the resilience of critical global supply chains, governments play an important role as facilitator, integrator, and provider of infrastructure and emergency resources, in co-operation with the private sector. A review of the actions taken by governments since the COVID-19 pandemic highlights that most countries have devoted resources to a better understanding of those risks and vulnerabilities in supply chains identified as critical for their economy. Some measures experimented with during the pandemic to reduce trade frictions were also made more permanent or systematic. New types of policies have emerged that consist in creating incentives for the relocation of production or diversification of supply for strategic products. These strategies are generally complemented with initiatives aimed at promoting international co-operation.

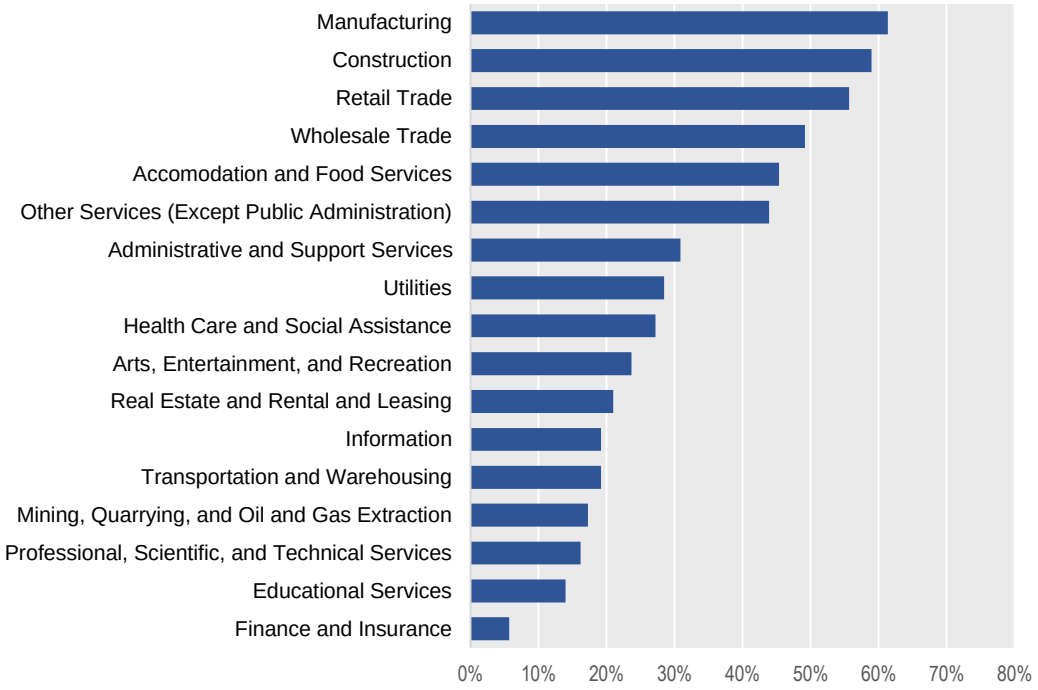
The review of the literature and recent actions by firms and governments highlights that four types of policy interventions have a potentially high impact: the reduction of logistics friction, regulatory convergence and flexibility, and the creation of an industrial commons followed by regular preparedness conferences with public and private stakeholders. The industrial commons strategy would convene stakeholders from government and the private sector to establish an integrated form of emergency preparedness comprised of inventory, backup production capacity and standby capabilities. Investments must be made to assemble stakeholders to collaboratively design the mechanisms, and protocols (playbooks) in advance of the next black swan event. This is the purpose of the preparedness conference, which should be organised as both an agenda-setting and work session.

Implemented effectively, this portfolio of measures would institutionalise the superior performance expected from redundancy when it is combined with flexibility. The disaster management capabilities represented by the industrial commons must be adapted, maintained, and rehearsed continuously. While these resilience strategies can be implemented at the country level, they are more efficient if coordinated internationally.

1. Introduction: Lessons from recent supply chain disruptions

In the wake of recent economic crises, resilience has become a priority for both firms and governments. The COVID-19 pandemic made citizens aware of the importance of supply chains for their health and wealth. Shortages of everyday items (like toilet paper) and essential goods (like medical masks) brought previously inconspicuous global operations into the public eye (Figure 1).

Figure 1. Supply chain disruptions in the United States during COVD-19, by sector



Note: A survey of US firms experiencing disruptions during the pandemic illustrates the extent of the disruptions and how many heterogeneous sectors were impacted. The situation in other economies and geographies was comparable.
Source: Helper and Soltas (2021[1]), based on data from the US Census Bureau and CEA calculations.

Although it was not the first disruption in recent history,[1] the scale and duration of the COVID-19 disruptions led the public, academics, and governments to ask whether these problems could have been avoided. The impression was that "business as usual" had failed society in its moment of need. There were calls for stress tests, and correction of production systems that appeared to have been designed for efficiency only, to the detriment of social well-being. Supply chain controversies were fuelled further by the Russian Federation's (hereafter "Russia") full-scale invasion of Ukraine in 2022, and its weaponization of energy and food markets. Some segments of public opinion began to question the entire system of global trade.

This debate puts both private and public stakeholders under pressure. It assumes that a trade-off exists between economic efficiency and supply chain resilience. To ensure availability of essential goods, firms are being asked to turn away from (excessive) cost-cutting to invest in backup suppliers, and "just-in-case" stockpiles. To render economies less dependent on partners that are not like-minded, their global operations should be subject to "de-risking", and repatriated via "friend-shoring", or reshoring. Policy

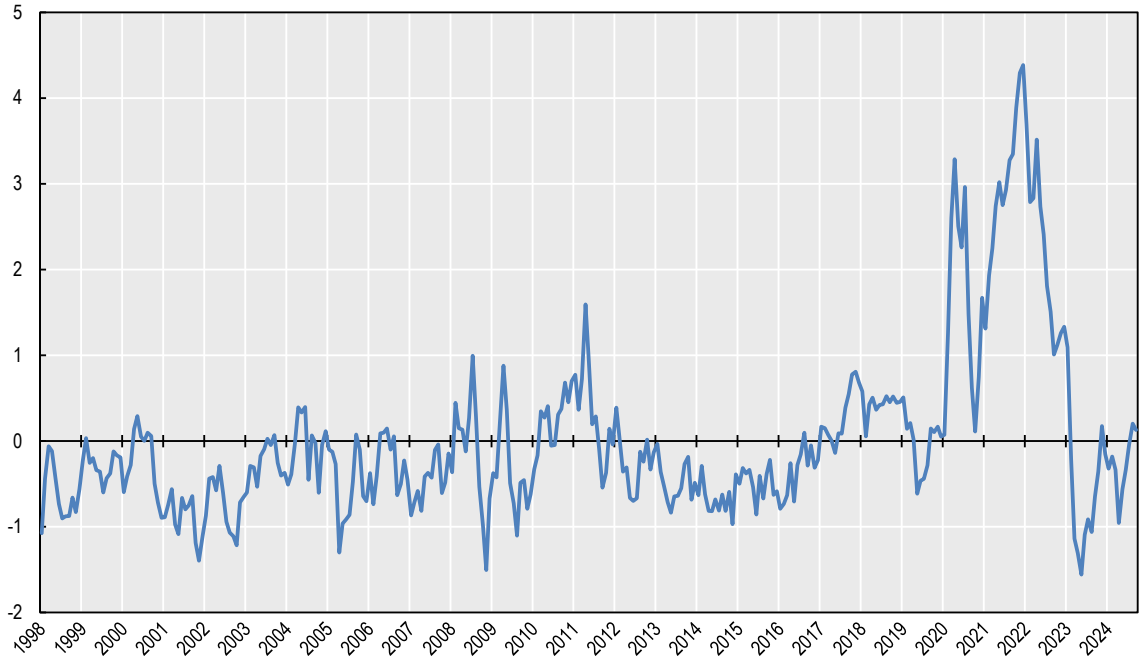
[1] For example, in 2010 the eruption of a volcano in Iceland disrupted the flows of material in global supply chains. This resulted in bottlenecks at the ports of Shanghai and Long Beach, as well as food shortages in the United Kingdom, and shutdowns of automotive plants in Germany. Pharmaceutical supply in Ireland narrowly escaped stockouts.

makers can find themselves called-upon to provide oversight of private sector operations to assure the resilience adequate to support economic or national security.

As can be seen on Figure 2, the level of global supply chain pressure[2] is now back to its historical average. As supply chains have recovered from the pandemic shock, the main driver of GVC reconfigurations might not be COVID-19 anymore. Decisions of supply chain managers will be guided by long-term strategic considerations that include not only a more uncertain global environment but also the continuing challenges of climate change or poverty in some parts of the world. Building resilient and sustainable supply chains will remain a key objective for policy makers.

Figure 2. The reduction in supply chain disruptions after COVID-19

Global Supply Chain Pressure Index, standard deviations from average value



Source: Federal Reserve Bank of New York.

The aim of this report is to contribute to discussions of what the right level of government intervention should be in the organisation of supply chains. It highlights the insights from supply chain literature which can support governments in designing policies to target resilience.

The rest of the report is organised as follows. Section 2 provides context by summarising what modern global supply chains are and how they behave under normal conditions, or "business as usual". These systems of production emerged quickly, undergoing a transformation which made them different from previous forms of industrial organisation.

Section 3 presents formal definitions of resilience under the two fundamental types of uncertainty. Section 4 then summarises the findings of operations and disaster management research on how resilience can be practically achieved in situations of ordinary uncertainty and in cases of extreme disruption. Dedicated attention is given to the interventions being debated today, such as inventory stockpiles, backup suppliers, and reshoring.

[2] The Global Supply Chain Pressure Index (GSCPI) is an index developed by the Federal Reserve Bank of New York that provides a synthetic measure of the intensity of supply chain disruptions based on data on transportation costs and Purchasing Managers' Index (PMI) surveys.

Section 5 provides an overview of recent actions taken by firms and governments to improve the resilience of supply chains. It looks at recent surveys of businesses and evidence on structural changes in sourcing strategies of firms. It also describes different types of policies at the country level and in specific sectors aimed at promoting resilience.

The report concludes with recommendations for resilience initiatives which can be effective for dealing with complex adaptive systems. Section 6 considers the role that government can play to enhance their robustness. It proposes to further explore the mechanism of 'preparedness conferences', which would convene public and private stakeholders to co-design what experts call an industry commons, with a playbook for emergency response.

2. Global supply chains: Complex, non-intuitive and vulnerable

Key terms: Complex adaptive systems, Detail complexity, Dynamic complexity, Bounded rationality, Learning organisation

Before reviewing the literature on their resilience, it is useful to briefly define the terms supply chain (SC) and global value chain (GVC). In the early 1980s, supply chain management was defined by industry practitioners who recognised that coordinating the system of material and information flows, both within and between firms, could materially improve business results and competitiveness. They advocated the "management of a chain of supply as though it were a single entity, not a group of disparate functions" (Davis, 1993[2]; Laseter and Oliver, 2003[3]). In the operations management (OM) literature, supply chain scholars began to address problems faced by firm-level managers to improve performance. Their strategies, which became increasingly global and networked, strove to create competitive advantage, profitability, asset productivity, customer service and market share, as well as sustainability.

The value chain of a firm was defined by Professor Michael Porter (1985[4]) of Harvard Business School. The concept unpacked the undifferentiated notion of a "production function" to describe how individual business functions (like procurement, manufacturing, distribution, and sales), contribute to create a good or service for which a customer is willing to pay (which is the managerial definition of "value"). Researchers reapplied this notion to the vertical dis-integration taking place within domestic firms under the last wave of globalisation (Feenstra, 1998[5]). The value-adding functions which were previously in-house have become firms distributed around the globe.

The developmental impact of global supply chains is the subject of a wide range of economics-related theories that inform policy makers. Economists refer to these networks as GVCs, coined in 2001 (Gereffi et al., 2001[6]). Sociologists view GVCs as successors to post-colonial global commodity chains (GCCs), to consider imbalances of power, and evaluate their impact on unequal participation and development. GVC analysts have also formulated theories of input-output structures aggregated at sector level (medtech, textile, agricultural GVCs), as well as structures of their governance. International Business scholars apply theories of externalisation to what they define as the "Global Factory", investigating the structures and activities of Multinational Enterprises (Buckley, 2009[7]). Economic geographers conceptualise the trade flows and production locations in what they call "global production networks", or GPNs. Bair (2009[8]) provides an overview of how these related streams of literature emerged over time.

For the sake of simplicity, this literature review of supply chain resilience uses only the terms global supply chains (GSCs) and global value chains (GVCs) interchangeably, depending on whether references are made to the operations or economic research. Prior to each section, key terms and takeaways are marked for reference.

Following the last industrial revolution, the original Ford Motor company made all components of its automobiles in-house, and even owned (among other sources of supply), the rubber plantations which supplied its tyre production. This degree of vertical integration is rare in today's world of specialisation and trade. The focus of firms on their core competences (Prahalad and Hamel, 1990[9]) has led to a decomposition of the corporate core (Billington and Kuper, 2003[10]), from which formerly in-house business functions were externalised (outsourced) to become individual firms. When early in the millennium

researchers measured a surge in export volume without a corresponding spike in GDP, this was interpreted as evidence of the growing vertical dis-integration of firms (Yi, 2003[11]). These specialist firms work within the supply chain, for example, as contract design and manufacturers, component suppliers, third-party logistics providers and resellers. Participants of a GSC do not necessarily export finished goods (like cars), but effectively *trade in tasks* (Grossman and Rossi-Hansberg, 2008[12]), which incrementally add value to intermediate products.

Today's GSCs are credited with enabling higher productivity (IMF, 2013[13]) because firms can simply join an existing supply chain rather than build the entire industrial base from scratch (Baldwin, 2011[14]). Enabled by technical innovations (like the IT revolution), political liberalisation (the opening of the People's Republic of China—hereafter "China"—and Eastern Europe, the creation of WTO), and steep drops in the cost of trade (containerisation), supply chains effectively represent a global division of labour and trade (Baldwin, 2016[15]), which has had a material impact on growth (IMF, 2013[13]; OECD, 2013[16]).

> *"In those early days, industrial power came from local sources such as horses, oxen, water wheels, and windmills; production was local. Consequently, supply chain disruptions were local, too. Earthquakes, tsunamis, famines, plagues, and floods struck around the world, but the effects did not travel far because most goods did not travel far. Since [then], the world has become much more reliant on long-distance supply chains…to provide the necessities of life. Modern technology has added new capabilities, but it has also added new vulnerabilities." (Sheffi, 2015[17])*

At the same time, the interdependencies in this globalised industrial system render it vulnerable to disruptions. A stockout in a single location will propagate, to trigger disruptions in those downstream locations which are waiting for supply (Davis, 1993[2]; Sheffi, 2015[17]). Firms must therefore either maintain formal risk management programmes or practice selected agile responses to everyday disruptions, as summarised by Tang (2006[18]). A shock, or a crisis like the COVID-19 pandemic, however, reveals the difficulties of adequate response at a national, or even global, scale. In these cases, operations theory provides some explanation of why the behaviour of supply chains may run counter to intuition and the logic of policymaking.

The fundamental purpose of a supply chain is to match supply to demand, under conditions of uncertainty, at the best total landed cost or TLC (Cohen and Lee, 2020[19]). TLC includes all the expenses (inbound logistics, production, transport, pipeline inventory, taxes and duty, and more), incurred from production to the delivery of the finished good to the user or customer. Designing a global supply chain involves balancing a number of objectives in a hierarchy of trade-offs. The objective of supply chain managers is not just to reduce costs but also to ensure appropriate quality, to maintain customer service, to avoid stockouts and to promote other objectives such as innovation or sustainability (Berger, 2005[20]; Christopher, 2011[21]). The supply chain literature confirms that the single-minded optimisation of individual functions or factors (like cost) tends to produce suboptimal performance at the system level (Sanders and Wagner, 2011[22]). The modelling literature and a recent benchmarking study of the logic of production location decisions (Cohen et al., 2018[23]) confirm that network configurations are determined by multiple decision variables. These factors include wages, tax, risk, customer requirements, target service levels, innovative capabilities, and competitive positioning. For example, available workforce becomes an increasingly important factor in the context of labour and skills shortages (Brunello and Wruuck, 2021[24]; Causa et al., 2022[25])

Once the desired balance of objectives has been achieved, the network of buyer-supplier relationships which comprise every supply chain creates strong interdependencies. These combine, often exponentially, to produce economic surplus. A school of thought on Network Competition therefore argues that today, it is no longer individual firms that compete, but supply chain verses supply chain (Christopher, 2011[21]). To illustrate with the most studied sector in the supply chain literature, automakers like BMW, Toyota and Tesla do not compete as German, Japanese or American multinational enterprises. This understanding belongs to the logic of old globalisation. Instead, they compete as global supply chains, with thousands of suppliers shipping the roughly 30 000 parts in a car around the world. Their output is "Made in the World", albeit with regional concentrations (Miroudot and Nordström, 2020[26]). To summarise, if "Twentieth-century globalisation is about made-here-sold-there goods crossing borders. Twenty-first century globalisation is also about factories crossing borders... The result was a de-nationalisation of comparative advantage and

a change in the nature of trade" (Baldwin, 2014[27]). When addressing the needs of individual domestic firms, policy makers should therefore consider the supply chains to which they contribute.

GSCs are Complex Adaptive Systems, or CAS (Choi, Dooley and Rungtusanatham, 2001[28]). These can be imagined as numerous (and proliferating), interdependent decision-makers, dispersed across an international theatre of operations. When the constituents buy and sell to one another, they create flows of information (in the form of orders, production specifications, delivery dates, and invoices), material (raw materials, semi-finished and finished goods), and money (payments, credit, refunds). Bottlenecks and stockouts can result from disruptions of any of the three flows. Because of the multiplicity of factors to continuously monitor and evaluate, decision-makers in supply chains often name complexity as a major challenge.

Complexity in systems takes two distinct forms (Senge, 1997[29]):

- Detail complexity arises from a high number of moving parts and processes within an interrelated system, which in the case of supply chains also crosses national borders.
- Dynamic complexity is created by the fact that the composition and behaviour of this system changes over time, through its own operative mechanisms, responding to shifts in markets and geopolitics. The system is always adapting and evolving.

Although the network generates value and competes as a system, orchestrating these systems as a whole differs from the way single firms are directed. Because of the sheer volume and dispersion implied by detail complexity, the operations of a supply chain are difficult to individually monitor or influence without analysis. Simon's (1979[30]) notion of bounded rationality, which recognises the practical cognitive limits of decision-makers in both collecting, and processing information, applies to detail complexity. In practice, managers inside the firm work with good-enough data and insights to arrive at timely decisions.

According to system dynamics theory, observers from outside the firm tend to overlook the dynamic nature of the CAS, underestimating the delayed effects of feedback loops on essential stocks and flows (Forrester, 1958[31]; Senge, 1997[29]). Dynamic complexity renders a snapshot (a qualitative assessment, data sample, or other performance measurement), of the supply chain quickly obsolete, whereby cause and effect may be difficult to determine. For these reasons, CAS are considered resistant to centralised policy and deterministic management (Choi, Dooley and Rungtusanatham, 2001[28]). Decision-making in supply chain systems has become progressively decentralised (Graves, 2021[32]), driven by structure.[3]

> *"Very often people are just role players within a [company's] system," Forrester says. "They are not running it; they are acting within it. This has not been a popular idea with people who think they are in charge … but in fact, unless they are knowledgeable in systems, they will fall into a pattern of doing what the system dictates. If they understand the system, they can alter that behavior."* Jay Forrester, pioneer of the field of industrial dynamics *(Dizikes, 2015[33])*.

Superior system performance is achieved through an alignment of interests, in which individual local objectives are prioritised, before trading them off hierarchically[4] (Cohen and Lee, 2020[19]). If traditional perceptions assume omniscient managerial control, system dynamics research emphasises the necessity of acting collectively as a Learning Organisation (Senge, 1997[29]), in which decision-makers become

[3] The structure of a supply chain is described by design features like speed of flows, the number and locations of nodes through which material flows, business models and strategy, among others. The configuration of the network (location of factory is a visible determinant, but not the only one), will have an impact on the speed of flows. Transport nodes, regulation of imports, and taxation regimes are other determinants. Information flow has been exponentially accelerated by information technology. Material flows have become cheaper and faster because of containerisation. This list is a small selection of the proliferating factors which play a role in supply chain structure and performance.

[4] Typical trade-offs to resolve and questions to be answered by managers include: how much customer service can our firm afford? How long is the customer willing, or able, to wait for their order before switching to a competitor? What are the tax benefits of completing a stage of production in any one location compared to the transport lead times from the next dependent node of activity? Pipeline inventories and safety stocks increase with distance to remote production locations, especially when slow and cheap modes of transport are used.

knowledgeable in the specific complexities and interactions of their system before designing interventions. Modelling the supply chain qualitatively and quantitatively are prerequisites for understanding its behaviour (Davis, 1993[2]; Zipkin, 2000[34]). Once its boundaries and parameters have been defined, testing how individual parameters play out under a variety of conditions should be an ongoing task. Used interactively, models do not deliver "the answer" like a cybernetic technology, they support finding the answer via "the learning effect of operations research" (Corbett and Van Wassenhove, 1993[35]).

Implications for supply chain resilience policy

- When devising policy, the traditional focus on domestic firms should be expanded to include the supply chains in which these firms participate.
- Policy interventions in complex adaptive systems like supply chains should be based on evidence and supported by expert analysis. Modelling and scenario testing can help decision-makers to become more knowledgeable of the system prior to intervening.
- The detail and dynamic complexity of global supply chains increase challenges for monitoring and assessment. Without timely, complete, and accurate data, there is a risk of making choices based on outdated or partial understandings of the system.
- When pursuing resilience of global supply chains, policy should focus on the performance of the system, and not target a single objective (such as assurance of supply), without calculating possible trade-offs (i.e. with economic efficiency, sustainability, or cost of implementation).
- In a complex adaptive system, a central authority (no matter how powerful or knowledgeable), cannot control outcomes. Superior supply chain performance is achieved through an alignment of stakeholder interests, calculated trade-offs, and co-ordinated action.

3. Definitions of risk and resilience

Key terms: Ergodic vs. non-ergodic uncertainty, Taxonomy of five supply chain risks, Resilience, Vulnerability

Supply chain management has been defined as matching supply to demand under conditions of uncertainty. When uncertainty has a negative impact on performance, it is considered a *risk*.

There is a trend in the literature to identify the differences between types of uncertainty and risk faced by supply chains. Of particular importance is the distinction between everyday ergodic uncertainties, and the non-ergodic uncertainties, which produce rare black swan events.[5]

The supply chain risk management literature defines a taxonomy which breaks down risk into five distinct categories (Wagner and Bode, 2009[36]):

[5] The formal definitions from Buckley (2020[138]) are: "An ergodic process is one whose properties can be deduced from a single (sufficiently long) random sample of the process. Non-ergodic processes change erratically at an inconsistent speed. In an ergodic process, every sequence or sizeable sample is equally representative of the whole. Consequently, this provides the condition that, in an interval of sufficient duration, a system will return to states that are closely similar to previous ones" (Puhr and Müllner, 2022[43]).

- Demand side risk can arise from volatile customer demand or self-inflicted variability through forecast inaccuracy, hoarding, and the bullwhip effect.[6]
- Supply side risk includes supplier default, capacity constraints, quality or technological issues.
- Regulatory, legal and bureaucratic risk (like tariffs, sanctions, tax regimes),
- Infrastructure risks (like port closures).
- Catastrophic risk (like a natural disaster, a war, or a global pandemic).

The first four types of risk (demand side, supply side, regulatory and infrastructure) ensue from ergodic uncertainty, and require *routine risk management* practices to achieve *resilience*. The fifth type, catastrophic risk, emerges from non-ergodic uncertainties and requires *disaster management strategies* in order to achieve *resilience*.

The supply chain literature, accordingly, defines *resilience* as the ability of a supply chain to return to normal operations following a disruption (Sheffi, 2008[37]; Miroudot, 2020[38]).[7] *Resilience* therefore does not mean the absence of disruption but is a measure of the speed and effectiveness of recovery. The mere occurrence of a disruption, however severe, does not imply that the system was not resilient. What matters is how quickly the system bounces back, and at what cost.

The literature defines a closely-related notion, the *vulnerability* of an entity (firm, supply chain, or country), as its "susceptibility to the negative consequences of a disruption" (Wagner and Bode, 2009[36]). Vulnerability can be evaluated as a combination of two factors (Sheffi, 2008[37]):

- The likelihood of disruption
- The preparedness of the entity for that disruption

The likelihood of business disruption has been demonstrated to increase with the detail complexity and connectedness of the supply chain configuration (Choi, Dooley and Rungtusanatham, 2001[28]; Wagner and Bode, 2009[36]; Mizgier, Jüttner and Wagner, 2013[39]; Bode and Wagner, 2015[40]), as well as density and node criticality[8] (Craighead et al., 2007[41]). Firms which focus on reducing v*ulnerability* will strive to reduce features of their system which drive up the probability of disruption. The activities leading to preparedness are discussed in the next section on resilience strategies.

Over time, the emphasis in research on supply chain risk has shifted from minimising *vulnerability* to increasing r*esilience*, because the latter is perceived as more actively oriented to results: "The notion of resilience thus has the positive connotation of flexibility and strengthening, whereas that of vulnerability can connote passivity, insecurity, and inevitability, none of which is helpful for mobilising action. Re-orienting from 'vulnerability' to 'resilience' also better captures the desired outcome – preparedness for dealing with unforeseen disruptive events" (van der Vegt et al., 2015[42]). The next section describes the variety of strategies – programmes, controls, processes, capabilities – that firms take in pursuit of resilience.

[6] The bullwhip effect was first described by Jay Forrester as the amplified demand variability that occurs upstream from orders placed downstream by final customers.

[7] There are other definitions of resilience that emphasise the ability to adapt and transform in response to adverse events. In the work of the OECD Committee for Agriculture, resilience is defined as "the ability to plan and prepare for, absorb, recover from, and adapt to adverse events" (OECD, 2020[139]).

[8] Node criticality refers to the importance of a node within a supply chain based on its value-adding role and contribution to the production of critical components.

4. Resilience strategies

4.1. Aggregate building blocks of resilience

Key terms: *Redundancy, Flexibility, Culture of responsiveness*

At the aggregate system level, supply chain risk theory defines the two basic building blocks of resilience to be *redundancy* and *flexibility*.

Redundancy can be set up using safety stock, backup suppliers, and excess capacity, whereby the costs of these investments must be managed (see discussion in next section). *Flexibility* is associated more with developing intangible capabilities, rather than assets. Puhr and Müllner (2022[43]) note that "shock resilience is closely related to organisational learning". According to Sheffi and Rice (2005[44]), firm-level flexibility should target the following five managerial areas: supply & procurement, conversion, distribution and customer-facing activities, control systems, and a *culture of responsiveness*. The culture of an organisation arguably plays a more important role than control systems or processes, especially in the interpretation of early signals and execution of response. In other words, inserting *redundancy* without establishing a *culture of responsiveness* may not achieve resilience in a supply chain.

Of the two building blocks, compared to *redundancy* and according to the theory, *flexibility* is considered the superior option, because its capabilities support continuous improvement and general competitiveness. Developing "responsiveness to disruption creates agility in operations" (Sheffi, 2008[37]; Sheffi, 2015[17]).

4.2. Routine risk management practices

Key terms: *Routine risk management, Vulnerability maps, Value-at-Risk, Time to recovery, ROI of economic supply chain risk capital*

In firms, the active management of risk takes a variety of forms, depending upon the type of risk to be addressed. Some firms put dedicated *risk management* or business continuity programmes in place, to recover quickly from disruptions, and minimise their impact on business results. Others work with selected individual measures, as described below.

According to Wagner and Bode (2009[36]) firm strategies can either aim to avoid the causes of risk altogether, or work to minimise their effects. Sheffi (2008[37]; 2015[17]) expands on this to define three categories of *risk management*:

- Avoidance
- Preparedness
- Response

Preparedness is achieved through a number of methods. Non-computational strategies for preparedness include scenario planning of imaginable disruptions. To design response plans, firms draft *vulnerability maps*, or matrices in which the likelihood of possible disruptions intersect with their severity of impact. Guided by these visualisations, managers draft contingency plans which address the most high-priority risks in their business systems (Sheffi, 2005[45]; Mizgier, Thakur-Weigold and Wagner, 2014[46]).

Another stream of risk management research borrows from the knowledge base in finance, where investment portfolio managers routinely measure indicators like *value-at-risk* (Mizgier, 2019[47]; Zhang et al., 2021[48]; Mizgier, 2022[49]). The process begins by selecting the most critical products, for which data is collected on material suppliers and the trajectory of their flows through the system. Having defined the business scope, the collective intelligence of the firm is tapped by polling staff about the history of disruptions, their likelihoods in the future, and how they estimated the *times-to-recovery* per event. Mathematical modelling of expected losses and profit- or *value-at-risk* in the future then approximates the risk profile and appetite of a firm (Mizgier, 2019[47]). The quantification of the value-at-risk, as well as

recovery time, in different scenarios will facilitate decisions on how much to invest in contingency plans and response.

Theoretical studies of supply chain risk management rarely address the cost of increasing resilience (van der Vegt et al., 2015[42]; Pournader, Kach and Talluri, 2020[50]).Yet, the redundancies, processes, and capabilities required to manage risk require significant investment, whose return must be managed. According to Wagner and Bode (2009[36]) "…supply chain risk management is not for free, managers are compelled to seek an efficient allocation of risk management resources and a reasonable cost-benefit trade-off." The total investment required to mitigate the firm's value-at-risk constitutes the *economic supply chain risk capital*, or ESCRC. Like other financial investments, firms are advised to assess the return-on-investment (ROI) of their ESCRC (Mizgier, 2018[51]).[9]

As previously mentioned, in practice, most companies have only partial data and understanding of their operational partners and dependencies. A pursuit of full visibility would require considerable investment of time, money, and organisational resources, and it must be repeated on a regular basis to accommodate dynamic complexity. However, even without a full mapping and visibility of the company's supply network, it is possible to conduct a good-enough analysis of the ROI on ESCRC (Mizgier, 2019[47]).

With today's technical capabilities to process larger volumes of transactional data, experts like Mizgier (2022[49]) see potential to meet the demands of detail complexity and attain an end-to-end view of the network. Although a recent policy forum in the journal *Science* calls for an alliance to map global supply networks in "a new era of microdata", potentially under the leadership of the OECD, it acknowledges the challenges of compiling, interpreting, and protecting the transparency of the more than "300 million firms, connected through an estimated 13 billion supply links… that produce most goods and services" (Pichler et al., 2023[52]). Besides exceptions like Inoue and Todo (2019[53]), who used a supercomputer to analyse over 1 million Japanese firms, there currently exists little research on full supply chain visibility beyond the second tier supplier. Another study of the utility of supply chain transparency recalls that users of information technology must be able to interpret what is revealed by the data, then use these insights to take meaningful action. They note that "analytics capability can provide insights on *what* to change to match supply and demand, [but] organizational flexibility enables firms to determine *how* to make the appropriate changes." Comparable to the other risk management strategies, creating information assets without a culture of responsiveness will not assure resilience (Srinivasan and Swink, 2017[54]).

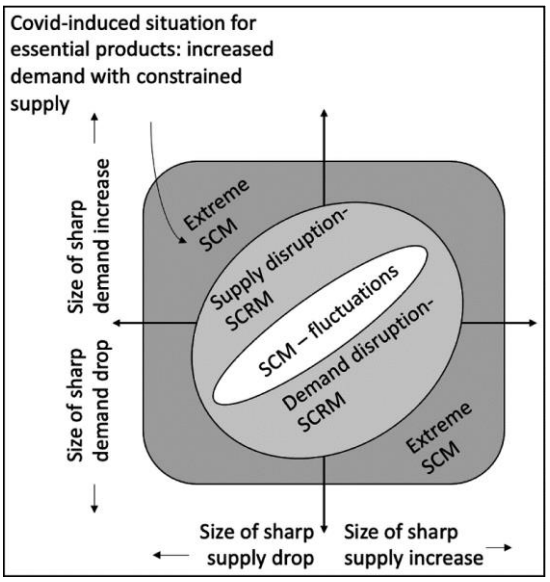
4.3. How emergency preparedness differs from routine risk management

Key terms: Differences in severity, Disaster preparedness, Disaster Management Lifecycle

After defining risk and resilience, it is necessary to establish what constitutes a disruption. A review of supply chain risk management literature which reflects on the learnings of "the COVID-19 era" observes that extant theory treats minor machine breakdowns and pandemics in the same way. The authors therefore recommend "a clear differentiation between crises (low probability—high-impact events) and other types of disruptions with varied levels of impact/likelihood, as they require different responses and different kinds of recovery and resilience planning" (Pournader, Kach and Talluri, 2020[50]). In other words, not every stockout, or interruption of business activity, constitutes a shock justifying policy intervention. Dealing with occasional stockouts at any one node is part of a firm's routine risk management, and not necessarily a sign of market failure. The material *differences in* severity of disruptive events are illustrated in Figure 3.

[9] It is interesting to note that pilots of this control system confirmed earlier findings that backup suppliers do not always ensure business continuity (Bode and Wagner, 2015[40]; Mizgier, 2022[49]; Fransoo, 2023[79]). We return to this insight in a later section.

Figure 3. Different scopes of supply chain management



Note: Sodhi and Tang (2021[55]) illustrate the different scopes of regular supply chain management, supply chain disruption risk management, and extreme supply chain management as they correspond to progressive increases in the scale of demand and supply chain fluctuations. Extreme supply chain management can be compared to disaster response.
Source: Sodhi and Tang (2021[55]).

A study of medical supply during the COVID-19 pandemic (Sodhi and Tang, 2021[56]) provides a taxonomy of disruption severity in terms of demand risk. It contrasts the demand characteristics of an emergency with those associated with non-ergodic business as usual. This results in four specific levels of demand challenges, expressed as a combination of frequency and multiples of average annual demand (Table 1).

Table 1. Four different scales of disruption severity, as measured by demand fluctuation

Number of demand challenges (DC)	Type of demand challenge scenario	Frequency of occurrence	Average Level of annual demand
C1	Regular healthcare with flu and other infections	Every 1 year	1 x
DC2	Severe flu	Every 2-3 years	2 x
DC3	Epidemics & minor pandemics	Every 5-10 years	3-4 x
DC4	**Severe pandemics (global)**	**Every 20-40 years**	**10 x**

Source: Adapted from Sodhi and Tang (2021[56]).

The global pandemic corresponds to the most extreme demand challenge scenarios, denoted by DC4, which saw a tenfold increase in demand for face masks[10]. The research concludes that the techniques of routine risk management are not fit for purpose when a black swan event strikes with its disproportionate scale (10x) of demand: "No manufacturer launching a product could handle such a distribution of demand by simply having a huge pile of just-in-case inventory" (Sodhi and Tang, 2021[56]). The case of the US Strategic National Emergency Stockpiles, or SNES, demonstrated that routine risk management failed when applied to the extreme challenges of several shocks with a tenfold increase in demand. According to their visualisation, this type of emergency requires "extreme supply chain management" (Figure 3).

When designing an appropriate response strategy, applying instruments of business-as–usual to the emergency typically creates waste. Successful resilience will depend on separating routine risk management from *disaster preparedness* (Tang, 2006[18]; Thakur-Weigold and Miroudot, 2023[57]). In cases

[10] In other product groups, the demand challenges can exhibit the opposite characteristics: requirements for office cafeteria and restaurant meals collapsed to zero as lockdowns prohibited public meetings and movement.

where resilience from “black swan” i.e. extremely rare events is to be achieved, the disaster management literature, which focuses on the equivalent of DC4 emergencies, offers guidance.

A seminal theory of emergency response defines the disaster management lifecycle (Carter, 1991[58]; Tomasini and Van Wassenhove, 2009[59]). This conceptualises four distinct phases of activity, which are executed sequentially within an integrated process, triggered by a non-ergodic, disruptive event (Figure 4). Conceptualising disaster management as a lifecycle (instead of *ad hoc* reactions), emphasises the dependencies, transitions, and communications between each phase.

Figure 4. The four integrated quadrants of the disaster management lifecycle

Source: Adapted from Carter (1991[58]) and Tomasini and Van Wassenhove (2009[59]).

It is possible to view a disaster as an isolated event and respond to a disruptive event without formal preparedness. This results in ad-hoc supply chains, which can be more or less effective (Müller, Hoberg and Fransoo, 2022[60]). It is, however, generally acknowledged that professional disaster preparedness, which benefits from the learnings of recovery and mitigation phases, makes the next emergency response faster, more effective, and less costly (Van Wassenhove, 2006[61]). These insights have led to a marked professionalisation of humanitarian operations in the context of disaster relief, helping them to improve outcomes, under time pressure with constrained resources.

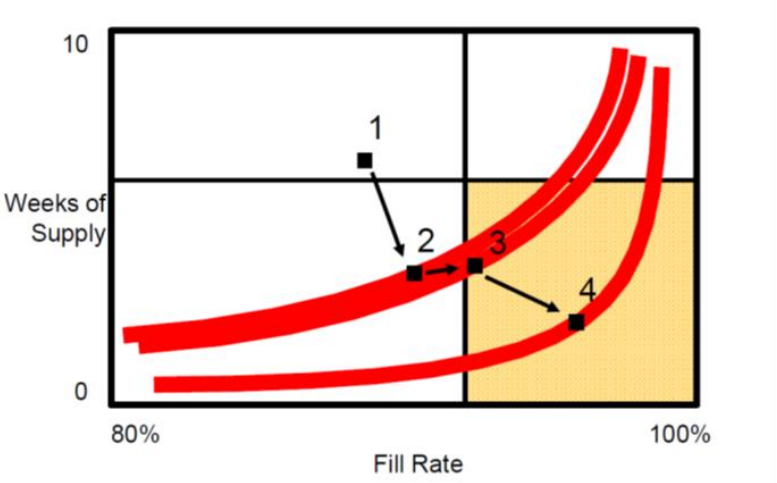
4.4. The use of inventory in global supply chains

Key term: *Efficient Frontier of Cost vs. Responsiveness*

To make sure that incoming customer orders can be filled, firms keep inventories of finished goods on hand, effectively as insurance to protect their margins (see also value-at-risk). Failure to fulfil an order because of stockouts will make it impossible to generate revenue. The higher the promised service level, the more inventory must be kept, and costs generated. To manage this fundamental balance in the supply chain, the basic theory of inventory management generates trade-off curves (Silver, Pyke and Peterson, 1998[62]; Johnson and Davis, 1998[63]; Hausman, 2004[64]), comparable to financial constructs of *efficient frontiers*. Because the curve is computed using statistical measures of the uncertainties in the system, research finds that the performance of individual supply chains can be assessed and fine-tuned by calculating the range of operational costs at which customer service (responsiveness to demand), is provided.

Every firm must manage the risks of routine ergodic operational variabilities like demand-side, supply-side, infrastructure, and regulatory uncertainties. Statistical measures of these uncertainties are inputs to constructing the trade-off curve. The more uncertainty in the system, the further up the curve will shift. At the extreme, full service generates infinite costs and managers will need to either reduce the most consequential uncertainties or live with lower levels of order fulfilment (Figure 5).

Figure 5. Efficient frontier of the cost of responsiveness



Note: An efficient frontier of the cost of responsiveness (customer service measured by order fill rates) can be constructed for each business case. According to inventory theory, this trade-off curve is dependent on the uncertainties of supply and demand, measured using standard statistical means (standard deviations of normal distribution).
Source: Adapted from Silver et al. (1998[62]).

When deciding how much inventory to keep, it is important to distinguish between regular and emergency supply chain operations. A catastrophic risk like a global pandemic ensues from non-ergodic uncertainty, which was measured by Sodhi & Tang (2021[56]) as requiring a tenfold multiple of routine ergodic demand (level D4 in Table 1). During the COVID-19 pandemic, shortages of essential goods, like face masks, led to calls for "just-in-time" stock levels be replaced by "just-in-case" stockpiles. According to inventory theory, fulfilling a D4 level of demand will move the trade-off curve unaffordably upwards. Because of its strategic implications, the following section devotes particular attention to the logic of this argument.

4.5. Firm-level inventory for routine risk management

Key terms: *Inventory-driven costs (IDC), One-size-fits-all*

Inventory is a redundancy strategy to achieve resilience. Contrary to the rhetoric of current debate, inventory is not *per se* a form of waste, nor is it desirable to eliminate inventory in pursuit of efficiency (Zipkin, 2000[34]). Firms therefore strive to maintain balanced "Goldilocks"[11] (Sheffi, 2020[65]) quantities of inventory, which are neither too much, nor too little, to respond to everyday volatility, at a reasonable cost (Tang, 2006[18]).

Johnson and Davis (1998[63]) describe how, to achieve that balance, the location of the efficient frontier is negotiated by the functional organisation of individual firms. There exists, for example, an inherent conflict of interest between finance departments (who seek to minimise cost of operations), and sales (who seek to maximize revenue by guaranteeing available inventory). Negotiations between these interest groups result in what they coined as the "service-inventory pendulum" of decision-making, in which stock levels swing up, then are corrected down, along the trade-off curve.

When computing the curve, the firm's investment in assets should ideally be calculated as fully-loaded *inventory-driven costs*, or IDC, compounding the costs of obsolescence, storage and handling, with the capital employed (Callioni et al., 2005[66]). When stockpiling perishable or highly innovative goods, the costs of obsolescence can exceed the other factors, and are often underestimated. Furthermore, large stocks of finished goods are a potential source of waste for firms, because the cushion provides an easy

[11] In the classic children's story, the child Goldilocks enters the home of three bears and samples their food to select what is neither too hot nor too cold, but just right, before consuming her preferred choice.

solution to fulfilling orders and leaves poorly-manufactured pieces undetected (Sheffi, 2020[65]). Over time, because stockpiles relieve the pressure to solve problems as they arise, firms or supply chains with high levels of inventory develop issues with quality.

The precise amount that each firm will keep is ultimately a strategic decision, which depends on the product type (innovative or standard commodity), business model (luxury, medical, service bundles), and location in the supply chain (pipeline, seasonal, safety stock). Even within a single firm, the best possible inventory policy may be low for finished goods (like cars), and high for spare parts (because repairs for grounded vehicles are usually urgent). A *one-size fits all approach* to inventory deployment can make firms less responsive to customer requests at higher-than-necessary costs (Fuller, O'Conor and Rawlinson, 1993[67]; Olavson, Lee and DeNyse, 2010[68]). The dynamic complexity of the system means that inventory policies must adapt to seasonality, technological innovations (new product introductions), and macroeconomic business cycles, to name but three drivers. A lack of differentiated supply chain strategy reduces their competitiveness, making consumer goods more expensive, and less accessible to consumers.

4.6. Government stockpiles for emergency response

During the COVID-19 pandemic, case studies of the government emergency stockpiles in various developed countries pointed out that centralised inventory of medical equipment and supply generally failed to meet needs (Australian National Audit Office, 2014[69]; Kamerow, 2020[70]; Laing and Westervelt, 2020[71]; Sodhi and Tang, 2021[56]; Feinmann, 2021[72]; Handfield et al., 2023[73]; Thakur-Weigold et al., 2022[74]). The extant research indicates a number of reasons for this: the selection of items needed in a crisis is hard to predict. Stock levels and quality are not clearly visible. The maintenance of a large-enough inventory to meet the demand challenge of a black swan event is prohibitively expensive. The high costs of the stockpile are subject to the vicissitudes of political budgeting and changes in administration. Processes for maintenance, stock rotation, or disposal of expired material are often not routinely foreseen, resulting in expiry and waste of material at times of need. In a federally-managed system, the coordination with local authorities, which is a prerequisite for speedy distribution to the last mile, is not routinely prepared. Centralised order management systems are not always in place, making it difficult to monitor inventory levels, and automatically match supply to demand. The issues converge to effectively create ad-hoc supply chains, which are characterised by avoidable expenses, stockouts, and firefighting.

The fact that overall performance of stockpiles in rich and poor countries was not significantly different during COVID-19 suggests that the root causes of failures are not attributable to resource availability alone. Capabilities and culture are likely to have played a role. After-action reviews of the centralised emergency vaccine stocks procured by the WHO on behalf of resource-poor countries confirmed that the last mile distribution had been delegated to local health ministries, and became an obstacle to vaccinations even when medical inventories were available in the central location (WHO, 2021[75]).[12] When managed centrally by government agencies, the necessary processes of regular inspection, reorder and disposal of expired or obsolete units were not consistently executed. Maintenance and readiness of government stockpiles is subject to budget cuts by subsequent administrations. Recalling the two building blocks of resilience defined in Section 4.2, redundancy in the form of just-in-case central inventory to be distributed tends to be ineffective, should a culture of responsiveness not be in place.

Learnings from the disaster management literature are, again, applicable to stockpiling, especially since humanitarian organisations, like governments, are under constant pressure to justify how they spend budgets to avoid charges of corruption and wasteful practice. In line with existing claims that flexibility is superior to redundancy, Kunz et al. (2014[76]) modelled the impact of prepositioned stockpiles within the dynamics of the system, to conclude that "pre-positioning of inventory leads to good results in terms of demand satisfaction, but at high costs that can barely be financed by the existing funding mechanisms. As a valuable alternative to such pre-positioning of inventory, we found that investments in DMC [Disaster Management Capabilities] can achieve remarkable results at much lower costs". This is confirmed by the studies of the COVID-19 pandemic response which recommended establishing supply chain capabilities

[12] The after-action review of the WHO's efforts revealed that the centralised co-ordination of a global Covid-19 response had not achieved its objective of equitable distribution of PPEs because of the failure to properly design a supply chain to support its strategic intent.

and solutions for public health administrators who usually manage emergency response exclusively in terms of medical therapies (Laing and Westervelt, 2020[71]; WHO, 2021[75]).

4.7. Backup suppliers

The ongoing deglobalisation and resilience debate calls for backup suppliers who will step up should other sources fail to deliver. Research indicates that this solution may not perform as expected.

First, doing business with multiple suppliers drives up horizontal detail complexity in the supply chain, which may actually increase the likelihood of disruption (Bode and Wagner, 2015[40]; Mizgier, Jüttner and Wagner, 2013[39]). Pilots of value-at-risk programmes found that backup suppliers did not necessarily mitigate the risk of single sourcing to improve resilience (Mizgier, 2022[49]). According to an earlier model of tightly-coupled, complex supply chains, when supply markets share raw material sources at less visible upstream locations "A multi-sourcing strategy in the second tier will not protect an OEM if there is an undetected single source embedded further up the chain. If the backup supplier is also brought down by the same raw-material supplier that caused the first supplier to default, little is gained" (Mizgier, Thakur-Weigold and Wagner, 2014[46]). A study of reshoring supply similarly concludes that "It is… important to realize that analogous to direct connections, a focal firm's indirect connections may also affect its supply chain structure … which in turn affects [supply chain resilience]. Therefore, reshoring direct (Tier 1) suppliers does not necessarily ensure that the entire supply network becomes resilient—it could simply mean that possible disruptions are pushed higher up in the supply chain" (Choudhary et al., 2022[77]).

Second, the diversification of the supply base tends to reduce the intensity of individual buyer-supplier relationships. A well-prepared single source supports recovery better than a less committed sourcing portfolio with impersonal market transactions (Jain, Girotra and Netessine, 2022[78]; Fransoo, 2023[79]). This finding is in line with the conceptualisation of resilience achieved through the complex adaptive system, and not through the isolated exertions of an individual node (Choi, Dooley and Rungtusanatham, 2001[28]). Since most firms have a broad supply base, ongoing statistical analysis will be necessary to discover which suppliers are business-critical, and therefore worthy of the managerial attention and financial investments to develop joint contingency plans (Mizgier, 2022[49]).

4.8. Geographic de-risking: Friend-shoring, near-shoring and reshoring

Although the "Made in the world" narrative still applies, GSCs have become more domestic since the peak of globalisation measured in 2011 (Jaax, Miroudot and van Lieshout, 2023[80]). Policy makers are considering the options of geographic de-risking and decoupling. This can take the form of friend-shoring, which is trading with allies or like-minded countries, near-shoring, which involves relocating operations in nearby countries, or re-shoring, which repatriates supply chain nodes. Although there is not always a clear definition, the concept of de-risking puts the emphasis on diversification and a reduction of trade dependencies without fully abandoning sourcing from countries identified as high-risk. Decoupling suggests going further and trying to cut most economic ties.

Various countries have launched programmes to stimulate local manufacturing. Empirical evidence suggests that efforts to redesign supply chains to reduce geographic risk generally fall short of expectations (Owen, 2012[81]; Hufbauer and Jung, 2021[82]; De Backer et al., 2016[83]; Arriola et al., 2020[84]; Schwellnus, Haramboure and Samek, 2023[85]). Reshoring the supply chain is often understood as relocating the factory only, which elides the necessity of developing a local supplier base. A comprehensive local reproduction of the ecosystem is not generally realistic in the short- to medium-term: "It is very unlikely that, in the current environment, new supply chains will be, to a high degree, developed locally" (Alicke, Hoberg and Mauhourat, 2022[86]; Dai and Tang, 2022[87]), leaving any risk of foreign supply markets unchanged.

Efforts to redirect trade through tariffs or other types of trade restrictions often lead to workarounds where the same products are still imported via authorised locations in third countries, increasing transport cost and activity, without adding value (Freund et al., 2023[88]). These can be interpreted as examples of self-organising actions, which both react to, and create the environment around the complex adaptive system (Choi, Dooley and Rungtusanatham, 2001[28]). The system will adapt and re-emerge in a different configuration that serves its own incentives (Hoang and Lewis, 2024[89]).

Reconfiguring supply chains to increase presence in politically safe locations convolutes their structure, as measured by criteria of optimal network design. By increasing detail and dynamic complexity, firms become more susceptible to disruption: "Shifting from long-chained global supply chains to more regionalised settings with short-chained configurations, a disruption in a local element can diffuse even more rapidly across the supply chain, affecting multiple actors in the chain." (Zhang et al., 2021[48]). Localised economic activities will remain prone to local disruptions (Reza-Gharehbagh et al., 2019[90]; Baldwin and Freeman, 2022[91]). Proximity has not been proven to increase control.

There is evidence that international trade relieved shortages and improved resilience during the COVID-19 pandemic (Miroudot, 2020[38]) and the war in Ukraine (Ossa, 2023[92]). A study by international business scholars of the events during the COVID-19 pandemic tested the relationship between multinationality and risk. It concluded that while internationalisation creates a general liability of foreignness that increases systematic risk, "it also generates an asset of multinationality that enhances shock resilience" (Puhr and Müllner, 2022[43]). This asset creates real options for supply chains in the face of uncertainty: "Production sites in multiple countries enables the flexibility which is prerequisite to resilience" (Thakur-Weigold and Miroudot, 2023[57]).

Inversely, a reduction of real options comes at a cost to supply chains and the countries which host them. An OECD study that tallies the costs of disruption with those of GVC localisation concludes that there is a material economic penalty to be expected from the reduction of interconnection and trade (Arriola et al., 2020[84]). A working paper on the economic impact of "friend-shoring" (Javorcik et al., 2023[93]) by the European Bank of Reconstruction and Development (EBRD) suggests that most European countries will not benefit in the medium run. Furthermore, countries with deep ties to global value chains could see a reduction of up to 4.6% of their GDP.[13]

5. Landscape of actions taken by firms and governments since COVID-19

While supply chain disruptions existed before COVID-19 and are also the result of more recent crises, such as Russia's invasion of Ukraine, the pandemic served as a catalyst for a reassessment of supply chain management by firms and more attention devoted to the issue of resilience by policy makers. This section delves into the multifaceted response by firms and governments worldwide to enhance the robustness and resilience of supply chains.

The first part of the section provides evidence on the adaptive strategies employed by firms to mitigate the risks exposed by the pandemic. It presents the results of business surveys on strategic reorientations in sourcing strategies, as well as results based on more aggregate data that nuance the understanding of firms' evolving practices. The second part of the section explores the various policy measures implemented by OECD governments to foster supply chain resilience, followed by an overview of on sector-specific responses. It concludes with an assessment of how the landscape of actions might impact economic performance, applying the principles of the resilience strategies reviewed in previous sections.

5.1. Evidence of changes in firm-level strategies

Since the onset of the COVID-19 pandemic, firms have been actively working to overcome disruptions and build resilience in their supply chains. According to McKinsey's survey of global supply chain leaders (Alicke et al., 2022[94]), firms have mostly used some combination of inventory stockpiles, dual sourcing and regionalisation of supply networks. The survey highlighted that many companies had increased their inventories as a resilience strategy, with 80% of respondents reporting inventory increases during 2021. Additionally, 71% expected to revise their inventory policies in 2022 and beyond. While changes in inventories may reflect short-term strategies to deal with disruptions, the survey also suggested shifts in longer-term strategies with 81% of respondents saying that they had implemented dual-sourcing strategies in 2021 and 44% indicating that they were developing regionalised supply networks. The survey also

[13] The authors admit that, because their model does not consider changes in the extensive margin and productivity gains, costs are likely to be underestimated.

showed a focus on three key ingredients for resilient supply chains: visibility, robust scenario planning and comprehensive and accurate supply chain data.

Another survey of 1 500 global decision-makers by Interos suggested that a majority of companies were planning 'wholesale changes' in their supply chain footprint, mainly motivated by reducing supplier concentration and diversifying supply (Interos, 2022[95]). Respondents expected that about half of their supply chain might be reshored or moved to a closer location within three years. Moreover, more than 60% of organisations expected to increase the number of companies in their supply chain over the next few years, indicating a trend towards diversification. Like the McKinsey survey, the Interos report further emphasised the importance of operational resilience, which requires proactive risk planning, assessment, mitigation and monitoring. It highlighted the necessity of continuous risk monitoring, with only 11% of organisations doing so.

However, it is important to distinguish between predictions and implemented changes actual shifts in supply chains (Altman and Bastian, 2023[96]). In fact, a report by the World Economic Forum provided detailed measures of the "gap between strategic intent and operational delivery", noting that while rhetoric may declare that "92% are regionalizing their value chains", reality suggests that only "28% aim to have nearly all in-region-for-region operations by 2030" (World Economic Forum, 2024[97]). At this stage, there is no evidence of a shift from global to regional trade flows or of a retreat from globalisation. The latest data confirm the trends described in Jaax et al. (2023[80]) with a stable level in the international fragmentation of production and a trend towards more domestic supply chains limited to some Asian economies that had high levels of fragmentation of production. The 2024 DHL Global Connectedness Index report also indicates a trend towards nearshoring in North America (based on trade flows) but highlights that overall globalisation has not given way to regionalisation (Altman and Bastian, 2024[98]).

At a more micro level, a report by the Swedish Agency for Growth Policy Analyses also highlights a discrepancy between what firms intended to do in the aftermath of the pandemic and what they have actually done (Nordstrom, 2023[99]). For example, a survey of Swedish firms in 2020 suggested that increasing risk diversification was one of the most common post-pandemic measures implemented by 33% of firms. But there was no evidence of increased risk diversification in 2021 and risk diversification had even decreased for medium and large enterprises. At the end, Swedish firms relied more on larger stocks of inputs to address temporary supply disruptions.

5.2. Overview of government policies

Since the pandemic, governments have also been active in analysing risks in supply chains and putting in place new policies aimed at boosting their resilience. These policies can be grouped in four categories: (i) initiatives aimed at identifying and assessing risks; (ii) measures aimed at facilitating trade and increasing flexibility in supply chains; (iii) incentives to firms to relocate or diversify supply; and (iv) international co-operation to promote resilience.

5.2.1. Initiatives aimed at identifying and assessing risks

Anticipating risks is one of the 'four keys to resilient supply chains', as described in OECD's web tool for preparedness and responsiveness.[14] Several governments have created specific task forces or offices to address supply chain issues and have produced detailed analysis on potential vulnerabilities in their supply networks using trade statistics, input-output data or more granular information at the firm-level. For example, the Australian government asked the Productivity Commission to develop a framework for identifying supply chains that are vulnerable to disruptions (Australian Government Productivity Commission, 2021[100]). The methodology involves the identification of vulnerable products through trade data and a data-driven assessment of the use of such products in essential industries. Expert assessment then identifies, among products that are vulnerable and essential, the critical goods and services that cannot be substituted easily or for which the production process cannot be adjusted in the short term.

In the European Union, the 2021 Industry Strategy update first carried out a bottom-up mapping of EU's strategic dependencies using trade data and an in-depth review of these dependencies in six sectors (raw

[14] See https://www.oecd.org/trade/resilient-supply-chains/

materials, active pharmaceutical ingredients, li-ion batteries, clean hydrogen, semiconductors and cloud and edge computing) (European Commission, 2021[101]). This exercise was followed by a second round of in-depth reviews deepening the assessment for raw materials and cloud and edge services, and adding new sectors in the areas of services and technologies (European Commission, 2022[102]). More recently, the European Commission developed an updated methodology to detect EU strategic dependencies using highly disaggregated product level trade data and network analysis to identify 'single points of failure' (SPOF) (Arjona, Connell and Herghelegiu, 2023[103]).

In the United States, the President Executive Order 14017 "America's Supply Chains" (signed on 24 February 2021) introduced a whole-of-government approach to assessing vulnerabilities in supply chains, starting with a 100-Day Supply Chain Review involving the Department of Commerce, Department of Energy, Department of Defense and Department of Health and Human Services (The White House, 2021[104]). The supply chain assessment covered four critical products: semiconductor manufacturing and advanced packaging, large capacities batteries (like those for electric vehicles), critical minerals and materials, and pharmaceuticals and active pharmaceutical ingredients (APIs).

In addition to reviews and assessments of vulnerabilities, governments have also set up specific task forces or designated specific parts of their administration to deal with supply chain issues and make recommendations on how to improve their resilience. For example, the United Staes created in June 2021 a Supply Chain Disruption Task Force to address the vulnerabilities identified in the 100-Day Supply Chain Review. Moreover, a White House Council on Supply Chain Resilience was established at the end of 2023 to devise a long-term strategy for resilient supply chains. The Council includes members from over 20 US government agencies.[15] Within the Department of Commerce, a Supply Chain Center (SCC) was also created to develop innovative supply chain risk assessment tools building on industry expertise and data analytics.

In Australia, the Office of Supply Chain Resilience was established in 2021 to advise the Australian government on supply chain risks and potential actions to improve resilience. Some countries have relied on expert groups, such as Ireland where the Department of Enterprise, Trade & Employment created an Expert Group on Global Value and Supply Chains as part of Ireland's 'Trade and Investment Strategy 2022-2026' (Government of Ireland, 2022[105]). In New Zealand, the Ministerial Strategic Advisory Group on Trade (an advisory board with experts) was asked to investigate how firms are preparing for disruptions and what the government can do to help (Sense Partners, 2023[106]).[16]

Finally, it should be noted that supply chain risk assessments can also be part of broader initiatives aimed at economic security and not dealing only with supply chain resilience. For example, in the UK, building resilience was addressed as part of an 'Integrated Review of Security, Defence, Development and Foreign Policy' (HM Government, 2021[107]). More detailed guidance on how to mitigate risks in supply chains was then provided as part of the Department for Business and Trade's (DBT) resilience framework.[17]

5.2.2. Measures aimed at facilitating trade and increasing flexibility in supply chains

During the pandemic, governments implemented a series of border measures aimed at facilitating trade and minimising supply chain disruptions. These measures reduced logistics friction and accelerated the emergency response. They included expedited clearance through "green lanes", the use of digital tools for the streamlining of documentary requirements, as well as enhanced co-operation across border agencies (OECD, 2020[108]). However, these trade facilitation measures were emergency ad-hoc responses rather than planned long-term actions (UNESCAP, 2021[109]). Most of them expired after a few months and when the level of disruptions was reduced.

[15] See https://www.whitehouse.gov/briefing-room/statements-releases/2023/11/27/fact-sheet-president-biden-announces-new-actions-to-strengthen-americas-supply-chains-lower-costs-for-families-and-secure-key-sectors/

[16] The government also asked the New Zealand Productivity Commission to undertake an inquiry into the resilience of the economy to supply chain disruptions. The final report is expected in February 2024.

[17] See https://www.gov.uk/government/publications/supply-chain-resilience/dit-supply-chains-resilience-framework

Nevertheless, some governments have explored to what extent some of these measures could be made more permanent or integrated in long-term trade facilitation plans. For example, the Canada Border Services Agency (CBSA) introduced in 2020 the 'Electronic Longroom', an email and digital stamping service for declaring goods. The objective was to limit the in-person submission of requests during the pandemic. In 2021-2022, the system was formalised as a permanent process (APEC, 2023[110]). While in most countries the automation and streamlining of customs procedures was initiated before COVID-19, the pandemic has accelerated the digitalisation of trade-related documents and the streamlining of regulatory requirements (Sorescu and Bollig, 2022[111]). In addition to the benefits in terms of reduced trade costs, such measures are also promoted as part of resilience strategies.

Another area where measures experimented with during the pandemic are also made more permanent or systematic, is the co-operation between border agencies, both domestically and internationally. Together with the availability of trade-related information and the development of automation tools, border agency co-operation is one of the top areas of reform driving changes in the OECD Trade Facilitation Indicators (TFIs) in 2020-2022 (OECD, 2023[112]).

In addition to trade facilitation, more flexibility in supply chains and capacity to adjust to shocks is promoted by governments through investment in transport infrastructure, digital infrastructure and data-sharing capabilities. For example, disruptions affecting maritime and air freight during COVID-19 encouraged the United States to further invest almost USD 50 billion in ports and airports as part of the Bipartisan Infrastructure Law in 2021. Congestions in ports also accelerated the deployment of port digitalisation initiatives started before the pandemic, such as the Cyber Port initiative launched by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) or the digitalPORT@SG initiative launched by the Maritime and Port Authority (MPA) of Singapore (APEC, 2023[110]). In the United States, the Department of Transportation (DOT) has also developed in 2022 a public-private partnership called Freight Logistics Optimization Works (FLOW) where ocean carriers, cargo owners, ports, terminals and railways can share logistics data.[18]

5.2.3. Incentives for firms to relocate or diversify their supply base

As highlighted in Section 5.1, firms have already started to reassess risks in their supply chains and to introduce changes in their sourcing strategies. Some governments have created incentives taking the form of subsidies or tax breaks to encourage the reshoring of some activities or the creation of additional capacity within the domestic economy, or abroad to promote diversification. In Japan, METI introduced in 2020 a 'Program for Promoting Investment in Japan to strengthen Supply Chains' with subsidies for Japanese firms building new facilities in Japan for products either largely produced overseas or essential for people's well-being.[19] In 2020, 146 projects were selected for programmes amounting to JYP 247.8 billion (USD 2.3 billion) and in 2021, 151 projects received support for a total of JYP 209.5 billion (USD 1.9 billion).[20] Another initiative, METI's 'Overseas Supply Chain Diversification Support Project', was aimed at diversification of overseas supply chains to ASEAN countries. A total of 92 projects were selected in 2020-2021. In May 2022, Japan enacted the Economic Security Promotion Act where further support was offered to companies for ensuring stable supply of key products (through grants and low-interest loans).

In the United States, a series of legislations introduced incentives for domestic production or diversification of supply in the critical sectors that were part of the 100-day supply chain assessment. In the health sector, a consortium for advanced manufacturing and onshoring of domestic essential medicines production was established and funds committed to develop novel platform technologies to increase domestic capacity for the production of APIs.[21] For semiconductors, the CHIPS and Science Act (2022) introduced incentives for domestic manufacturing, while also encouraging engagement with US partners and allies to strengthen the global supply chain. For large capacity batteries, financing to domestic supply chains was provided through the Bipartisan Infrastructure Law (2021) while the Inflation Reduction Act enacted a consumer tax

[18] See https://www.bts.gov/flow.

[19] See https://www.jetro.go.jp/en/invest/attractive_sectors/manufacturing/government_initiatives.html

[20] See https://www.meti.go.jp/english/press/2020/1120_001.html and https://www.meti.go.jp/english/press/2021/0702_003.html

[21] See https://www.whitehouse.gov/wp-content/uploads/2023/06/Supply-Chain-Report-Card.pdf.

credit for purchases of electric vehicles with final assembly in North America and meeting critical mineral and battery component requirements (i.e. a certain percentage of critical minerals sourced from the US or processed in the United States). The Bipartisan Infrastructure Law also included funding to identify potential US production and processing locations for critical minerals.

In the European Union as well, the resilience of the semiconductor ecosystem and the prevention of semiconductor shortages was addressed through support to EU-based manufacturing activities as part of the European Chips Act (Regulation 2023/1781). The Critical Raw Materials Act (Regulation 2024/1252) set benchmarks by 2030 for domestic capacities along the strategic raw materials value chain, while also promoting the international diversification of supply (see below in Section 5.3).[22]

5.2.4. International co-operation to promote resilience

The resilience of supply chains has also been addressed in many international initiatives, at the plurilateral, regional or bilateral level. An example of bilateral co-operation is the UK-Australia supply chain resilience initiative, formalised at the 2021 G20 Leaders' Summit.[23] The objective of the initiative is threefold: (i) sharing experience in recognising supply chain vulnerabilities and risks; (ii) promoting solutions to achieve supply chain resilience; and (iii) supporting co-operative international efforts to ensure robust and sustainable global supply chains. A pilot phase is foreseen while inviting other countries to join.

Another example of international collaboration (this time trilateral) is the Supply Chain Resilience Initiative between Australia, India and Japan.[24] Two Ministerial meetings took place in April 2021 and March 2022. The initiative encourages the sharing of best practices on supply chain resilience and the support of trade and investment diversification.

The US Supply Chain initiative also put the emphasis on international co-operation to decrease global vulnerabilities. In October 2021, the United States organised a Summit on Global Supply Chain Resilience with the European Union and 14 like-minded countries.[25] A follow-up dialogue took place in July 2022 with the organisation of a Supply Chain Ministerial where 17 countries (and the European Union) joined the Joint Statement of Cooperation on Global Supply Chains.[26] Participants intend to work together on crisis response to mitigate supply chain disruptions and to build collective, long-term resilience through a set of principles, such as transparency, diversification, security and sustainability.

International co-operation also took place in existing international fora, such as the G7. In 2022, the resilience of supply chains was identified as a key priority by the German presidency and the next year, under the Japanese presidency, G7 leaders released a Statement on Economic Resilience and Economic Security.[27] In the G20 as well, the topic featured in the work of the Italian presidency (with the previously mentioned Summit on Global Supply Chain Resilience organised in the margin of the G20 Summit in Rome). In 2023, under the Indian presidency, a G20 Generic Framework for Mapping GVCs was adopted.[28]

Finally, the Indo-Pacific Economic Framework for Prosperity (IPEF) Supply Chain Agreement (signed on 14 November 2023) presents an innovative approach to enhancing supply chain resilience on a regional

[22] See https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en.

[23] See https://www.gov.uk/government/publications/uk-australia-supply-chain-resilience-initiative/uk-australia-supply-chain-resilience-initiative-introduction-module.

[24] See https://www.dfat.gov.au/trade/for-australian-business/boosting-supply-chain-resilience.

[25] Australia, Canada, Democratic Republic of Congo, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Netherlands, Singapore, Spain, and the United Kingdom.

[26] The three additional countries are Brazil, Costa Rica? and France.

[27] See https://www.mofa.go.jp/files/100506843.pdf.

[28] See https://g7g20-documents.org/fileadmin/G7G20_documents/2023/G20/India/Sherpa-Track/Trade%20and%20Investment%20Ministers/2%20Ministers%27%20Annex/G20_Trade%20and%20Investment%20Ministers%20Meeting_AnnexA_25082023.pdf.

basis.[29] Although not binding in terms of trade commitments, the agreement sets shared expectations for partners to: (i) identify and monitor supply chains for critical sectors and key goods; (ii) improve coordination and response during crises; (iii) strengthen supply chain logistics; (iv) enhance the role of workers and boost workforce development; and (v) identify opportunities for technical assistance and capacity building. The agreement foresees the creation of an IPEF Supply Chain Council in charge of overseeing the development of action plans for specific critical sectors to help companies address bottlenecks in supply chains. Moreover, a Crisis Response Network will be established to provide an emergency communications channel for IPEF partners during supply chain disruptions. This new approach relies on the commitment and collaborative efforts of member countries to be operationalised.

5.3. Sector-specific measures and initiatives

As highlighted in the previous section, supply chain initiatives generally focus on specific sectors identified as critical or strategic. Specific measures in three of these sectors are described below.

5.3.1. Medical supply chains

As COVID-19 was a health crisis that highlighted that the provision of many essential medical goods, such as face masks, was not guaranteed in the context of a pandemic, many countries have introduced new measures and initiatives to promote health resilience, with a focus on supply chains.

As illustrated in Table 2 with policies implemented by selected OECD countries, resilience strategies in the aftermath of COVID-19 were also a combination of increased monitoring, coordination, diversification and shift to local production (OECD, 2023[113]; OECD, 2024[114]). Task forces involving health authorities and other stakeholders were put in place to address supply and logistics issues. Improved transparency and monitoring of supply chains and stocks are other measures put in place in a number of countries to deal with disruptions. Several countries also reported initiatives to develop domestic production, while diversification of supply was also promoted through changes in regulation aimed at facilitating the entry of products from alternative suppliers.

However, it is important to highlight that shortages of medicines existed before COVID-19 and are still an issue after the pandemic (Chapman, Dedet and Lopert, 2022[115]). Root causes of shortages are found in manufacturing and quality issues (e.g. contaminations leading to the removal from the market of large quantities of products while stopping production for affected suppliers), pricing mechanisms (e.g. low prices for some off-patented medicines reducing the number of suppliers and encouraging the offshoring of production) and inadequate procurement and distribution systems. Addressing these root causes is an objective of health authorities in addition to strengthening resilience for severe health crises (OECD, 2024[114]).

A resilience strategy specific to medical supply chains is the use of compulsory stockpiling systems. Switzerland and Canada have such systems with rolling stockpiles that are held and managed by manufacturers (OECD, 2023[113]). In July 2023, Australia introduced a new minimum stockholding requirement for a set of lower price medicines subject to shortages. Manufacturers are required to hold either four or six months of stocks in the country (as Australia is geographically far from its main suppliers). To compensate firms for the extra costs associated with compulsory stockpiling, the government increased prices for the medicines subject to the new requirements and established floor prices to protect them from future price reductions.[30]

In addition to Japan and the United States, other countries have put in place or are considering reshoring strategies for the resilience of medical supply chains. For example, France launched in 2022 a large-scale investment project ‘France 2030’ that includes as an objective the reshoring of production of 50 key

[29] The IPEF includes Australia, Brunei, Fiji, India, Indonesia, Japan, Korea, Malaysia, New Zealand, the Philippines, Singapore, Thailand and Viet Nam.

[30] See https://www.pbs.gov.au/info/industry/pricing/medicines-supply-security-guarantee

medicines. Eight new projects have been identified for the production of antibiotics, anaesthetics, painkillers and cancer drugs with a EUR 160 million support.[31]

Table 2. Policies implemented to avert supply chain disruptions for medical products reported by OECD countries

Country	Changes in regulations	Multi-stakeholder approach	Monitoring and co-ordination	Local production
Belgium	-	Creation of a taskforce of authorities and stakeholders to guide appropriate approaches	Stock monitoring system combined with epidemiology forecasting	-
Canada	Introduction of interim orders for expedited authorisation	Creation of a logistics advisory committee, composed of all provinces and federal government leads	-	Made in Canada initiatives for new manufacturers
Czechia	Use of national-level derogations for entry to the market	-	Internet platforms and other tools to co-ordinate delivery	-
Israel	-	-	-	Development of local production chains
Italy	Issuing of import determinations Simplification of regulations, such as simplification of oxygen management procedures	Creation of a community of experts and several crisis committees to supervise and intervene as required	Monitoring, co-ordination and guarantee of supply to institutions using real-time information	In case of shortages, providing technological transfer to the Military Pharmaceutical Chemical Plant in Florence for manufacture1
Switzerland	Introduction of a compulsory stockpiling system	Creation of a taskforce by the Federal Office of Public Health cooperating with hospitals and the private sector to ensure adequate supply of essential medicines	Stock monitoring system for medicines that were essential in the fight against the pandemic	-

Note: Based on answers from OECD Resilience of Health Systems Questionnaire 2022.
Source: OECD (2023[113]).

Measures specific to the health sector also include preparedness and response to health emergencies. Such initiatives are more focused on the assessment of health risks and epidemiological surveillance but now include supply chain considerations, such as working with the industry to identify potential vulnerabilities in supply chains or to ramp up production in case of an emergency. For example, in the European Union, the Health Emergency Preparedness and Response Authority (DG-HERA) was established in 2021 to ensure the availability of medical countermeasures in the event of future health crises. HERA works on the preparation of critical lists of medicines and medical devices to respond to crises as well as EU-wide stockpiles (OECD, 2024[114]). In addition, DG-HERA set up in January 2024 a Critical Medicines Alliance bringing together governments, regulators, businesses and the civil society to address and avoid shortages of critical medicines.[32] This initiative can be seen as close to the concept of 'preparedness conference' further described in section 6.4 below.

[31] See https://www.gouvernement.fr/france-2030-accelerer-la-relocalisation-de-la-production-de-medicaments-essentiels-sur-le-territoire

[32] See https://health.ec.europa.eu/health-emergency-preparedness-and-response-hera/overview/critical-medicines-alliance_en

Finally, there are also international co-operation initiatives on resilience that are specific to the health sector. For example, Canada, Mexico and the United States convened in 2021 a Public Health Supply Chain Dialogue under the North American Plan for Pandemic and Animal Influenza (NAPAPI) Health Security Working Group. At the WTO, there was also a Trade and Health Initiative presented by Canada and the Ottawa Group[33] to the WTO General Council in December 2020 (WT/GC/223). One objective of the initiative was to strengthen global supply chains and facilitate the flow of essential medical goods during the pandemic. Finally, a pandemic agreement is also negotiated by WHO countries to improve prevention, preparedness and response to future pandemics at a global level.[34]

5.3.2. Critical raw materials for the green transition

Another area that was subject to renewed policy action in the last two years is the provision of raw materials for the green transition. Several reports alerted on the risks of concentration of supply and structural shortages for products such as electric vehicles batteries, solar panels or wind turbines (IEA, 2022[116]; OECD, 2023[117]; Kowalski and Legendre, 2023[118]).

Several countries have put in place critical minerals strategies to deal with the issue, including Australia, Canada, Japan, the United Kingdom and the United States, as well as the European Union (Calvino, 2022[119]). These policies generally include four types of measures: (i) the promotion of domestic production (when feasible) and diversification of supply; (ii) government support to promote R&D and develop substitutes; (iii) incentives and regulatory changes to increase the recyclability of critical minerals, and (iv) international co-operation and the pursuit of special deals with key suppliers.

In the European Union, the European Raw Materials Alliance (ERMA) was launched in October 2020 to diversify the supply of raw materials and increase resilience. The approach is to rely on an industrial alliance to create an ecosystem in the European Union where raw materials industry capabilities can be developed, innovation and investment can take place to ensure more reliable and secure access while promoting sustainability and the circular economy. Further measures were adopted as part of the Critical Raw Materials Act (CRMA) in 2024, including some non-binding targets to produce key strategic raw materials within the European Union and new obligations for firms to ensure resilience.

In the United States, the Inflation Reduction Act of 2022 introduced several tax incentives for clean energy supply chains while also including provisions to increase the domestic supply of critical minerals needed in these supply chains. As previously mentioned, there is a broader effort to foster investment in clean energy as part of the Bipartisan Infrastructure Law, in particular with the Advanced Energy Manufacturing & Recycling Grant Program of the Department of Energy.[35]

International co-operation is also a tool used to diversify supply and promote resilience in the context of raw materials. For example, between 2021 and 2024, the European Union has established strategic partnerships on raw materials with 14 countries.[36] Such agreements aim at developing joint projects, cooperating on research and innovation, strengthening capacities and facilitating trade and investment.

Another international initiative is the Minerals Security Partnership (MSP) where 13 countries[37] and the European Union collaborate to ensure security of supply while promoting sustainability and adhering to high ESG standards.[38] More specific to clean energy supply chains, G7 Climate, Energy and Environment Ministers adopted in 2023 under the Japanese presidency a Five-Point Plan for Critical Minerals Security.

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[33] Australia, Brazil, Canada, Chile, European Union, Japan, Kenya, Korea, Mexico, New Zealand, Norway, Singapore, Switzerland ?and the United Kingdom.

[34] See https://www.who.int/news/item/28-03-2024-who-member-states-agree-to-resume-negotiations-aimed-at-finalizing-the-world-s-first-pandemic-agreement.

[35] See https://www.energy.gov/mesc/advanced-energy-manufacturing-and-recycling-grants.

[36] As of July 2024, https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/raw-materials-diplomacy_en.

[37] Australia, Canada, Finland, France, Germany, India, Italy, Japan, Korea, Norway, Sweden, the United Kingdom, and the United States.

[38] See https://www.state.gov/minerals-security-partnership/.

The plan includes actions to improve forecasting of long-term supply and demand, to develop resources in a responsible manner, to recycle more and share capabilities, to promote innovations and to prepare for supply disruptions.[39]

5.3.3. Semiconductors

The semiconductor industry has experienced recurrent shortages in 2020-2023 with root causes not limited to the impact of the COVID-19 pandemic and the war in Ukraine (Mohammad, Elomri and Kerbache, 2022[120]). The global supply chain has evolved with major private investment in multiple geographies as well as new risk mitigation strategies implemented by firms (Varadarajan et al., 2024[121]). This shift was supported by several public sector policies.

Resilience strategies focused on the promotion of domestic manufacturing and diversification of supply. In the United States, the CHIPS and Science Act provided USD 52.7 billion for the semiconductor industry, including USD 39 billion in manufacturing incentives. Similarly, the EU Chips Act, enacted in 2023, set as a goal to increase the share of the EU in world semiconductor production from 10% to 20%, mobilising EUR 43 billion in public and private funds through different funding mechanisms. In Japan, a USD 4 billion fund administered by METI was also set up to support additional production capacity in Japan.[40] Tax incentives and support programmes were also put in place in Korea, for example as part of the 2021 K-Belt Semiconductor Strategy (Kim, Yoo and Kim, 2023[122]). These support programmes are generally not limited to subsidies for production but also for R&D, as well the promotion of partnerships across firms in different countries. In the case of the EU, the package also includes a coordination mechanism between the Commission and Member States, as well as a monitoring mechanism to prevent and respond to future crises.[41]

As in other sectors, resilience strategies also explored how international co-operation or engagement with specific partners can lead to more resilience. For example, the United States and the European Union established in 2023 an early warning system for semiconductor supply chain disruptions under the US-EU Trade and Technology Council.[42] Discussions between the United States and the European Union also cover the use of subsidies and the exchange of information on their respective support schemes in order to avoid a subsidy race.

5.4. Assessing recent policy changes applying principles of resilience management

We consider here the strategic implications of the recently-enacted policies and network redesigns in light of the literature reviewed above. Applying the principles of resilience strategy presented in the previous sections, it is helpful to group recent government initiatives into two categories: the first support the system-level performance of the supply chain by reducing avoidable waste and encouraging alignment between decision-makers. These include measures which reduce logistics friction (e.g. expedited authorisations at border controls, simplification of procedures), share information and system intelligence, or coordinate decision-making with a multi-stakeholder approach (e.g. public-private taskforces and expert crisis committees).

The second category of government initiatives consists of one-off interventions that generally target the domestic segments of supply chains. These include mandatory stockpiling requirements, subsidies for domestic production, and local content regulations. In these cases, the supply chain is not managed as a system, in which the government is one of multiple, interdependent decision-makers. It is too early to assess the impact of these initiatives, but the previous analysis and literature review suggests that such measures can potentially distort operative demand- and capacity-planning at the firm level if they are not co-ordinated with the private sector and internationally.

[39] See https://www.meti.go.jp/information/g7hirosima/energy/pdf/Annex005.pdf.

[40] See https://www.meti.go.jp/english/policy/external_economy/investment/pdf/0324_001e.pdf.

[41] See https://digital-strategy.ec.europa.eu/en/policies/european-chips-act.

[42] See https://www.whitehouse.gov/briefing-room/statements-releases/2023/05/31/u-s-eu-joint-statement-of-the-trade-and-technology-council-2/.

For example, mandatory stockpiles of finished products repeated in multiple countries could create additional volatility in demand and limit the ability of firms to shift products where they are needed or to implement the principle of 'postponement' (i.e. creating more flexible forms of inventories for key components that are needed for a variety of final products). Forcing the location of production to a single country also reduces the solution space for configuring the physical distribution network, while minimising the real options for optimal design. Domestic production has not been proven to eliminate risks, or even ensure economic viability over the long term.

Finally, governments who take the non-systemic approach will need to repeatedly approve budgets for support and subsidies over multiple years, together with extensive R&D and training programs, or else risk white elephant projects, domestic labour shortages and innovation gaps. The following section therefore puts the emphasis on the practical alternatives to this category of government measures. It considers strategies that expand the solution space and promote alignment in the interdependent GVC system. Some of these strategies are already reflected in the measures adopted by countries that were described in this section.

6. The role of governments in supply chain resilience

Government responses to crises have often been viewed critically by scholars (Sheffi, 2008[37]) who point out that policy interventions can complicate firm-level supply chain responsiveness and constitutes its own category of risk (Darby et al., 2020[123]) or can trigger unpredictable adaptations in the system (Sodhi and Choi, 2022[124]). Experts therefore generally recommend caution and moderation while highlighting a number of measures that can positively impact supply chain resilience.

These begin with a clear delineation of roles and responsibilities. The recent call for stress-tests of supply chains (Simchi-Levi and Simchi-Levi, 2020[125]) invites comparison with failing banks during the financial crisis of 2008. In response to that global disruption, governments enacted regulation to ensure adequate capitalisation of the banks (2009 Dodd–Frank Wall Street Reform and Consumer Protection Act, Basel regulatory frameworks). These are logical interventions because the taxpayer is ultimately liable in case of bank failure. Their representatives should ensure the best possible degree of monitoring and prevention. However, risk should not be collectivised when reward is privatised. In the case of supply chains, the costs incurred by interventions in supply chain network design (factory location), or operative assets ("recapitalising" with inventory levels, imposing redundant capacity), are borne by private shareholders and punished by markets (Hendricks and Singhal, 2003[126]; Hendricks and Singhal, 2005[127]).

All policy should be based on evidence and analysis. Regulators who are aware that complexity creates obstacles to accurate, complete and timely datasets, will be better prepared to co-design appropriate reporting and controls together with commercial managers who can contribute their tacit knowledge of how to balance competing supply chain objectives. This may initially increase the cost of governance, but will also improve its effectiveness over time.

Policy makers have an important role to play as facilitators, enablers, and providers of infrastructure and emergency resources, in co-ordination with the private sector (Quarshie and Leuschner, 2020[128]). Four interventions with potentially high impact are described in this section: a reduction of logistics friction, the promotion of regulatory co-operation and flexibility, the creation of an industrial commons and preparedness conferences of public-private stakeholders. While these resilience strategies can be implemented at the country level, they are even more efficient if coordinated internationally.

6.1. Reducing logistics friction

The supply chain management literature emphasises that if a country wants to compete in a world of supply chains, it should reduce the costs of its flows (Lee, 2010[129]; Hausman, Lee and Subramanian, 2013[130]; Cohen and Lee, 2020[19]). Early work on the impact of logistics performance on trade by Hausman et al. (2013[130]) illustrated how individual nations differ widely in their ability to process the flow of information and goods (Table 3). Logistics friction has a direct impact on the productivity of firms and GDP (Hausman,

Lee and Subramanian, 2013[130]). Not least, as humanitarian organisations will confirm, in an emergency, expedited import and export of goods can have a life-saving effect.

Table 3. Comparison of logistics performance across a sample of countries

Country	Cycle time to export a 40-foot container of cotton textiles	Cost of importing a 20-foot container, including all trade-related costs & inbound transport
Kazakhstan	81 days	
Mauritania	39 days	
Kyrgyz Republic		USD 3,000
Germany		USD 937
Sweden	8 days	USD 700

Source: Hausman et al. (2013[130]).

The advantages of reducing the cost of moving goods is self-explanatory. It is worth emphasising, however, that each day saved in an import process will eliminate at least one day of inventory kept elsewhere in the chain to meet demand. OECD work on Trade Facilitation Indicators has documented the costs associated with administrative efficiencies at the border (Moïsé, Orliac and Minor, 2011[131]; OECD, 2018[132]; OECD, 2020[133]).

As highlighted in Section 5.2.2, the pandemic has accelerated efforts to streamline trade-related documentation requirements and to implement digital tools. However, more can be done to fully implement the WTO Trade Facilitation Agreement and to draw lessons from the COVID-19 crisis to reinforce crisis preparedness mechanisms (Sorescu and Bollig, 2022[111]). More ambitious trade facilitation commitments can also be found in regional initiatives or new types of agreements, such as, inter alia, the Framework Agreement on Facilitation of Cross-Border Paperless Trade in Asia and the Pacific, the AEAN Single Window Agreement or the Digital Economy Partnership Agreement signed by Chile, New Zealand and Singapore (UNESCAP, 2021[109]). This latter agreement illustrates the link between trade facilitation measures and data-related provisions that can support the development of data analytics and cross-border exchange of logistics information.

Moreover, despite successive rounds of trade liberalisation at the multilateral and regional level, there are still tariffs and non-tariff measures that create frictions for the exchange of the most essential goods, such as medicines (OECD, 2023[113]), suggesting an agenda for a review of trade barriers that reduce the resilience of critical supply chains.

Trade-related paperwork and tariffs are avoidable costs that compound when intermediary goods cross multiple borders in a GSC. Since intermediates can cross borders several times, these trade frictions magnify costs exponentially: “in a highly fragmented production process (n=10), …a 5% tariff leads to a 25% increase in the price of the final good – while a 20% tariff would increase the same price by 160%” (OECD, 2013[16]). Reversing this logic reveals the power of economic integration, since “vertical specialization can serve as a propagation mechanism magnifying tariff reductions into large increases in trade” (Yi, 2003[11]).

6.2. Promoting regulatory co-operation and flexibility

Section 4 has described how flexibility (combined with redundancy) can lead to superior risk management strategies. While at the firm-level, establishing a *culture of responsiveness* plays an important role in promoting flexibility, the capacity of firms to adjust to disruptions also depends on the regulatory environment in which they operate. Trade facilitation is one type of regulatory co-operation that aims at simplifying and harmonising export and import processes in order to reduce trade frictions. But regulatory co-operation can go beyond trade procedures and apply to a broader category of rules that have an impact on the capacity of firms to quickly reorganise their supply chains when facing disruptions.

These rules cover a variety of technical regulations, standards, conformity assessments and market authorisations that are sector-specific or product-specific. They also generate frictions (i.e. additional costs and time) when firms reorganise their supply chains. For example, a stock-out can be observed in a given

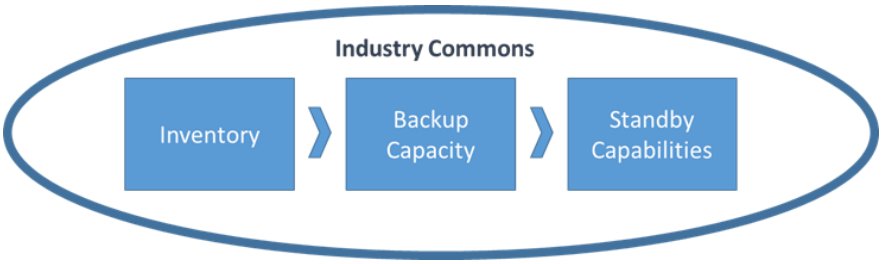
market while firms continue to produce the good for other markets. Due to differences in regulations (for example, packaging and labelling requirements), it might not be possible to serve the market where shortages are observed with the products destined to other markets. Or it would involve additional costs and time (repackaging or even changing some of the characteristics of the product).

Regulatory flexibility refers to the ability to temporarily lift certain requirements or accelerate authorisations or license procedures for essential products or services without reducing safety or quality requirements (OECD, 2024[134]). Several examples of regulatory flexibility have been highlighted during COVID-19. For example, national health authorities (or the European Medicines Agency in the context of the European Union) introduced a series of regulatory flexibilities to accelerate the development of COVID-19 vaccines and therapeutics in relation to clinical trials, market authorisations or labelling (Klein et al., 2022[135]; OECD, 2024[114]). While the objective was not to lower health standards but rather to accelerate procedures, regulatory flexibility during a crisis can be seen as a re-evaluation of how important the implementation of specific rules or standards is as compared to the emergency of the situation and a more important objective (such as saving the life of people during a health emergency). As such, regulatory flexibilities are generally temporary and subject to a post-crisis assessment, even if their successful implementation can lead to more permanent regulatory reforms. Regulatory flexibility can be even more efficient to deal with severe crises when flexibilities are discussed and agreed in advance (possibly as part of preparedness conferences, see section 6.4 below).

6.3. Creating an industrial commons

In response to the poor performance of government stockpiles during the Covid-19 pandemic, Sodhi and Tang (2021[56]) recommend an alternative investment which might achieve better outcomes: the creation of an industrial commons. The commons strategy for resilience would convene stakeholders from the government and private sector to establish three integrated forms of emergency preparedness: inventory, backup production capacity and standby capabilities (Figure 6).

Figure 6. The three components of an industrial commons



Source: Adapted from Sodhi and Tang (2021[56]).

Implemented effectively, this portfolio of measures would institutionalise the superior performance to be expected from a combination of redundancy and flexibility (Kunz, Reiner and Gold, 2014[76]; Sheffi, 2015[17]). Taking ventilators as a current example, the inventory stockpile would plan only for the peak of an emergency demand, which is assumed to strike in one region of the country at a time, therefore stockpiling a smaller amount than the tenfold D4 level (bringing down the cost-service trade-off curve). To meet unforeseen demand spikes flexibly, the type of items in storage must be multi-purpose, to be applicable to a number of situations, and easy to use, to minimise or eliminate user training. Once the disaster operations have consumed the emergency stockpile, backup capacity in the form of manufacturing partners contracted just for these events, is activated. The excess demand for ventilators is then either filled by producing more, or shifting existing stock from areas of less need, to those with flare-ups of contagion. Finally, should the emergency demand exceed what the combined stockpile and capacity can fulfil, or unanticipated needs arise, a consortia of experts comes into play to rapidly respond and expand capacity. This capability base will include production facilities in related industries, researchers, and technology experts.

Table 4 provides an overview of the resources to be deployed in sequence respectively at the level of individual company, sector, and national government. The supporting infrastructure and policies which must be in place to enable the progressive activation of the commons is indicated.

Table 4. Resources to be deployed for the creation of an industrial commons

Resources to be deployed	Level of Deployment		
	Within company at corporate level	With other companies at sector level	With government at national level
Inventory	Post-ponement of final goods	Standardised components/APIs	National stockpiles
Capacity	Flexible capacity for volume and variety	Joint venture 3-D printing	University and govternment labs
Capability	R&D Flexible workforce	Joint R&D	Government funding for R&D
S/C infrastructure, policies, and procedures	*Allocation* *Regular preparation against major disasters*	*Shared warehouses and transportation*	*Transportation network* *Standards for inter-operability*

Source: Adapted from Sodhi (2024).

According to Sodhi, an industrial commons effectively addresses supply chain disruptions in which demand greatly exceeds supply, and this change is both sudden and unexpected. To meet that unplanned change in consumption, supply must be increased to avert negative consequences like loss of life or economic shocks. If the increase in supply is temporary, i.e. required only for a period of weeks or months, and the extent and impact or unmet demand varies by region, the industrial commons will be the most efficient and effective form or response, compared to *ad hoc* interventions or isolated government stockpiles.

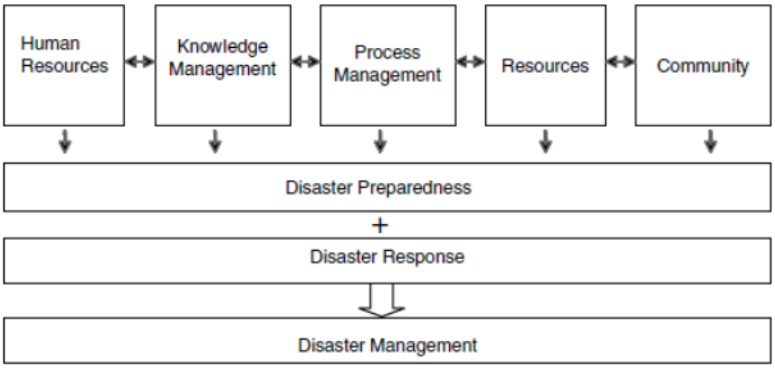
In order to be feasible, investments must be made to assemble the members, mechanisms, and protocols (playbook), of this commons in advance, then continuously maintain and rehearse them to assure readiness. Because emergency and disaster preparedness can only be achieved at a systemic level, it is the industry commons which must be "stress-tested" and not individual firms or supply chains.

6.4. Preparedness conference of public-private stakeholders

Azadegan and Dooley (2021[136]) declare that the "challenge of the new 'risk landscape' can only be faced by broadening and deepening the involvement of more of the stakeholders in the value chain." The disaster management literature acknowledges lack of coordination between responding entities as one of the main causes of slow, wasteful, and ineffective response. The necessary integration of independent decision-making can begin by convening these stakeholders in a preparedness conference. Sodhi and Tang (2021[56]) also emphasise that coordination, alignment of interests and pooling of resources will be prerequisite to the success of an industrial commons. The potentially combative relationship between public policy makers and commercial managers can be mitigated by co-designing the consortia's mechanisms, operative processes, and protocols, in a collaborative working space. The conference can accelerate targeted results by substituting sequential decision-making with immediate policy coordination. Public-private stakeholders would review the evidence to establish a shared understanding of their system, collaboratively work out the details of the system, and draft a feasible schedule of implementation, to which they officially commit.

The literature provides practical support for the detailed agenda of the conference. In a seminal paper on supply chain management in disaster response, Van Wassenhove (2006[61]) identifies the five components of emergency preparedness, which will eventually enable the subsequent response and professional management of the disaster lifecycle (Figure 7).

Figure 7. The five components of preparedness



Source: Van Wassenhove (2006[61]).

The expected outcomes of the preparedness conference include the detailed design of each of these components. Playbook templates are available for reference in Kunz et al. (2014[76]) and Sodhi and Tang (2021[55]). A draft agenda for the event can be formulated as a series of questions to be answered by the cross-functional participants, together with the deliverables of the conference (Table 5). Each question roughly corresponds to one of the five components of preparedness listed in Figure 7: human resources, knowledge management, process management, resources and community. The workshop should not focus its design decisions on individual assets (like stockpiles or information technology), but plan how these are best deployed to achieve final outcomes (measured for example by time-to-response or time-to-recovery). During the Covid-19 crisis, huge efforts were poured into developing the vaccine technology and securing national supplies, leaving the design of high-speed, cost-effective distribution as a local afterthought. One of the learnings from the ensuing underperformance is that it was vaccinations, not vaccines, which save lives (Thakur-Weigold et al., 2022[74]). In other words, when government facilitates the preparedness conference, it should integrate the contributions (including assets), of multiple stakeholders to ensure the desired performance targets.

Preparedness can be organised by individual countries or by regions which plan to respond to emergencies together. For example, in the case of smaller countries, it may be advantageous to pool resources and co-ordinate preparedness measures together with neighbours to achieve its industrial commons. The rehearsal of the emergency playbooks together with the measures of time-to-response and time-to-recover should be reviewed during each conference. To identify performance gaps and address any change in administrative or other boundary conditions, they should be convened at regular intervals to ensure that preparedness is maintained. More details on how to operationalise preparedness conferences is provided in Annex A.

Table 5. Potential draft agenda of a preparedness conference

Agenda action item	Question to be answered by the conference design team	Deliverable for Emergency Preparedness
1	Who has to take action?	• RACI defined (i.e. responsible, accountable, consulted and informed) • Governance and control mechanisms
2	Do all the necessary actors know what to do when the emergency strikes?	• Playbook • After-action reviews • Knowledge-sharing & management
3	Who will pay for what? What other resources will be donated in kind?	• Budget plan • Human resource plan • Information technology plan
4	Since this is not how present operations are organised, what is the plan to institutionalise the culture of emergency preparedness?	• Change management plan, signed off by leadership teams, • Communication plan for the public and non-participant stakeholders
5	How will the participant stakeholders ensure the sustainability of emergency preparedness during "quiet" periods of business-as-usual?	• Schedule of reviews to update playbook to new boundary conditions • Rehearsals and stress tests of industrial commons • Schedule of reviews of budget plan

Note: To remain focused on intended outcomes, the cross-functional design teams are asked to answer a series of questions, in order to produce the deliverables which will be required to take appropriate action.

7. Concluding remarks

This report has provided an overview of research on supply chain resilience and potential implications for policymaking. It has also described the different actions taken by firms and governments to strengthen the resilience of supply chains and highlighted four types of policies that have a high impact to mitigate risks and ensure preparedness for future crises.

While pointing out that not every disruption necessitates government intervention, the report underscores the crucial role of governments as facilitators and integrators, providing infrastructure and emergency resources in collaboration with the private sector. Government intervention should focus on significant risks or disruptions that exceed the capabilities of firms' routine risk management practices.

The report stresses the importance of strategic segmentation in resilience strategies, distinguishing between routine uncertainties and extreme 'black swan' events. Applying routine risk management tools, such as stockpiles, to major disruptions can lead to waste, environmental burden and underperformance. Instead, tailored strategies should address these distinct risk categories to ensure efficiency and effectiveness.

A critical aspect of policymaking is the necessity for evidence-based decisions. Policy makers must understand the complex adaptive systems that constitute global supply chains. Policies should aim to improve the system performance, considering the inherent trade-offs such as material availability versus costs. This requires comprehensive, accurate, and timely data to avoid decisions based on outdated or partial information.

Governments have launched a number of regulatory initiatives to address supply chain resilience and assure the supply of critical materials. The measures can be grouped into two categories: the first group generally reduces waste and increase alignment between decision-makers. The second group consists of one-off interventions that do not generally work with the mechanisms of the complex adaptive system. Regulatory efforts should adopt proven practices like postponement, and programmes which expand, rather than contract, the solution space.

Additionally, the alignment of competing interests is paramount. Superior supply chain performance is achieved not through central control but through the alignment of stakeholder interests, calculated trade-offs and coordinated action.

Among the four high-impact policy interventions described, the concept of an industrial commons is particularly noteworthy, as it highlights the challenges of creating efficient strategies for severe crises, such as the COVID-19 pandemic. The industrial commons involves a combination of inventory, backup production capacity and standby capabilities, integrated into a systematic approach to emergency preparedness. Implementing an industrial commons requires assembling members, mechanisms, and protocols in advance and maintaining them through regular rehearsals and updates. Stress-testing the industrial commons, rather than individual firms or supply chains, ensures systemic readiness and can be done through the mechanism of preparedness conferences described in the report.

Pre-existing or recently-enacted government initiatives that regulate stockpiling, collect proprietary information on the structure or operations of GVCs, or convene expert task forces to manage national security of supply, should be integrated into the collaborative mechanisms of the industrial commons.

By adopting evidence-based policies, strategically segmenting resilience measures and fostering international co-operation, governments can significantly mitigate risks and ensure a more resilient global supply chain system. The ongoing commitments to these principles and practices will be essential in navigating future disruptions and safeguarding economic stability and public well-being.

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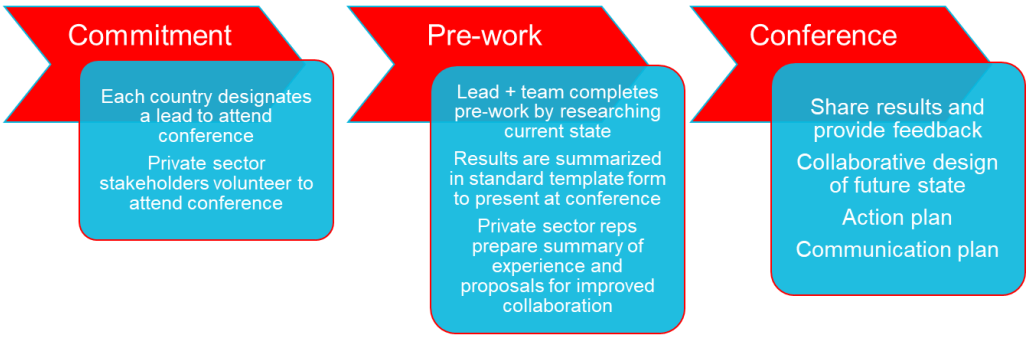
Annex A. Operationalising the preparedness conference

Section 6.4 of this report recommends a preparedness conference as a means by which the multiple stakeholders of global supply chains convene to work on creating an industrial commons for disaster preparedness. This annex provides a summary of practical steps to operationalise a preparedness conference. By the term “disaster”, we mean any highly-disruptive event which requires an emergency response at the national and international level.

The notion of a preparedness conference is based upon two fundamental insights from research and practice: the first of which confirms that superior supply chain performance is achieved through the alignment of stakeholder interests, calculated trade-offs, and coordinated action. The second insight is that, compared to an ad-hoc reaction, preparedness improves the speed and effectiveness of an emergency response. The preparedness conference would therefore assemble key public and private stakeholders to collaboratively design a country’s (or region’s) emergency response, in advance of the next disaster. The conference is conducted like a design workshop, a method proven to accelerate decision-making and alignment, and considered more effective than if the heterogeneous interest groups were to work independently in silos, to make decisions in sequence.

The initial recommendation foresees the creation of the industrial commons at national levels, and in the case of small countries, in regions of cooperating nations. Working in three subsequent phases (Figure A A.1), conference participants will design in detail how nation-level resources and processes will be deployed to achieve desired outcomes. The following describes the practical steps and managerial principles recommended during each phase of agenda-setting and work.

Figure A A.1. The three phases of the preparedness conference



Define the risks and commodities for which to prepare a commons

Evidently, each country faces any number of risk scenarios in the supply chains of essential goods, ranging from public health emergencies, to military conflicts, to supply disruptions. A preparedness conference addresses one category of risk at a time, which is agreed upon in advance. If successful, it will build capacity that can be deployed to address the next set of preparedness scenarios. In other words, the learnings and actions implemented in one preparedness conference can be re-applied to other risk categories, re-deploying the capacity developed in the first prototype supply chain.

For the selected category, each country should identify risk scenarios for which they choose to prepare first. This includes a definition of the negative consequences to be avoided (input for budgets), the spatial scope (concentrations of populations, regions), critical items which must be distributed in a crisis when markets practically fail (ventilators, vaccines, chips), manufacturers and suppliers of critical items, and secondary prerequisites (goods and services) of outcomes (medical staff, vials, electricity, isolation units, etc.).

Designate Preparedness Lead and Team

Prior to the conference, each country should designate a lead to attend the conference. Pre-work which comprises data-gathering of current state and other relevant information must be completed by individual countries under the designated lead. The results of this pre-work will be summarised in standard template forms to present at the conference.

Complete baseline study of the particulars of each country's own case

Decision-makers in each country must become knowledgeable about their own system before making interventions into complex adaptive systems like global supply chains. Prior to the conference, each country or region will need to complete a detailed review of the particulars of its own case. This pre-work should be completed by the stakeholders and the teams reporting to the decision-makers themselves. The shared knowledge base which is thereby created comprises a vital part of national capacity-building. It is therefore important that the pre-work is not delegated to outside consultants or experts, because the learnings will not be accessible when it is needed.

Reality check: if the decision-makers in a country don't have the resources to do complete its own baseline study, it must logically conclude that it doesn't have the resources at the time to create emergency preparedness, be it in the form of an industry commons or otherwise. In such cases, the human resources and leadership situation should be re-assessed and restocked prior to joining a conference.

In this baseline study, each country should compile an overview of their current state of operative preparedness. We recommend applying the Van Wassenhove Framework of emergency preparedness (Van Wassenhove, 2006[61]) to focus on key areas of operations, measure responsive potential, and identify the gaps in the existing system. For each gap, an internal action plan will have to be formulated, to be shared during the conference with other participant countries. Feedback sessions will be held during the conference especially to coordinate action-planning between public and private stakeholders, but also to enable cross-learning and identify synergies or opportunities to pool resources.

Work with Checklists to target system-level outcomes

> *One essential characteristic of modern life is that we depend on systems – on assemblages of people or technologies or both – and among our most profound difficulties is making them work.*
>
> *A. Gawande, The Checklist Manifesto (2009)*

According to (Gawande, 2009[137]), a checklist is a template for agile, decentralised decision-making. It facilitates the teamwork and alignment required to reach a desired outcome. We thereby emphasize what a checklist is *not*: it is not the codification of a standard procedure as instructions for mindless execution. Benchmarks of checklists which have been designed to respond to critical scenarios can be referenced in the fields of aviation, the WHO checklist for surgical safety, and construction. As national teams work through checklists of the emergency preparedness components (specified by the Van Wassenhove framework, see Table A A.1), they are also encouraged to codify Standard Operating Procedures for core processes. These SOPs will have to be updated on a regular basis to ensure that they reflect current boundary conditions and system details.

Table A A.1. Sample of checklists

Disaster management capabilities workstream	Checklist of tasks or deliverables
Human Resources	Staff in place to execute processes Leads for each core process or deliverable are designated Regular trainings are scheduled
Knowledge Management	Early warning system is in place Debriefs of previous responses capture lessons learned Emergency Playbook is in place Checklist libraries are in place
Process Management	Core processes have been designed & updated with lessons learned Annual rehearsals/simulations take place
Resources (financial, assets)	Budget for assets and staff is available Variable costs for last-mile distribution and maintenance are covered
Community	Reduction of logistics friction at local borders; emergency customs pre-clearances are negotiated Local populations are informed of response plans

Note: Sample of checklists recommended for the five components of the Van Wassenhove model of Disaster Preparedness. Should one or more of these components be incomplete or absent from the national plans, the performance of the disaster response will be diminished.

One of the reasons for a lack of preparedness during the recent pandemic was a focus on resources and assets only. The unwitting neglect of the remaining components of the Van Wassenhove framework, especially processes and human resources, is a common pitfall. For example, accumulating large stockpiles without designing allocation and call-off processes, inventory management systems which rotate out expiring material, or last-mile distribution will not support emergency response.

The pre-work for the conference will therefore work through checklists which focus not only on activity and assets, but on what has to be done in order to achieve outcomes. This fine distinction is best understood through examples:

> Q: How many people can be vaccinated with the stockpile system?
> (NOT: How many vaccines do we have on-hand?)
>
> Q: How long is the time to vaccination in each region of the country?
> (NOT: A response task force is in place and the regular healthcare system will take care of patients.)

How the Preparedness Conference proceeds

Section 6.4 of the report presents a high-level draft agenda and deliverables of the Preparedness Conference. Assuming that each participating country has completed its pre-work in the form of a baseline study, the following is a list of practical steps to be taken during the conference.

The conference begins by sharing the current state of each country or region:

1. List of gaps
2. Analyses of conflicts and issues
3. Grouping of most important actions to be taken
4. Feedback by private sector specialists on gaps, conflicts, and possible solutions
5. Sharing of success stories and best practices

The second half of the conference is dedicated to co-ordinating action plans:

6. Form task forces to work on priority areas
7. Private sector specialists volunteer / are invited to contribute to relevant areas or topics
8. Draft a roadmap of actions + milestones + deliverables. Specify owners of each deliverables
9. The summary report of pre-work results is distributed and stored in the knowledge management share for reference during execution of the roadmap