

# 5



## Rising Risks to Global Value Chains

Etel Solingen, Bo Meng, Ankai Xu

The expansion of global value chains (GVCs) has plateaued since the global financial crisis of 2008–2009 due to the slowdown in hyperglobalization (Chapter 1; Antràs 2020a; World Bank 2020). Old and new risks to GVCs, as well as shocks, threaten the continued viability of these chains. The risks and shocks include extreme weather events, trade and technology wars, increased protectionism, geopolitical tensions, and COVID-19. IMF (2021a) defines risk as the effect of uncertainty on objectives—and by inducing uncertainty, shocks constitute an underlying source of risks, along with limited information and an imprecise understanding of the sources and mechanisms triggering shocks, which contributes to uncertainty. Given all this, the first three sections of this chapter are taken up by an overview of the sources, mechanisms, and effects of the three main types of meta-risks: geopolitical, environmental, and those stemming from the COVID-19 pandemic.<sup>1</sup> While addressing primarily the implications of the three risks for GVCs, these sections also take note of reverse causal effects, where GVCs exacerbate those risks.<sup>2</sup> The chapter then examines the relative resilience of GVCs to shocks depending on the nature and magnitude of the shock as well as on GVC features, industry and firm topographies, availability of substitutions, degree of transactional stickiness, and type of shock (geopolitical, environmental, COVID-19). The subsequent section examines mutual interactions across all three risks and their compounded

---

<sup>1</sup> This chapter leaves out a vast literature on managerial, operational, cost, and other standard risks that are amply analyzed in the business literature. On the limited attention to the effects of trade policy on GVCs until 2018, when GVCs became a primary target of tariffs, see Grossman and Helpman (2020).

<sup>2</sup> Studies on the impact of GVCs on environmental degradation are more common than studies on the impact of geopolitical risk on GVC-related environmental and pandemic risks or studies on the effects of all three meta-risks on GVCs, this chapter's main theme.

effects. The chapter concludes with policy recommendations and a discussion on future directions in the burgeoning analysis of risks to GVCs.

## Sources, Mechanisms, and Effects of Geopolitical Risks on Global Value Chains

Geopolitical shocks have not only become a primary concern for the future of GVCs in recent years but also entail important implications for whether and how states can handle environmental and pandemic shocks. Concerns over political risk have never been absent from the typical list of potential risks to GVCs, but they have gained only nominal attention in most business-oriented analyses of risk focusing primarily on domestic sources, including potential social, economic, and political upheavals within countries.<sup>3</sup> This chapter focuses on broader systemic and interstate geopolitical risks, whose sources may lie in the domestic politics of states, but are diffused globally and entail a high potential for unleashing vicious cycles and downward spirals.<sup>4</sup> These meta-risks, triggered by trade and technology wars, export controls, boycotts, cyberattacks, and other typically unilateral uses of coercive economic statecraft, have wider and deeper second- and third-order implications for GVCs than conventional business risks.<sup>5</sup> Trade-related geopolitical meta-risks, including the trade tensions between the United States (US) and the People's Republic of China (PRC), and Brexit, were the biggest threats to global economic growth in 2019 (Lund et al. 2020), with negative implications for the subsequent management of COVID-19.

### Sources of Geopolitical Risks

Varying proclivities of states to embrace or discourage interdependence via GVCs can be traced to two contrasting domestic political-economy strategies. These are animated by disparate political incentives and yield different domestic distributional consequences. Real-world strategies never match ideal types by definition, but rather lie along a continuum. Ideal-type outward-oriented strategies emphasize economic growth via access to global markets, capital, and technology; regional cooperation and predictability; and domestic macroeconomic stability that reduces uncertainty, encourages savings, enhances foreign investment, and fosters GVC participation. These outward-oriented strategies seek to lower tariffs, behind-the-border barriers, and transaction costs, as well as foster

<sup>3</sup> A 2016 survey of 1,409 GVC professionals puts geopolitical risk 12th out of 13 risks (O'Marah 2017).

<sup>4</sup> For a more detailed analysis of geopolitical risks, see Solingen and Inomata (2021) and Solingen (2021).

<sup>5</sup> Baldwin (2020) defines economic statecraft as the use of economic means to pursue foreign policy objectives—whether noble or nefarious—and distinguishes it from other forms of statecraft, including diplomacy, military statecraft, and propaganda. This chapter focuses on economic statecraft of the nefarious type that unleashes or exacerbates geopolitical and geo-economic tensions. Meta-risks, including militarized interstate disputes, military threats, displays or use of force, and other offensive signals short of actual war, are not a focus of this chapter, but they can have crucial interactions with economic statecraft.

private entrepreneurship—and they have been at the heart of East Asia’s GVC expansion (Escaith and Inomata 2013).

These strategies underscore the pursuit of absolute mutual gains from GVCs, and they have allowed firms from East Asia, Europe, and the US to lubricate trade, maximize efficient production, and contribute to technological upgrading (Inomata and Taglioni 2019). Firms in the PRC have been able to leap over classical developmental phases via access to US brands and markets (Xing 2021a, 2021b). As technology and innovation became ever more central to growth, the opportunity costs of discarding that GVC infrastructure have arguably risen. GVCs have also connected East Asian economies more deeply than ever and in more intricate patterns that arguably helped states transcend erstwhile armed hostilities. Despite asymmetries, states focused on maximizing absolute gains from participating in GVCs that buttressed outward-oriented strategies.<sup>6</sup>

By contrast, inward-oriented, hypernationalist strategies benefit politically from rejecting, restricting, or disrupting GVC interdependence, considered anathema to self-reliance. Protectionist, populist, and techno-nationalist policies aim to substitute foreign sourcing and offshore production with domestic production and to retract GVCs from perceived adversarial suppliers of intermediate goods and services, a trend that has intensified in recent years.<sup>7</sup> Turns to inward-oriented strategies are the deeper sources underlying current trade and technology tensions. Contemporary research traces inward-looking turns in developed countries to an interrelated cluster of economic anxiety, inequality, loss of manufacturing jobs to industrializing countries, including the “China shock,” and technological change (Autor, Dorn, and Hanson 2013; Acemoglu and Restrepo 2020).<sup>8</sup> GVCs led by multinational corporations (MNCs) promoted efficiency on a global scale, but not necessarily fair income distribution within states or across GVCs (Meng, Ye, and Wei 2020). But others find the aggregate detrimental economic effects of globalization on US manufacturing labor to have been modest, although concentrated geographically and temporally (Krugman 2021a; Posen 2021). Mutz (2021) emphasizes noneconomic “sociotropic” considerations fueling populist turns, especially nationalism, self-sufficiency, and other social-psychological biases that often bear little association with economic data. Indeed, nationalism and populism have not eluded some East Asian economies that have benefitted disproportionately from globalization.

<sup>6</sup> On incentives for outward-oriented political leaders to tame conflict, see Solingen (2007) and Kastner (2007). On intricate patterns connecting East Asian economies through GVCs and their potential effects on dampening armed conflict, see Solingen and Inomata (2021).

<sup>7</sup> Techno-nationalism is a subset of mercantilist thinking that, in its extreme form, restricts most exports of technology, innovation, and scientific knowledge to maximize geopolitical advantage, technological self-reliance, and state power.

<sup>8</sup> Wang et al. (2018) argue that inputs from the PRC helped downstream US firms expand employment in nonmanufacturing sectors and boost real wages.

The rise of inward-oriented strategies has brought asymmetries in trade balances, barriers to market access, tariffs, subsidies, and industrial policy back to the fore, along with concerns over relative gains (who gains most), raw distributional considerations, and real or presumed risks to national security. Hence inward-oriented strategies emphasize risks *from*—rather than risks *to*—GVCs, especially risks associated with the diffusion of strategic technologies. As Chapter 2 notes, the dramatic expansion of trade in services and intangible assets, research and development (R&D), product design, branding, know-how, and marketing and retailing via GVCs have exacerbated distributional concerns. Most GVCs are becoming more knowledge-intensive, especially pharmaceuticals, medical devices, machinery and equipment, computers and electronics, and information technology (IT) services.

Unsurprisingly, technology wars have zeroed in on GVC decoupling and reshoring, especially in high value-added tasks, as conduits for enhancing self-reliance, preventing diffusion of frontier technologies, and protecting intellectual property (IP) and national security. Fueling this approach is a contested assumption that Thucydides Traps are inevitable in cycles of great power transitions, inducing high mistrust, uncertainty, and war.<sup>9</sup> According to this view, technological diffusion arguably endows adversaries with greater economic power. Furthermore, economic and technological power are fungible and can be transformed into military and other forms of power. This reasoning thus underscores an assumption that economic exchange entails negative security externalities (Gowa and Mansfield 1993). Preventing those externalities requires the identification of “choke points” or foundational, cutting-edge technologies with broad applicability and thwarting their diffusion throughout the industrial and military complexes of adversaries, as well as creating dependencies by monopolizing production. While generating heightened geopolitical risk, these zero-sum strategies also help rally hypernationalist support at home.

Distributional analysis of complex GVCs, with intermediates crossing borders at least twice, is intricate. Nuances in relative gains, especially in knowledge-intensive sectors, can lead to competing interpretations of the benefits and risks in GVC interdependence. GVCs embed both features of competition and collaboration, and of absolute and relative gains. Different balances of gains and costs can be wielded within the malleable arena of domestic politics. GVCs can thus not only become casualties of geopolitical risk but also help fuel it.

### Causal Mechanisms in Geopolitical Risk

With relative gains as the animating principle underlying economic exchange, inward-oriented strategies generate geopolitical risks that affect GVCs through supply, demand, or both through the following mechanisms:

<sup>9</sup> Allison (2017) adapted the original insight from Thucydides to US-PRC relations, but both the putative “trap” as a typical empirical pattern and even its applicability to the Peloponnesian War is contested (Waldron 2017; Nye 2017). On the conceptual vagueness and empirical inaccuracy of “balance of power” categories in international relations scholarship, see Vasquez (1999).

- (i) **Magnifying generalized uncertainty.** Geopolitical risk does this over the short and longer time horizons of GVCs. The trade policy uncertainty index of Ahir, Bloom, and Furceri (2019, 2021), which has been fairly stable since 2005, began rising as the US-PRC trade war intensified in 2018. It declined slightly with the December 2018 agreement halting the escalation of tariffs and spiked again in 2019 following expanded US tariffs, as the index reached tenfold previously recorded highs. The jump—felt most strongly in the Americas and Asia—foreshadowed declines in gross domestic product (GDP) growth. The US-PRC trade tensions may have added 20% to global uncertainty since 2016 at one point, according to the index. Constantinescu, Mattoo, and Michele (2020) find that the rising economic policy uncertainty since mid-2018 was associated with a 1% decline in world trade growth, with similar effects on GVC trade, suggesting the effects could potentially be even more negative in the longer term due to withheld investment. Countries with high levels of GVC engagement have been adversely affected by the US-PRC trade tensions, but some third parties have benefitted via trade diversion. Firm-level surveys confirm rising uncertainty induced by the trade and technology war, with 86% of US-China Business Council members reporting that bilateral trade tensions had hurt their PRC business by mid-2020 (US-China Business Council 2020). One survey found that only 9% of surveyed firms relocated manufacturing or sourcing out of the PRC in 2019 (AmCham China 2020). The three most important justifications for relocating—rising significantly from 2018—were an uncertain policy environment, the PRC's labor costs, and US tariffs. Another survey found that US-PRC trade tensions—manifested in retaliatory tariffs, uncertainty of supply on all ends, and shifts to alternative suppliers—affected 81% of US firms operating in the PRC by 2019, up from 73% in 2018 (US-China Business Council 2019). About 30% of respondents in this survey—twice as high as in 2018—reported slowed, delayed, or canceled investment in the US or the PRC due to increased costs and uncertainty from geopolitical tensions. Uncertainty over the US-PRC economic relationship was the primary reason for decreased investment by 27% of firms in technology and R&D-intensive industries and for 33% in services in the 2021 China Business Climate Survey (AmCham China 2021a).
- (ii) **Reducing trust in the integrity of global value chains.** Preserving and expanding GVCs hinge on data-based technology—big data, artificial intelligence, Internet of Things, cloud computing—that requires globalizing markets that reward large-scale R&D investments. This entails mutual trust to offset the fact that big data unsurprisingly triggers concerns over national security and personal privacy. Yet beyond-production GVC activities related to these technologies are precisely those most likely to be affected adversely by rising mistrust aggravated by geopolitical risk. Inward-looking turns have led to plummeting trust between the US and the PRC and also in regional and global contexts. This weakens trust in the viability of complex GVCs, especially those pivoted on data technology. Rising nationalism and unilateralism have undermined confidence in international institutions whose primary mission is to build trust. They do so through various mechanisms, such

as helping states overcome collective-action problems, reducing uncertainty, lowering transaction costs, enhancing information about preferences and behavior, monitoring compliance, detecting state defections from their commitments, increasing opportunities for cooperation, diminishing the costs of retaliation, facilitating linkages across issue areas, and offering focal points or salient solutions (North 1981; Keohane 1984; Williamson 1985). These institutions underpinned freer economic exchange and the expansion of GVCs through outward-oriented policies in earlier decades. Rising unilateralism has also undermined macro regional arrangements, but two recent ones—the Comprehensive and Progressive Agreement for Trans-Pacific Partnership and the Regional Comprehensive Economic Partnership—may help strengthen trust and expand GVCs among partners.

- (iii) **Diluting the expected benefits from participation in global value chains relative to their political or economic costs.** This happens because the political costs of participation in GVCs rise in inward-looking environments that emphasize risks from GVCs while sidelining the negative externalities from decoupling. The high complexity of GVCs—compounded by the enhanced role of services, data, and IP intangibles—renders popular scrutiny over whose interests are served by GVCs, and at whose expense, harder to scrutinize. GVCs become legitimate foci of attention and suspicion, as well as useful targets of populist manipulation and misinformation, further mollifying nationalist constituencies and increasing support for putative gains from self-reliance. Retracting such policies once they have been unleashed becomes politically more costly, turning the politics of GVCs into a double-edged sword. On the one hand, as Chapter 2 notes, gains associated with GVCs, especially for MNCs, obscure their actual contribution to national income, because conventional statistics do not include the transfer of intangibles via GVCs. On the other hand, GVC decoupling can make middle-income traps stickier and harder to avoid for industrializing countries, thereby hindering the promised road to prosperity.<sup>10</sup> While private firms embedded in GVCs have been the engines of employment creation, decoupling hinders their global competitiveness, destabilizes stable and predictable production platforms, and severely reduces their ability to climb the value-added ladder in manufacturing and services.<sup>11</sup>
- (iv) **Inducing vertical contagion.** Geopolitical risk does this through spiraling retaliatory responses to export controls, boycotts, sanctions, cyberattacks, and other forms of coercive economic statecraft. For instance, the Made in China 2025 industrial policy plan approved in 2015, the 2016 “innovation driven” development strategy, and the 2017 restructuring of artificial intelligence value chains geared to attain self-sufficiency in wide-ranging high-tech sectors became self-fulfilling

<sup>10</sup> Middle-income traps could reduce per capita GDP by 50% of what it might be in 2050 (Nag 2011). On middle-income traps and upgrading through GVCs, see Engel and Taglioni (2017).

<sup>11</sup> One example of positive technical spillovers is the Republic of Korea’s reliance on its high levels of GVC participation to begin exporting 90% of its COVID-19 test kits by April 2020 (Miroudot 2020).



precursors of spiraling disputes (Shih 2021). In 2018, the Trump administration unleashed tariffs and calls for reshoring GVCs to counter the PRC's forced technology transfers, government subsidies to state-owned firms, limits on market access, failures to enforce IP, and trade imbalances. By 2020, the PRC doubled down on “internal circulation” policies explicitly deployed to bolster domestic supply chains and state-owned enterprises. The Biden administration's first GVC policy report in June 2021 emphasized building resilience through investment in innovation, inclusive worker diversity, and domestic manufacturing capacity by small and medium-sized enterprises (White House 2021). That report also stressed that the domestic production of all essential goods is neither possible nor desirable, that GVCs must be globalized, and that resilience requires international cooperation and strong relations with allies and partners sharing basic values, including workers' rights and environmental protection. It urged reciprocity, transparency, fair-trade practices, protection from cyberattacks, and stronger international trading rules, including enforcement mechanisms.<sup>12</sup>

Tit-for-tat escalatory GVC policies and technology restrictions might accelerate substitution by domestic firms, but could also preclude them from accessing services, operating systems, and other core inputs (intangibles) from leading global suppliers and limit the proceeds of foreign sales of intangibles for R&D use.<sup>13</sup> Similar contagious dynamics have emerged in GVC-related disputes between Japan and the Republic of Korea and those involving the Republic of Korea and the PRC, India and the PRC, and the PRC and Australia, among others. Adverse unintended effects dominate in many cases, leading to vicious circles, downward spirals, and suboptimal outcomes for all. The pursuit of ostensible efforts to accelerate self-sufficiency, extreme decoupling, and technology-denial trigger responses that heighten the very risks intended to be avoided in the first place, creating a “self-reliance paradox.”

- (v) **Exacerbating horizontal contagion effects.** Geopolitical risk spills over upstream and downstream, as well as onto other GVC nodes and third parties along a GVC and beyond. Whether tariff barriers are imposed to offset asymmetric tariffs, subsidies, or other unfair trade practices, they notoriously trigger contagion throughout networks, as discussed later in greater detail.
- (vi) **Decreasing the movement of people and expertise across global value chain nodes.** Human beings are at the heart of GVC infrastructures, especially in services and intangibles. Undermining the mobility of this vital component of GVC operations also undercuts other beneficial interactions. As tensions rise, they often spill over into additional domains where mobility is curtailed, triggering sanctions

<sup>12</sup> Related legislative packages complement this ambitious blueprint that dwarfs in comparison with PRC spending on industrial policy and infrastructure.

<sup>13</sup> Xing (2021a, 2021b) finds GVC redeployment to other countries to be even more damaging for the PRC than the direct effects of tariffs, undermining the country's export capacity significantly in the longer term by severing PRC firms from GVCs, where the latter obviate the costs and risks associated with R&D, brand development, and marketing.

and detentions of foreign scientists, scholars, journalists, and other foreign nationals, all of which decrease valuable exchanges.

## Effects of Geopolitical Risks: What's at Stake

To understand what is at stake, it is important to consider the impressive growth in the parts and components trade in Asia and the Pacific. For instance, the PRC's regional share of imports rose from 12% in 1995 to 40% in 2017, its import volume surged twelve fold, and its export volume fourteen fold in the same period (Solingen and Inomata 2021). Furthermore, US shares from the PRC in the parts and components trade increased from 3% in 1995 to 21% in 2017 and from 5% to 25% in the same period for other sources in Asia and the Pacific. Nearly all countries in this region increased the domestic value added of services embodied in their gross exports to global markets from 2000 to 2016 (Mariasingham et al. 2020). Yet a recovery in GVC participation rates from 2016 to 2018, especially in complex GVCs, stalled from 2018 to 2019 with the onset of US-PRC tensions.

No definitive quantitative assessment of the cumulative effects of geopolitical shocks on GVCs is yet possible as they are still unfolding. Moreover, the effects of the COVID-19 pandemic were superimposed on preexisting geopolitical shocks, conflating the two effects. A simulation by the Organisation for Economic Co-operation and Development finds that “localized global regimes”—dominated by inward-looking strategies averse to GVC trade—are more vulnerable to shocks, magnified risks of food insecurity, and higher costs of adjustment OECD (2021).<sup>14</sup> By contrast, “interconnected economies” adjust more painlessly and increase the security of supply via both international and domestic substitution. Grossman and Helpman (2020) estimate that tariff levels of 25% on intermediates impose sizable welfare losses on the country imposing them; this rises further at higher tariff levels, which also encourages GVC relocation to lower-cost tariff-exempt sites or reshoring. Gentile, Li, and Mariasingham (2020) find that a full-scale US-PRC tariff war layering an additional 25.00% tariff on all bilateral imports (beyond those of May 2019) would decrease US GDP by 0.22% and the PRC's by 0.47%, employment by 0.31% in the US and 0.55% in the PRC, and trade by over 2.00% in the US and 4.00% in the PRC. Lower investment in the PRC would amplify those effects, leading to a potential GDP contraction of 1.00% in the PRC and 0.22% in the US (this simulation excludes trade in services). As Chapter 3 points out, export controls and market access restrictions imposed under national security considerations resulted in Huawei Technologies Co. Ltd. losing its ranking as the world's second largest smartphone company, with its market share shrinking from 17% in early 2019 to 4% in early 2021.

<sup>14</sup> Regimes raising import tariffs on all traded products to 25% and domestic subsidies by 1% would result in lower economic activity, lower incomes, and higher GDP losses when exposed to a 10% cost increase in imports and exports.



Geopolitical risks affecting large economies enmeshed in GVCs typically diffuse through the global economy. Cascading effects of uncertainty linked to calls for GVC “decoupling” are evident in trade, investment, and firm performance, and the expectations of Japanese firms, affiliates, parent companies, and third-country subsidiaries of firms from the world’s third largest economy. The analysis in Zhang (2021) of survey data from 2017 to 2020 from Japan’s Ministry of Economy, Trade and Industry shows significant declines in sales, exports, and employment of affiliates in the PRC with the highest exposure to trade between North America and the PRC. The level of concern over conflict and geopolitical risk from US-PRC relations, the Democratic People’s Republic of Korea, and the trade dispute between Japan and the Republic of Korea was relatively low in 2017, but it had doubled by early 2020. The later section on relative GVC resilience and adaptation to risks discusses firm-level adaptations to geopolitical uncertainty.

Many consider geopolitical risk to be the main challenge to globalization (Antràs 2020a). Geopolitical shocks target highly vulnerable components, sectors, and industries with high input specificity and limited geographic mobility; GVC hubs with a high potential for diffusing throughout an economy; knowledge-intensive GVCs in specialized and localized ecosystems with unique suppliers and difficult-to-substitute expert pools; and dual use (civilian and military) frontier technologies. Geopolitical shocks have heterogeneous effects across locations, sectors, firm types, and income levels contingent on the specific GVC targets and mechanisms analyzed earlier. They can lead to declines in the GVC participation rates of targeted countries, affecting smaller firms in particular, although large knowledge-intensive firms typically become core targets. Although Viet Nam in particular but also other Southeast Asian countries may have benefitted economically from US-PRC geopolitical entanglements, all of them regard with trepidation pressures to align with potentially bifurcated GVCs that could erode those economic gains in the longer term. Australia, India, and Japan launched the Supply Chain Resilience Initiative to confront uncertainty over further inward-oriented turns in the US and the PRC.

Transpacific geopolitical shocks have also reinforced trends toward the regionalization of complex GVCs. Both market-based incentives to reduce costs and political incentives to circumvent extended World Trade Organization (WTO) negotiations have enhanced the intra-regional shares of complex GVC trade in Asia, Europe, and North America (Xiao et al. 2020). The US withdrawal from the original Transpacific Partnership and the 2020 completion of the Regional Comprehensive Economic Partnership, along with other regional institutional developments, have also reinforced GVC regionalization. Geopolitical considerations are also buttressing renewed efforts to diversify into pan-American, eastern European, Mediterranean, and other regions adjacent to main GVC hubs.

Other effects of geopolitical risk and coercive economic statecraft are more sparsely addressed in the economics literature, including the likelihood that declining levels of GVC interdependence will also reduce barriers to more severe—militarized—interstate conflict. Hence, peace could also be at stake. A long lineage of scholarship on international relations since the Enlightenment’s *Doux commerce* assumed that greater economic interdependence

heightens the cost of major armed conflict, lowering its probability and enhancing cooperation.<sup>15</sup> Gains from trade, in this view, are substantial enough to take primacy even when they do not necessarily eliminate other ambitions. A competing theory holds that economic interdependence has not—and cannot—prevent major armed conflict, often wielding the failure of the pre-1914 first wave of globalization to prevent World War I. Decades of research have not dispelled disagreements over the relationship between economic exchange and militarized conflict, largely because empirical studies differ on underlying causal mechanisms, competing referents of interdependence and conflict/cooperation, model specification, measurement, data sources, and temporal boundaries. Studies have also primarily addressed gross bilateral trade, foreign direct investment (FDI), and preferential trade agreements, but not explicitly GVCs.

GVCs engender novel mechanisms that may further raise the costs of forgoing interdependence and arguably foster stronger incentives to uphold peaceful exchanges than would be the case in their absence. These effects might be especially relevant to knowledge-intensive complex GVCs where intangibles bind states in ways that transcend classical trade or financial interdependence. Alternatively, the battle for higher value-added shares could overwhelm incentives to maximize trade, growth, and employment. These incentives underpinned decades of striking GVC expansion in East Asia and induced restraint in handling disputes. In turn, the resulting geopolitical stability, predictability, and cooperation lubricated further GVC expansion, which would have been unimaginable during the period of wars in East Asia in earlier times or in other world regions with much shallower GVC infrastructure. The world is at an inflection point: geopolitical tensions could heighten GVC vulnerability or GVCs could prove more resilient to these tensions than were early 20th century forms of economic exchange. Either scenario makes GVCs pivotal to the region's future direction.

## Sources, Mechanisms, and Effects of Environmental Risks on Global Value Chains

Environmental risks are hazards with adverse, probabilistic consequences for human beings or the environment (Whyte and Burton 1980). This chapter's focus is on the environmental risks associated with geophysical (e.g., earthquakes, volcanic eruptions), meteorological (e.g., extreme temperatures, storms), hydrological (e.g., floods, landslides), and climatological (e.g., drought, wildfires) hazard events (UNDRR 2020). Although the number of large disasters in terms of human casualties has declined, the economic damage from disasters triggered by natural hazards has increased significantly, as data from the Emergency Events Database show.

<sup>15</sup> Different mechanisms include the opportunity costs of war, declining spoils from plunder, trade as a signaling mechanism, trade as facilitating changes in state preferences over outcomes, trade as fostering shared norms against hypernationalism, and trade agreements as facilitating trust and helping to overcome credible commitment problems.

The devastating floods in western Germany and Zhengzhou caused by record rainfall, as well as record-breaking fires in California and an unprecedented heatwave in western Canada, among many other such events in 2021, vividly illustrate how global warming and extreme weather exert massive destruction and disruption worldwide. These events disrupted the operations of many major MNCs, sparking concerns over the potential impact on global supply chains (Koehl 2021; Patton, 2021).

## Sources of Environmental Risks

Some environmental risks stem from natural causes while others are anthropogenic (created by human activity), including climate change, environmental pollution, deforestation, erosion of natural habitat, and biodiversity loss. The scientific evidence on climate change and the associated environmental risks is compelling. Increased production and resource extraction has greatly contributed to detrimental changes due to the burning of fossil fuels and the release of greenhouse gas (GHG) emissions. Climate change can lead to land and ocean temperature rises and rising sea levels, intensifying environmental risks by increasing the frequency and severity of hydrometeorological hazards, as well as the size of the area affected (Hoegh-Guldberg et al. 2018; IPCC 2021). Other forms of environmental degradation, such as air and water pollution, deforestation, and the decline of biodiversity, are also undermining the productivity, resilience, and the adaptability of nature, fueling extreme risk and uncertainty for economies, GVCs, and well-being (Dasgupta 2021).

Growing international trade associated with GVCs has contributed to climate change by increasing energy consumption and CO<sub>2</sub> emissions in GVC-related transportation and production (World Bank 2020; Meng et al. 2018; Wu, Hou, Xin 2020). GVCs can lead to rising GHG emissions through four main channels. First, GVCs are associated with greater distance between regions in the distribution network, and greater distances translate into higher GHG emissions from transportation, which is estimated to be responsible for 3.5% of total global emissions (Cristea et al. 2013). Second, participating in GVCs further accelerates the growth of the global energy footprint, in which stronger backward linkages can increase energy use. Zhang et al. (2020) find that GVCs resulting from MNCs' assets and suppliers abroad account for about 20% of CO<sub>2</sub> emissions, although this figure has fallen slightly since 2011. Third, international carbon leakage—production moving to countries with less stringent climate measures—leads to the burden-shifting of emissions and threatens climate mitigation targets. And fourth, the cost-benefit of GVCs has resulted in an abundance of production and excessive waste in products, including electronics, plastics, and food. It is estimated that a record 53.6 million metric tons of electronic waste was generated worldwide in 2019, up 21% in just 5 years (Forti et al. 2020), and 242 million metric tons of plastic waste is generated annually (Kaza et al. 2018). Beyond climate change, the impact of GVCs also extends to other environmental indicators, such as biodiversity loss. Lenzen et al. (2012) estimate that about 30% of threats to global species are driven by international trade in commodities, including coffee, tea, and sugar, and textiles and other manufactured items.

The emergence of GVCs has also given rise to higher exposure to environmental risks, as GVCs are often accompanied by large-scale clustering and agglomeration where firms in the same or connected industries tend to locate close to one another. Production centers are often developed in coastal areas and river basins with high population concentrations and lower transport costs. Although industrial agglomeration reduces production costs and enhances cooperation between firms, it can potentially lead to higher exposure to environmental risks when disasters triggered by natural hazard happen in areas of concentrated population and industrial activity (Gereffi and Luo 2014).

Even so, GVCs also have mitigating effects on GHG emissions and climate change. International trade may lead to lower CO<sub>2</sub> emissions if production and distribution via GVCs entail lower emissions than domestic production (le Moigne and Ossa 2021). Without international trade, domestic production would increase to meet consumption needs. Moreover, technology spillovers through participation in GVCs contribute to the diffusion of new environmentally sustainable technology, thus facilitating the transition toward carbon neutrality in both developed and developing countries. Participation in GVCs also means that supplier firms must comply with global standards and environmental certifications to meet the demand of lead firms, which can cut down their carbon footprints.

Overall, the rise in environmental risks can be traced to an increase in industrial activity, including the expansion of GVCs. By expanding the geography of industrial activity, GVCs have also increased the exposure and vulnerability to environmental risks. Yet, GVCs can also help address environmental risks by diffusing environmentally friendly technology and standards.

### Causal Mechanisms in Environmental Risk

Environmental risks can pose significant threats to economic systems through the direct impact on firms and individuals exposed to natural hazards, as well as indirectly through the effect of these hazards on suppliers and customers. The rise of GVCs means that firms are more interconnected through input–output linkages where different stages of production are spread across geographical locations. GVC interdependence enables greater efficiency, but it also creates vulnerabilities. Relatively small environmental shocks can result in significant supply chain disruptions. Adverse shocks can affect both domestic and global economies via direct and indirect channels and from both the supply and demand side. Some of the specific mechanisms include:

- (i) **Disruption due to lost production.** Direct supply effects occur when firms stop producing due to an environmental-related disruption (e.g., a disaster triggered by natural hazard). Disasters not only result in human casualties but also cause destruction of capital assets, inventory, and infrastructure. From a macroeconomic perspective, the negative impact on output delivers a shock to the aggregate supply curve, resulting in a decline in real output and employment, as well as potential negative impacts on economic growth. Long-term environmental shifts, such as climate change, could

also affect the availability and productivity of raw materials and production factors. Examples of these impacts include land and capital destruction from rising sea levels, crop productivity impacts on agriculture, and labor-productivity impacts resulting from rising temperatures and stress on human health (Dell, Jones, and Olken 2012). The impact of climate change on agricultural productivity alone can lead to a decline in welfare equivalent to 0.27% of GDP worldwide, with larger losses in developing countries (Costinot, Donaldson, and Smith 2016). Tourism services are also highly susceptible to climate change through changes in snow cover, rising sea levels, coastal degradation, and extreme weather.

- (ii) **Indirect effects due to disruptions from upstream suppliers.** Problems at any point in a GVC can reduce output substantially if inputs enter production in a complementary fashion (Jones 2011). Some widely adopted supply chain management strategies, such as the just-in-time practice and lean supply chain management, correspondingly raise the chances of a supply chain disruption during a disaster-induced disruption (Abe and Ye 2013). Although this mechanism applies to both domestic and global value chains, the presence of cross-country input-output linkages in GVCs means the indirect impact of an environmental risk can potentially affect firms in other countries. This impact is most acutely felt in complex industries, such as automobiles and semiconductors, where substitutes are difficult to find. Tokui, Kawasaki, and Miyagawa (2017) find that about three-quarters of Japan's output loss from the 2011 earthquake and tsunami resulted from indirect effects through supply chain disruptions.
- (iii) **Rising demand for certain goods and services.** In the immediate aftermath of disasters, demand rises sharply for food, medical supplies, and emergency equipment, as well as for services to aid the relief efforts. Capital-intensive services, such as telecommunications and transportation, are in high demand, but domestic capacity to deliver these services is often severely diminished (Xu and Kouwoaye 2019), resulting in shortages and rising prices of essential goods and services. The rising demand is often met by supplies from unaffected locations, including imports. Meanwhile, disasters can trigger demand for nonessential goods and services to decline, causing many businesses to lose the sales they normally rely on.
- (iv) **Demand effects transmitted to other sectors.** The rising demand for essential goods can lead to increasing prices of raw materials and intermediate inputs, affecting upstream sectors. Conversely, the negative impact on the income of businesses and households can suppress the prices for products and intermediate inputs in upstream sectors, potentially resulting in an economic contraction.
- (v) **Cost of moving goods and personnel across borders.** GVCs are underpinned by complex transportation and logistics that move intermediate and final goods across borders. The effects of climate change could be manifested in damages to trade infrastructure, such as ports and roads, and shipping and flight routes, from more frequent extreme weather events or rising sea levels, causing supply,

transport, and distribution chain disruptions (Dellink et al. 2017; IPCC 2014). Transport disruptions translate into supply chain disruptions that act as amplifiers of disaster-induced economic shocks (Colon, Hallegatte, and Rozenberg 2021).

### Effects of Environmental Risks: What's at Stake?

The emerging consensus in the literature is that environmental risks, including climate change, exert a negative impact on economic output, and the negative impacts become disproportionately larger as temperature rises increase (Kahn et al. 2019). GVCs can worsen the impact of environmental risks by transmitting the adverse shocks to upstream and downstream activities.

Examining the impact of disasters on GVCs provides insights into the potential effects of environmental risks. Carvalho et al. (2021) find the propagation of the shock of the 2011 Japan earthquake accounted for a 0.47% decline in the country's real GDP growth in the year following the disaster. The shock not only affected the disrupted firms' immediate transaction partners but also their suppliers' suppliers and customers' customers. This indirect propagation effect corresponded to roughly a 2–3 percentage points decline in annual sales growth. The potential propagation of shocks over an economy's production network can affect a significant fraction of firms, resulting in volatilities in aggregate economic performance. Inoue and Todo (2019) predict that the indirect effects due to propagation from a mega earthquake on major industrial cities in Japan are substantially larger than their direct effects. Barrot and Sauvagnat (2016), in a study on effects of disasters over 30 years in the US, find that affected suppliers impose substantial output losses on their customers, especially if they operate in industries producing differentiated goods, if they have a high level of R&D, or if they hold patents. These findings suggest that input specificity, especially reflected in the intangible components of GVC trade (patents, R&D, and so on), is a key determinant of the propagation of idiosyncratic shocks in an economy. The sales growth and stock prices of firms fall significantly when a disaster hits one of their specific suppliers.

GVCs not only transmit shocks within domestic economies but also play an important role in cross-country transmission. When suppliers in source countries are affected by disasters, it is not uncommon for firms to report production delays and profit losses as their suppliers fail to provide parts and components on time. For instance, Thailand's 2011 floods affected hundreds of manufacturers and cut off the supply of about 100 components to the country's automakers. With many suppliers hit by the flooding, automakers scrambled to procure replacement parts and assess the extent of the disruption on their supply chains. Toyota Motor Corporation's production lines in Malaysia, North America, Pakistan, the Philippines, and Viet Nam had to be adjusted to make up for the output disruptions in Thailand (Abe and Ye 2013). After the 2011 Japan earthquake, the unavailability of Japanese inputs caused both domestic and international production to fall sharply—automobile production, for instance, fell by 24% in the Philippines, 19.7% in Thailand, and 6.1% in Indonesia. And the production of electrical components fell by 17.5% in the Philippines and 8.4% in Malaysia (Abe and Ye 2013).



Boehm, Flaaen, and Pandalai-Nayar (2019) study the role of trade and MNCs in the cross-country transmission of shocks by examining the US affiliates of Japanese MNCs after the 2011 Japan earthquake. They find that US firms highly dependent on Japanese inputs suffered large output losses after the earthquake; their drop in exports corresponding to roughly one-for-one with the drop in imports, suggesting there was virtually no scope for substitution for other inputs for these firms. Längle, Xu, and Tian (2020), in a study on the US hurricane season in 2005, find that PRC processing manufacturers with tight trade linkages to the US reduced their intermediate imports from the US in the months following the hurricane season. They find, however, no consistent evidence of international propagation of supply shocks along GVCs. Similarly, Kashiwagi, Todo, and Matous (2018), in a study on the impact of 2012's Hurricane Sandy using datasets that map firm-to-firm transactions, find no propagation of negative shocks outside the US, possibly because internationalized US firms are generally more productive and have better access to information about global markets. Firms embedded in GVCs can more easily substitute partners whose operations have been hampered by a disaster.

Overall, historical incidences of disasters suggest that GVCs can propagate idiosyncratic shocks and affect the suppliers and consumers of firms via domestic, regional, or global production networks. The impact of disasters can also extend beyond national borders and affect foreign firms with direct and tight linkages to affected firms. There is so far little empirical evidence of shock propagation to foreign firms that does not have direct trade linkages to a disaster-affected region, suggesting a limited scale of GVCs in transmitting disaster shocks across countries. Because the frequency and severity of disasters and other environmental risks are projected to increase, risks to GVCs are likely to grow substantially (Lange et al. 2020). Increased instances of disasters and supply chain disruptions will further affect the organization of GVCs, potentially leading to shifts of GVC centers to regions with lower exposure to environmental risks.

## **Sources, Mechanisms, and Effects of Pandemic Risks on Global Value Chains**

COVID-19 triggered chaos from city lockdowns, the closure of national borders, and social distancing, unleashing a global economic crisis. The sudden restrictions in both the domestic and international movement of people and business operations were a blow to lifestyles and the conventional GVCs supporting them, triggering unprecedented uncertainty and challenges to global governance.

### **Sources of Pandemic Risks**

Pandemics have occurred throughout human history (e.g., smallpox, tuberculosis, the Black Death) and they appear to be increasing in frequency (e.g., the 1918 influenza pandemic, HIV/AIDS, the 2009 swine flu pandemic, and COVID-19). The source of pandemic risks is viral. In most cases, cross-species transmission events lead to

outbreaks in humans (Menachery et al. 2015). It might not be possible at this stage to determine precisely how humans were initially infected with COVID-19, but scientists must be given sufficient time to reach the final answer.

COVID-19 triggered pandemic proportions not only because of its epidemiological features but also due to heightened levels of transnational connectivity and mobility related to human activity, including via GVCs. Epidemiologically, the COVID-19 virus spreads more easily and causes more serious illnesses in some populations. The virus can also take longer before becoming symptomatic, and people can be contagious for longer periods compared with influenza viruses. Some variants of COVID-19 spread faster and are more transmissible or infectious, thus vaccination levels of 58%–94%, higher than for most adult-vaccine benchmarks, may be required to end the COVID-19 pandemic (Lund et al. 2020). Beyond specific virus characteristics, much easier, faster, cheaper, and more frequent cross-border business travel supporting GVC operations, as well as tourism and other travel categories, have affected the risk and rate of human-to-human transmission. This explains why countries have applied a wide range of localized or national lockdowns and border control measures to minimize COVID-19's spread. The next section examines in detail some of the mechanisms of pandemic transmission through GVCs, including findings related to the effects of lockdowns on GVCs.

## Causal Mechanisms in Pandemic Risk

The mechanisms through which the COVID-19 shock affected GVCs include:

- (i) **Adjustments in demand and supply.** These adjustments trigger “stress responses” (e.g., risk avoidance behavior) by individuals, firms, investors, governments, and other market agents via multiple channels, both domestically and internationally. For example, people tend to be more self-restrained in work and consumption activities taking place in “3Cs” environments—closed spaces with poor ventilation, crowded places with many people nearby, and close-contact settings. Consequently, declines in labor force participation, increases in absenteeism, and decreases in working hours have affected the supply of labor in GVCs (Cowan 2020; ILO 2021). Quarantine measures and lockdowns accelerated remote working, leading to a surge in demand for information and communication technology goods, medicines, and online services. Demand plummeted for many manufactured goods and services, including airlines, tourism, restaurants, sports, and other services that are highly dependent on face-to-face communication (OECD 2020). Uncertainty about when economies and sectors will recover has resulted in shifts in medium- and long-term investment decisions. Mandatory and nonmandatory policy measures, including city lockdowns, school closures, social distancing, and national border closures, also pose risks to GVCs.
- (ii) **Globalization.** This mechanism is a significant factor in the spread of COVID-19 risks (Bogoch et al. 2020; Lau et al. 2020; Linka et al. 2020). Higher stages of globalization are characterized by easier, faster, cheaper, and more frequent

cross-border travel supporting business operations in GVCs. The COVID-19 virus is unprecedented in its capacity to take advantage of highly globalized contexts and spread at surprising speed across borders (Mas-Coma, Jones, and Marty 2020). Countries with higher levels of socioeconomic globalization were initially exposed to higher case–fatality ratios (confirmed deaths to confirmed cases), but subsequent waves diffused through other countries (Farzanegan, Feizi, and Gholipour 2020).

- (iii) **Highly complex and integrated GVCs.** The complexity of modern GVCs amplified the risks from COVID-19. No country is completely immune to the health and economic impact of COVID-19 (Strange 2020). Even highly isolated ones have felt its effects. At the other end, Sweden initially conducted an unorthodox experiment to build herd immunity, avoiding lockdowns. It still suffered significant economic losses compared with its locked-down neighbors, partly due to high levels of integration in GVCs. Many countries have deep linkages with the three global GVC hubs (the US, the PRC, and Germany) via trade and investment (Gao et al 2021). Once COVID-19 affects those hubs, the ripple effects are felt throughout all phases of production from material supplies to distribution (Baldwin and Freeman 2020; Kumagai et al. 2020). The impact of COVID-19 on a country or region depends not only on its economic size and ability to cope but also on its degree of participation and linkages with GVC centers (Maliszewska et al. 2020; Sforza and Steininger 2020). Guan et al. (2020) confirm propagation effects through GVCs via forward and backward linkages even to countries not directly affected by COVID-19. In a scenario where COVID-19 is strictly contained within the PRC, GDP losses for the PRC are still substantial (16.7% of the PRC’s annual GDP), but propagation via GVCs—within and beyond the PRC—raise these losses to 21.5%. Another model-based analysis, by Inoue and Todo (2020), shows that had Tokyo been under lockdown for 1 month, the indirect economic effect via GVC propagation to other regions would be twice as large as the direct effect on Tokyo itself.
- (iv) **Global value chain dynamics, uncertainty, and foreign direct investment.** GVCs operate in a context of highly dynamic market mechanisms, affecting investors’ information and evolving decisions under uncertainty. Indeed, the World Uncertainty Index reached a record high at the onset of the COVID-19 pandemic in the first quarter of 2020. Global FDI flows fell by 42% in 2020 and a 5%–10% slide was projected for 2021, as foreign affiliates experienced difficult operational, market, and financial conditions, and plummeting profits (UNCTAD 2021). Resumed production helped turn the PRC into the largest FDI recipient in 2020, with inflows rising 4% from 2019. Because FDI is the most salient form of GVCs and a key driver of these chains, extreme uncertainty about the path, duration, magnitude, and impact of COVID-19 led to vicious cycles that dampened investor confidence, altered short-term investment decisions, and created spillovers along the entire GVC, leading to further declines in employment and investment. Over two-thirds of multinational investors in developing countries reported GVC disruptions, and lower revenue and production, within months of the outbreak (Saurav et al. 2020).

## Effects of COVID-19 Risks: What's at Stake?

The COVID-19 pandemic is an unprecedented shock affecting all GVC dimensions in an uncertain environment. Broadly, three features of COVID-19 effects on GVCs distinguish the pandemic from past health or economic shocks. First, compared with the outbreak of severe acute respiratory syndrome (SARS) in 2003 and the global financial crisis, the impact of COVID-19 on GVCs is far more global, larger scale, and longer lasting (Yeyati and Filippini 2021). The global recession it unleashed was the deepest since the Great Depression. Kissler et al. (2020) argue that COVID-19 surveillance must be maintained because a resurgence in contagion is possible even as late as 2024.

Second, GVCs are mainly organized and controlled by MNCs, which account for about 50% of global trade, 33% of output and GDP, and 25% of employment (Cadestin et al. 2019). Qiang, Liu, and Steenbergen (2021) note that with the onset of COVID-19, 77% of surveyed MNC affiliates reported a fall in GVC reliability in middle- and low-income countries during the second quarter of 2020, declining to 41% in the third quarter. Small and medium-sized enterprises supplying MNCs were especially vulnerable to demand and supply shocks, forcing sharp reductions in hiring, travel, and other costs. The impact of COVID-19 on a firm depends on how dependent the intra- or inter-firm relation is between MNCs (lead firms) and domestic firms (suppliers) or between large firms and small and medium-sized enterprises, as well as on GVCs' governance type. For example, the most important feature of contemporary GVC arrangements is the factoryless phenomenon examined in Chapter 2. An increasing number of MNCs, especially from developed countries, have no production facilities but they own IP rights or product designs for goods manufactured or assembled by factoryless producers, typically located in developing countries. Developed countries thus have a strong comparative advantage in knowledge-intensive sectors at the high end of GVCs, while developing countries enjoy strong comparative advantage in labor-intensive sectors at the lower end (Meng, Ye, and Wei 2020; Meng and Ye forthcoming). This might partly explain why developed countries' services exports, developing countries' goods exports, and employment in smaller firms in developing countries have been more strongly affected by COVID-19 in the short run (Maliszewska et al. 2020; UNCTAD 2020).

Third, the spatial extent of COVID-19 is the most important driver of the global cost on GVCs. A landmark study by Guan et al. (2020) estimates the global costs of COVID-19 lockdowns on GVCs measured in value-added losses, which depend more on the number of affected countries and the duration rather than the strictness of lockdowns. In a scenario where the PRC alone was affected, COVID-19 lockdowns would have reduced global value added by only 3.5% of GDP. Instead, the spread to highly developed economies in Europe and the US would have decreased value added almost fourfold to 12.6%. The modelled impacts of COVID-19 lockdowns are even greater, decreasing global GDP by 26.8%. The global spread and relatively strict (60%) lockdowns for 4 and 6 months would decrease global value-added losses by about 4% over a higher level of strictness (80%) for 2 months. Hence, the bigger the spatial spread of COVID-19 and the longer the temporal duration of lockdowns, the

larger are the declines in global value added. It should be noted that even in scenarios where COVID-19 does not spread globally, sectors highly dependent on GVCs, such as the PRC's electronics and Germany's automotive industries, would be quite vulnerable.

The study also confirms propagation effects through GVCs via forward and backward linkages even to countries not directly affected by COVID-19. Importantly, low- and middle-income countries are far more vulnerable to indirect effects than developed countries. Propagation effects, in turn, will continue to inflict disruptions even after the pandemic has been controlled in the source countries. In a scenario where Europe and the US apply strict containment measures for 2 months, they would incur larger direct losses of 15%–20% of their GDP, but the costs of propagation to lower-income countries would be smaller than under lengthier lockdowns. COVID-19 containment has both substantial positive externalities (i.e., all countries benefit considerably when the PRC imposes strictest measures), and negative externalities (i.e., all countries suffer from containment in other countries via reduced demand). The positive externalities of containments dominate, however.

Even in scenarios where COVID-19 does not spread globally, sectors that are highly dependent on global GVCs would be quite vulnerable. The shortest and strictest containment in the PRC would result in a decrease of 27.3% in global value-added in electronics (20.0% direct PRC losses). In a scenario of global spread, the decline would be 40.0%. For Germany's automotive industry, the "PRC only" contained, strict, and brief lockdown would result in a modest value-added loss to German GDP of 1.8%. But the scenario of COVID-19 spreading to developed countries subject to 4-month lockdowns would raise German value-added losses to 28.8%, with significant upstream and downstream effects on its GVC partners.

Fourth, governments are facing considerable challenges in designing and conducting well-balanced policies to mitigate the impacts of COVID-19 on GVCs. These vary significantly across industries, regions, firm type, and income groups in both directions (positive or negative) and magnitude (Guan et al. 2020). So, policy responses designed to tackle one adverse impact may end up exacerbating another, placing policy decisions between a rock and a hard place. Pandemics also evolve dynamically when there is high uncertainty, posing formidable challenges for balancing resources across the short, medium, and long terms. As mentioned earlier, big synergies exist between efforts to stem the spread of the COVID-19 pandemic, an increasing risk of unilateralism, protectionism, and backlashes against economic globalization, all of which make balancing domestic and international considerations more difficult. The wildly uneven distribution of COVID-19 vaccines and other barriers to medical supplies, equipment, and materials imposed early in the pandemic fall under this rubric (Bown 2021). The section examining compounded risks elaborates on those synergies. Table 5.1 summarizes the discussion on the sources, mechanisms, and effects of each risk type on GVCs.

**Table 5.1: Sources, Mechanisms, and Effects of Geopolitical, Environmental, and Pandemic Risks**

Features	Risk Type		
	Geopolitical	Environmental	Pandemic (COVID-19)
Main sources	<p>Rising inward-oriented political-economy strategies</p> <p>Emphasis on relative gains, asymmetries, negative externalities from global value chain (GVC) interdependence (especially in high-tech)</p> <p>Trade and GVCs</p>	<p>Natural hazards, climate change, and biodiversity loss</p> <p>Increased production, resource extraction, and GVC trade</p> <p>Higher exposure due to industrial clustering by GVCs</p>	<p>Onset and spread of COVID-19 reaching pandemic proportions</p> <p>Trade and GVCs</p>
Common mechanisms	<p>Supply or demand shocks or both</p> <p>Magnified generalized uncertainty</p> <p>Reduced trust in GVC integrity</p> <p>Exacerbated contagion (spillover)</p> <p>Diluted expected benefits from GVCs relative to political/economic costs</p> <p>Decreased movement of people, expertise, foreign direct investment across GVC nodes</p>		
Unique mechanisms	<p>Export and investment restrictions</p> <p>Technology denial</p> <p>Vertical contagion (retaliatory spirals)</p> <p>Spillovers undermine cooperation in other issue areas, including security, relevant to GVC operations</p>	<p>Direct impact on human casualties, capital, inventory, and infrastructure</p> <p>Higher demand for essential goods/services and decline in demand for others</p> <p>Large disruptions in trade infrastructure/routes</p>	<p>Restrained consumption</p> <p>Urban density, geographic agglomeration, transportation, poverty, inequality</p> <p>Diminished face-to-face communication</p> <p>Lockdowns affect production and consumption</p>
Effects	<p>Global scope, cascading effects</p> <p>Heterogeneous effects across locations, sectors, firm types, income levels, production concentration</p> <p>Decline in GVC participation rates</p> <p>Smaller GVC partners most affected</p> <p>Industrializing states most affected</p> <p>Increased unemployment</p> <p>Decreased individual income/consumption</p>	<p>Disaster risks diffuse upstream and downstream via GVCs</p> <p>Limited evidence of cross-border transmission of disaster shocks</p> <p>Exposure to natural hazards projected to increase</p> <p>Heterogeneous effects across locations and sectors</p>	<p>Global scope, long-lasting, marked by waves</p> <p>Significant changes in lifestyle and work patterns</p> <p>GVC hubs most affected, cascading effects</p> <p>Foreign-owned firms with higher reliance on GVCs are more likely to be affected</p> <p>Heterogeneous effects across locations, sectors, firm size, short/long term</p> <p>Challenges to firm/country risk management</p>
Most affected sectors	<p>Foundational high-tech sectors, especially “strategic” technologies (artificial intelligence, semiconductors, quantum computing, aerospace, robotics)</p> <p>Trade in intangibles across GVC types: research and development, product design, branding, marketing, retailing</p>	<p>Agriculture and tourism (due to rising temperatures and extreme weather)</p> <p>Transportation (susceptible to extreme weather)</p> <p>Effects on other sectors contingent on location and magnitude of shock</p>	<p>Negative: airlines, tourism, accommodation, restaurants, sports, plastics, chemicals, rubber</p> <p>Positive: pharmaceuticals, e-commerce, e-entertainment, live-stream conferencing, information and communication technology</p>

Source: Authors.



## Relative Global Value Chain Resilience and Adaptation to Risk

This chapter's working definition of GVC resilience entails the ability of these chains to anticipate and prepare for severe disruptions in a way that maximizes capacity to absorb shocks, adapt to new realities, and reestablish optimized operations in the shortest possible time. The degree of GVC resilience across risks depends on the nature and magnitude of shocks, whether shocks are sector- or region-specific, distinctive GVC features, industry and firm topographies, availability of substitutions, and degree of transactional stickiness in GVC partnerships. The following elaborates on how these different dimensions affect GVC resilience:

- (i) **Nature and magnitude.** GVCs are more resilient to smaller shocks than larger, synchronized ones (Huneeus 2018). GVC relationships are often difficult and costly to form, leading to stickiness, such that only large shocks induce incentives to alter relations (Antràs, Fort, and Tintelnot 2017). Firms typically consider the fixed costs of multisourcing too large to bear, especially in the absence of large shocks.
- (ii) **Sector- or region-specific.** Resilience also depends on whether a shock is specific to one region or country. GVCs can reduce their exposure to localized shocks via diversification of demand and supply or increase their exposure to shocks that are specific to sectors (or products) in which a country specializes. Caselli et al. (2020) find country-diversification effects to be eight times larger on average than sector-specialization effects. The net effect is that trade reduces volatility in most cases, especially when shocks are not correlated across countries. Industries that can relocate easily to other countries when facing “policy interventions” may be more resilient than those heavily constrained due to localized network and lock-in effects (Lund et al. 2020).
- (iii) **Global value chain structure and choke points.** Shocks propagate more strongly when intersectoral linkages are asymmetric (Acemoglu et al. 2012). General-purpose suppliers—iron and steel mills, electric power generation and distribution, petroleum refineries, and real estate, for example—can act as potential choke points. MNCs, especially large ones, may be less resilient to particular shocks as are more complex, lengthier GVCs. GVC linkages have a significant association with increased international business-cycle co-movement between the individual firms and countries they trade with (di Giovanni, Levchenko, and Mejean 2018). Upstream sectors, especially those with higher specificity, are more likely to propagate GVC shocks. Supply-side shocks propagate downstream much more powerfully than upstream, whereas demand-side shocks have smaller effects on prices and propagate upstream via suppliers' adjustment-of-production levels and input demands (Acemoglu, Akcigit, and Kerr 2016). The more agglomerated sectors are, the more likely they are to transmit shocks across them.

- (iv) **Availability of substitutions.** Critical GVC nodes can amplify shocks. With low substitutability, disruptions cascade and halt the entire production; with higher substitutability, sudden surges in domestic demand can be met via external supply. The time horizon is crucial: elasticity of substitution can be low in the short run whereas longer time horizons enable eventual substitution, which mitigates shocks (Yilmazkuday 2019). Complex GVCs are especially at risk, particularly in electronics.

The availability of substitutes is connected with the degree of transactional stickiness in GVC relationships. Solingen and Inomata (2021) propose a framework for estimating relative GVC resilience based on three criteria related to stickiness: scarcity of alternative suppliers, level of sunk costs (physical and intangibles), and volume of informational exchange between partners. Capital-intensive sectors are more likely to face fixed investments in physical production infrastructure, which may inhibit the relocation of production or sourcing from alternative suppliers, making them less resilient. Labor-intensive GVCs in apparel, textiles, and furniture, by contrast, can relocate more easily, making them more resilient. GVCs often rely on numerous specific investments, such as purchasing specialized equipment or customized products, which entail developing specific relationships and repeated interactions, especially when contract enforcement is weak (Antràs 2020b). Knowledge-intensive GVCs typically operating in specialized and localized ecosystems, with unique suppliers and expert pools, are harder to substitute. Fear of IP expropriation or imitation may prevent firms with intangible assets from engaging with too many suppliers, strengthening their incentives to choose vertical integration where they own or control suppliers (Antràs and Yeaple 2014). Specific GVC relationships lower resilience to exogenous shocks.

While GVCs may in some situations amplify the impact of shocks, they can also help mitigate their effects and enhance resilience (Baldwin and Freeman 2020; Miroudot 2020). Participating in GVCs may increase vulnerability to foreign shocks, but it can also reduce vulnerability to domestic shocks (Espitia et al. 2021). Diversified suppliers and cross-national production networks can adjust more easily to risks and shocks. Highly diversified inputs can mitigate the impact of shocks via two channels: first, each individual variety matters less in production, reducing volatility; second, the other varieties can become substitutes that offset the shock (Koren and Tenreyro 2013). In sum, the benefits of relying on diversified suppliers and clients outweigh the potential disruptions engendered by GVCs (Todo, Nakajima, and Matous 2015). Outward-oriented strategies are thus more likely to increase resilience, whereas inward-oriented ones can increase vulnerability, especially since across-the-board domestic substitution is typically unrealistic.

## Global Value Chain Resilience to Specific Meta-Risks

**Geopolitical risk.** Anticipating relative GVC resilience to geopolitical risk is challenging, especially as coercive economic statecraft targets idiosyncratic sectors, industries, or firms based on sometimes unexpected, ad hoc, inconsistent, and dynamic political considerations. The generic correlates of resilience identified earlier may apply to

geopolitical risk. But unlike environmental and pandemic risks, geopolitically driven economic statecraft entails purposeful actors targeting especially vulnerable products, sectors, and industries due to their high input specificity and GVC hubs with a large potential for spreading disruption (e.g., rare earth derivatives or semiconductors). The conjunction of hubs with high input specificity makes for more vulnerable targets. Knowledge-intensive GVCs in specialized and localized ecosystems with unique suppliers and expert pools are harder to substitute.

Typical geopolitical targets include countries controlling concentrated levels of specific inputs, behaving as unreliable suppliers, and imposing illegal or arbitrary trade restrictions. When international economic exchange becomes subordinated to maximizing power in all its forms, IP-intensive and dual-use technologies with civilian and military applications become primary targets.<sup>16</sup> Contemporary examples include information and communication technology (ICT), artificial intelligence, quantum computing, semiconductors, aerospace, advanced robotics, and other frontier technologies identified as strategic. Complex GVCs may be tempting targets, but they can also be resilient. Economic statecraft also targets countries perceived to be violating international agreements or norms in environmental, labor, human rights, or security domains, including cybersecurity (Solingen 2012). Consumer boycotts—with or without government prodding affecting consumer incentives—target particular products, firms, or sectors (e.g., boycotts against products from Japan or the Republic of Korea in the PRC or boycotts against Japanese products in the Republic of Korea).

Empirical studies on resilience to geopolitical risk arrive at different conclusions even for similar cases. Li and Liu (2019) show different responses by PRC firms and consumers to a 2012 dispute with Japan. Electromechanical, transportation, and other consumer goods imports declined significantly because of the dispute, but less salient intermediate goods and food much less so. Intermediate inputs for firms may be arguably more resilient than inputs for consumers, especially those exposed to hypernationalist rhetoric. Li and Liu (2019) find a similar pattern in the PRC's boycott of goods from the Republic of Korea following the 2017 Terminal High Altitude Area Defence (THAAD) missile defense system crisis, where consumer-led measures were less restrained than firms importing Japanese intermediates, including ICT. They also find the effects of the 2012 dispute to have dissipated within a year. Luo and Zhou (2019) suggest the 2010 PRC boycott of Japanese goods dissipated within 6 months.

Barwick et al. (2019) argue that automobiles may be relatively resilient to boycotts in the PRC insofar as brand preferences are strong (sticky), cars are produced with over 50% local ownership, and foreign brands provide offsetting incentives to retain loyalty. Yet automobiles are especially vulnerable to politically inspired consumer boycotts because of their high visibility, high cost, high substitutability, and high susceptibility to

---

<sup>16</sup> For a primer on Nazi Germany's reliance on economic statecraft to maximize raw power, see Hirschman (2018).

vandalism. Japanese brands declined nearly 50% with the boycott and a slower decline persisted for several years. Since the 2012 boycott, Japanese firms in the PRC declined from 14,394 in that year to 13,685 in May 2019. The same dispute in 2010 and the growing tensions in 2012 also led to significant reductions in imported Japanese cameras (Li and Liu 2019). Geopolitically inspired consumer boycotts in the PRC, especially against European and US products, recrudesced in 2021 as GVC segments become targets.

Even when economic statecraft affects GVC resilience only marginally, and there is no guarantee this will be the case in the future, geopolitical risk is known for its potential for escalating beyond economic tensions, spilling over into militarized conflict even when all states prefer to avoid this outcome.<sup>17</sup> New frontier technologies exacerbate geopolitical risks and uncertainty even if some are intended to lower them both.

**Environmental risk.** A distinct feature of environmental risk is that disasters tend to be confined to a region and last for relatively short periods. Broader shocks, such as climate change, have heterogeneous effects on different regions. This geographical and temporal dispersion means that, although GVCs can amplify environmental risks, especially in agglomerated industrial locations, they can also play a positive role in enhancing resilience via international diversification. Insurance, better infrastructure, and migration can also mitigate adverse effects.

There is some evidence of firms adjusting procurement and trade routes immediately after disasters. After 2011's floods in Thailand, firms were more likely to lower local procurement shares, increasing imports from Japan or PRC substitutes (Hayakawa, Matsuura, and Okubo 2015). After Japan's 2011 earthquake, at least 40% of exports went through alternative Japanese ports, especially technology-intensive products (Hamano and Vermeulen 2020). And ports affected by Hurricane Katrina in 2005 also experienced significant and lasting trade reductions, while shipments from adjacent ports experienced significant increases (Friedt 2021). In the medium term, GVCs often enhance resilience by anticipating environmental risks. Following Japan's 2011 earthquake, local firms diversified suppliers, including foreign sourcing, arguably to overcome domestic production and transportation disruptions (Zhu, Ito, and Tomiura 2016). Because of this disaster, Japan's automobile industry increased standardizing or modularizing car parts across car types to diversify GVC partners (Todo and Inoue 2021). The 2011 earthquake, however, did not lead countries dependent on Japanese suppliers to reshore, nearshore, or diversify in automobile and electronics, and trade in intermediates was disrupted less than trade in final goods (Freund et al. 2021).

---

<sup>17</sup> The ability to adjudicate ex post facto whether armed conflict resulted from such spillovers, rational intentions, incomplete information, cognitive biases, or other variables remains elusive.

Domestic and foreign services, including weather forecasting, insurance, telecommunications, and logistics, also help mitigate damages from environmental risk, shifting the burden to GVCs. Insurance coverage in low- and middle-income countries remains low, however. Firms severely affected by the 2011 Thai floods were more likely to subscribe to property insurance before the floods and had weaker incentives to invest in recovery, providing evidence for adverse selection and moral hazard in corporate insurance markets (Adachi et al. 2016). Longer-term measures for coping with risks focus on preparedness and environmental policy, and these are discussed in the section on policy recommendations.

**Pandemic risk.** COVID-19 was a “foreseeable unexpected event,” with repeated warnings of scientists on disastrous pandemics largely ignored (Walls 2020). A 2012 World Economic Forum survey on the risk of GVC disruptions included a “pandemic,” assigning it a probability of 11% versus 19% for a global energy shortage and 17% for labor shortages (WEF 2021). Yet the GVC world finds itself in a perfect storm, forced to undergo swifter transformations (UNCTAD 2020). COVID-19 laid bare the fact that individual countries may account for overwhelming supplies of certain inputs exported across GVCs, creating potential bottlenecks (Bacchetta et al. 2021). India and the PRC, for example, account for about 80 % of the active pharmaceutical ingredients market. But bottlenecks can result even if inputs are produced across diverse geographies, particularly if there are severe capacity constraints. These remain evident from the continued disruptions affecting GVCs throughout 2021.

The longer the GVC, the more likely it is to be exposed to risks, for two main reasons. First, because firms operate across longer distances (geographic, economic, cultural, or institutional), bounded rationality and bounded reliability challenges increase (Verbeke 2020). And second, GVCs have lacked redundancy and risk-mitigation plans to cope with extraordinary shocks, such as COVID-19 (Silverthorne 2020). Concentrating on efficiency and productivity, and reducing production costs, made GVCs less resilient, leading to rising calls for diversification. Espitia et al. (2021) find GVCs to be more resilient to negative demand shocks in the absence of COVID-19.

Lund et al. (2020), examining firms’ responses to various risks including the COVID-19 pandemic, estimate that “16 to 26 percent of exports, worth \$2.9 trillion to \$4.6 trillion in 2018, could be in play,” possibly reverting to domestic production, nearshoring, or offshoring to new locations in the next 5 years. Others suggest that COVID-19 may propel GVCs to further “micro-modularize,” reducing the risk of single micro-modules and enabling easier substitution (Verbeke 2020). Substantial GVC nationalization or regionalization risks reducing the diversification of suppliers and opportunities for some developing countries. Yet others, especially those closer to major markets, could capture growing opportunities from increased geographical diversification (UNIDO 2020; Qiang, Liu, and Steenberg 2021). GVCs in medical supplies and devices have benefitted nontraditional exporters even more than traditional ones (Bamber, Fernandez-Stark, and Taglioni 2020).

Table 5.2 summarizes the discussion of generic correlates of GVC resilience and more specific conditions related to resilience in geopolitical, environmental, and COVID-19 risks.

Table 5.2: Relative Global Value Chain Resilience and Adaptation to Risks			
Features	Risk Type		
	Geopolitical	Environmental	Pandemic (COVID-19)
Generic correlates of global value chain (GVC) resilience	<p><b>Variables affecting relative resilience</b></p> <p>Nature and magnitude of shock, including size and sector/region specificity</p> <p>Distinctive GVC features, including symmetric versus hub and presence of choke points</p> <p>Industry and firm topographies, including upstream versus downstream and geographic dispersion</p> <p>Availability of substitutions (short, long term)</p> <p>Degree of transactional stickiness in GVC partnerships</p> <p><b>Selected findings</b></p> <p>GVCs can amplify the impact of shocks</p> <p>GVCs enable diversification that mitigate risks, reduce volatility, and enhance resilience</p> <p>Longer GVCs are more vulnerable</p> <p>Shocks propagate more strongly in GVCs featuring asymmetric intersectoral links and choke points (where a few hubs or lead firms connect the network)</p> <p>Supply-side shocks propagate downstream more powerfully than upstream</p> <p>Relative GVC resilience hinges on the availability of substitutions, short and long term, and on the stickiness of supply chain relationships</p> <p>Firms build resilience via automation, digitalization, diversification, “just in case” strategies, capacity buffers, regionalization, near shoring, and shorter GVCs</p> <p>Reshoring has hardly been the norm so far</p> <p>Digitalization increases vulnerability to cyberattacks</p>		
Correlates of GVC resilience and vulnerability by specific risk type	<p>Geopolitical shocks target knowledge-intensive, specialized, and localized ecosystems with unique suppliers and expert pools, often difficult to substitute (high input-specificity) and with high potential for propagating</p> <p>Lead firms with intangible assets limit range of suppliers for fear of intellectual property exploitation</p> <p>Typical targets: countries with highly concentrated levels of specific inputs, unreliable suppliers, countries erecting illegal/arbitrary restrictions or are perceived to violate international agreements or norms in environmental, human rights, or security</p>	<p>Extreme events often highly localized and temporally confined, hence GVCs enable adjustment (shock absorber)</p> <p>GVCs can amplify environmental risks in the short run, especially in agglomerated industry locations</p> <p>GVCs can enhance resilience by allowing diversification; some evidence of firms diversifying after disasters</p>	<p>Value chains with higher complexity, length, and more concentrated production or distribution are relatively more exposed to risk</p> <p>Substantial GVC nationalization or regionalization risks reducing diversification and opportunities for countries to benefit from GVCs</p> <p>The absence of robust coordination across countries exacerbates damages to GVCs</p>
Firms’ adaptation strategies by risk type	<p>Geographic and supplier diversification, domestic and international</p> <p>Substituting away from concentrated or politically unreliable firms/country suppliers</p> <p>Developing alternatives to unique suppliers with high input specificity</p> <p>Moving production and sourcing away from firms/countries showing rising geopolitical risk, arbitrary restrictions, lack of transparency, treaty violations, nationalist backlash</p> <p>Enhancing protection from state and private cyberattacks</p>	<p>Short-term: adjust procurement share, substitute with alternative suppliers, customers, and trade routes</p> <p>Medium-term: adjust supply chain relationships to diversify exposure to environmental risks; insurance to protect against large losses</p> <p>Long-term strategies: changes in production patterns, trade, and migration policies to mitigate environmental damage</p>	<p>Localization of production of essential supplies; reduction in irreversible investments abroad</p> <p>Enhance diversity of trading partners (suppliers or buyers) in GVCs to allow easier substitution</p> <p>Accelerated adoption of digital technologies</p> <p>Improved balance of resource allocation between virtual and physical activities</p>

Source: Authors.



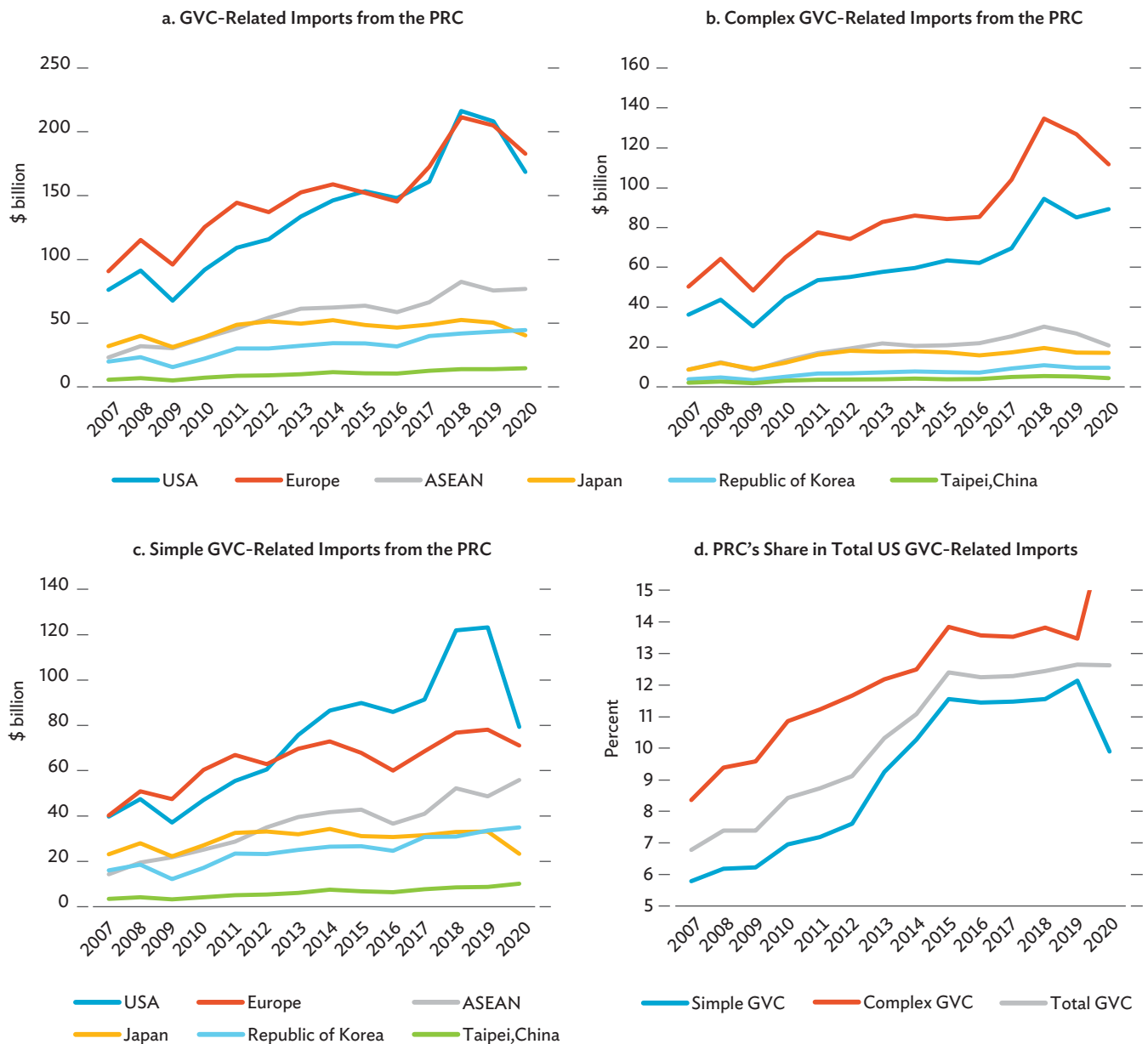
## Compounding Risks

The previous sections examined the sources, mechanisms, and effects on GVCs of each risk type largely in isolation. Those risks, however, have become compounded. Environmental and pandemic risks have been long-standing concerns in the context of GVC resilience. Geopolitical shocks, for one, have become an even greater threat than at any time in recent decades not only for their potential to disrupt GVCs directly but also to lower the likelihood that states will cooperate in preventing environmental and pandemic shocks affecting GVCs. COVID-19 was superimposed on preexisting geopolitical risks, deepening concerns with GVC dependence in medical equipment, pharmaceuticals, and vaccines, especially as individual economies dominate markets in critical inputs. In turn, heated controversies over the exact path through which COVID-19 first jumped into humans aggravated geopolitical tensions between the US, the PRC, and other economies, making cooperation on GVC on matters related to COVID-19 even more difficult. The pandemic raised the uncertainty initially induced by geopolitical tensions to its highest level in early 2020, although the onset of vaccination in early 2021 reduced this significantly (Ahir, Bloom, and Furceri 2021). Meier (2020) finds that GVC disruptions lengthen “time to build” (the delivery lag of capital goods) by 1 month, depressing GDP by 1.0% and aggregate total factor productivity by 0.2%.

In another instance of compounding risk, studies show that deforestation and climate change have increased the incidence of infectious diseases (Lafferty 2009) and fueled regional conflicts (Gleick 2014). Carbon border-adjustment policies proposed by the European Union to offset carbon emissions embedded in imported inputs have raised concerns that these policies could arguably mask protectionism and increase tensions. Compounded risk effects are especially visible in semiconductor shortages, where geopolitical, environmental, and COVID-19 shocks that especially affect East Asia created bottlenecks throughout critical GVCs. Factory closures caused by COVID-19 triggered global semiconductor shortages in 2020 and 2021, and this was exacerbated by extreme weather hitting Japan; Texas; and Taipei, China; with effects felt by automobile factories across all major GVC hubs in Asia, Europe, and the US.

Compounding risks make any definitive assessment of the cumulative impact of geopolitical shocks on GVCs, or of the separate effects of COVID-19 on them, more difficult, as those effects are conflated. Figure 5.1 gives a preliminary snapshot of selected aggregate effects on GVC-related imports from the PRC by Association of Southeast Asian Nations members; Europe; Japan; the Republic of Korea; Taipei, China; and the US from 2007 and 2020. Total European and US GVC imports from the PRC (panel a) have grown significantly since 2016, but show a clear inflection point downward since 2018—under the trade and technology war—which exacerbated throughout 2020 by COVID-19.

**Figure 5.1: Aggregate Effects on Global Value Chain-Related Imports from the People's Republic of China by Association of Southeast Asian Nations Members; Europe; Japan; Republic of Korea; Taipei,China; and the United States**



ASEAN = Association of Southeast Asian Nations, GVC = global value chain, PRC = People's Republic of China, USA = United States.  
Source: Authors' calculation based on Asian Development Bank's Multiregional Input-Output Database. <https://mrio.adbx.online> (accessed 31 July 2021); Asian Development Bank estimates.

Panels b and c disaggregate between complex and simple GVCs. Complex GVC-related imports from the PRC by European partners declined considerably since 2018—under the trade and technology war—whereas simple GVCs declined mildly and only in 2020, when COVID-19 was overlaid on geopolitical concerns. Interestingly, the decline in complex US GVC imports in 2018 and 2019, with the inception of the trade war, was reversed in 2020 despite combined geopolitical and pandemic uncertainty. Simple GVC-related US imports from the PRC declined dramatically in 2020, perhaps reflecting

more of a COVID-19 effect. They have grown slightly for the Republic of Korea and more noticeably for Association of Southeast Asian Nations members since 2016, but declined for Japan in 2020. Panel d shows a stable PRC share of total complex GVC-related imports into the US since 2015, declining slightly from 2018 to 2019 under rising geopolitical risk, but rising sharply in 2020 despite compounded geopolitical and COVID-19 risks. A stable PRC share in simple GVC-related imports increased slightly in 2019, but has declined significantly since then under compounded risks.

How have firms and GVCs adapted to compounded meta-risks? Automation, digitalization, diversification, multiple sourcing within and across economies, “just in case” inventories, redundancy, capacity buffers, nearshoring of production or suppliers, better GVC mapping, and transparency and visibility have emerged as the dominant responses for coping with compounded uncertainty. Reshoring has hardly been the standard GVC response as of mid-2021, arguably because GVCs reflect market mechanisms and efficiency more than nonmarket shocks (Meng and Ye forthcoming; Qiang, Liu, and Steenberg 2020). Yet there is no guarantee this trend presages the future. Automation and digitalization have emerged as dominant GVC responses to uncertainty, but are also pregnant with implications for potential declines in employment, rising inequality and poverty in developing and developed economies, truncated technological upgrading in developing economies, and greater risk of cyberattacks.

Systematic data on ongoing relocation and reshoring is still fragmentary, although firm-level surveys provide a window into extant responses to the twin shocks (Solingen 2021). An October 2019 survey found that 90% of US firms were affected by US-PRC trade tensions, requiring diversification of suppliers, risk management, and cost control; 60% of respondents ranked those tensions as their top concern over the next 3 years (PwC and AmCham China 2020). A March 2020 subset of that survey (25 large US firms in the PRC) showed that only 44% of respondents thought US-PRC decoupling was “impossible,” down from 66% in October 2019. About 94% of respondents put the PRC among the top five priorities in 2015, declining to 82% by 2019 with the onset of trade tensions (US-China Business Council 2019). Out of over 700 firms deployed globally, 96% of US-based firms and 100% of European ones listed the PRC among their top-three sourcing countries in 2019, declining to 77% and 80%, respectively, by March 2021 (Zhou 2021). US-PRC trade tensions were the most significant driver of GVC changes in 2019, including a loss in the PRC’s global export market share (Baker McKenzie 2020). “Rising tensions in US-PRC relations” were not among the top five business challenges in surveys in 2017 and 2018, but rose to third highest in surveys in 2019 and 2020, and ranked top by late 2020, especially in the category of services (76%) and technology and R&D-intensive industries (65%) (AmCham China 2021b). In a 2021 survey of 900 GVC managers from Europe and the US, 51% of respondents reported disruptions from COVID-19, 51% from geopolitical events and the US-PRC trade dispute, and 25% from disasters (Interos 2021).

In 2019, most firms in an American Chamber of Commerce survey considered “in China for China” strategies suitable for mitigating the impact of trade and technology tensions, and 83% had no plans to relocate GVC production or operations (AmCham China 2020). By early 2020, however, 33% firms reported to have moved sourcing and manufacturing out of the PRC or were planning to do so, with US–PRC tensions featured in decisions to relocate to non-US destinations for 50% of those firms (John and Raman 2020). Tariffs, which according to this survey increased costs by up to 10% for about 40% of respondents (rising costs were even higher for another 10%), were the primary factor driving sourcing or production out of the PRC for 73% of respondents. Concerns over the technology and trade war accounted for 30% of incentives to diversify out of the PRC. A 2020 American Chamber of Commerce in Shanghai survey shows that whereas 81% of firms projected increases in PRC investments in 2016 (before the trade tensions), only 48% did so in 2019 (once tensions were in place), and this was down to 28% in 2020 from the compounded effects of the trade and technology war and COVID-19 (AmCham Shanghai 2020).

The outcome of the 2020 US elections restored some confidence, with nearly 63% of respondents in an American Chamber of Commerce in Shanghai survey reporting greater optimism about doing business in the PRC, 82% not planning relocation, 85% expecting no increases in trade restrictions or tariffs, and only 10% still planning to relocate over 20% of their production out of the PRC, citing uncertainty about US-PRC relations as a top concern (AmCham Shanghai 2020; AmCham China 2021a). Visa and travel restrictions related to the COVID-19 pandemic affected 75% of respondents and, by 2021, 92% of US and other foreign firms and 85% of PRC firms deemed an escalation of US-PRC trade tensions to be quite likely or very likely (AmCham [based in Guangdong, PRC] 2021). Most other surveys on US-PRC trade tensions did not envisage a massive or immediate GVC relocation out of the PRC, given the country’s comparative advantage and domestic market size. However, significant diversification increased via “China+1” and “China + many” strategies, and it is possible that the longer-term incentives of firms to relocate may not be detectable at the time of writing. Lock-in effects raise the costs of relocation away from upstream and downstream partners in the short term (Qiang, Liu, and Steenbergen 2021).

The International Monetary Fund, in a mid-2021 economic outlook of Asia and the Pacific, notes little evidence of bifurcation into parallel structures aligned with the US or PRC sphere of influence, but warned against trade tensions morphing into technological decoupling that would inflict much larger costs on the global economy (IMF 2021b). Yet geopolitical tensions reinforced a preexisting trend driven by the PRC’s rising labor costs pushing firms from Japan; the Republic of Korea; and Taipei, China to relocate production and final assembly to Southeast Asia and India. The 2021 American Chamber of Commerce in China Business Climate Survey reports that developing Asia captured 42% of favored destinations, developed Asia 7%, Canada and Mexico a combined 19%, the European Union 7%, and the US 14% (AmCham China 2021a). A Japan External Trade Organization April 2021 survey of 424 Japanese companies with affiliates in the PRC reported that 86% had no plans for relocation in the short term (Zhou 2020).

Japan disbursed nearly \$3 billion by early 2021 to support 203 Japanese firms with incentives to reshore, especially in medical and semiconductor industries (Regalado 2021). Some firms reported that they had moved sensitive business activities out of the PRC to hedge against regional geopolitical risks. US and PRC export controls became the biggest concern for Japanese firms with subsidiaries in the PRC, replacing tariffs, in a survey in late 2020 of 2,700 of these firms (JETRO 2021). In 2021, LG Corporation announced plans to reduce global dependence on the PRC for materials and components for electric vehicle batteries on account of broader international concerns over lithium and cobalt supplies and prices.

The accelerated digitalization of GVCs has pushed firms to automate production, store key information online, and create an industrial Internet of Things, allowing computers built into factories, cars, and offices to communicate with each other. The COVID-19 pandemic accelerated this trend by several years (McKinsey & Company 2020). However, economies at different levels of digitalization and firms with different R&D endowments and GVC positions create digital divides. Furthermore, new technologies cannot mitigate all the adverse economic effects of COVID-19; GVCs still require face-to-face interaction to complement virtual interaction.

Digital technologies also have a dark side. Digitalization has increased vulnerability to cyber security risks to GVCs and associated infrastructure, compounding all three meta-risks. Jamilov, Rey, and Tahoun (2021) found that cyber risk has quadrupled since 2002 and more than tripled since 2013, with both the number of firms and intensity of the impact at record highs. Geopolitical and pandemic risks have, in turn, exacerbated cyber risks, targeting a widening range of global industries deployed along GVCs. In a typical vicious cycle, cyberattacks have aggravated geopolitical and pandemic risks, which in turn have fueled campaigns of misinformation and public deception. The 2021 Interos survey of 900 European and US GVC managers found that only 22% of respondents were not affected by cybersecurity breaches (Interos 2021). The World Economic Forum's *Global Risks Report 2021* cites cybersecurity among the top risks facing the world (WEF 2021). A combustible combination of geopolitical tensions and cyberattacks have intensified risks to GVCs at a time of diminished trust and weak multilateral cooperation.

In 2019 and 2020, a US federal grand jury indicted a group of Chinese nationals labeled "Apt41" for cyberattacks against 100 companies in the US and elsewhere, accusing them of theft of IP along with business and customer data (Department of Justice 2020). The charges mentioned targets including software developers, computer hardware manufacturers, and telecommunications providers, as well as universities, think tanks, and governments. Other charges included a hacking campaign over 7 years in relation to the aviation, defense, education, government, health care, and biopharmaceutical sectors worldwide (Kiran, Warrell, and Murphy 2021; White and Shepherd 2021). In 2020, the European Union imposed its first cyber sanctions against individuals and organizations from the Democratic People's Republic of Korea, the PRC, and the Russian Federation for alleged cyberattacks, including Operation Cloud Hopper against a lead GVC firm.

A cyberattack on Microsoft Exchange compromised over 100,000 servers worldwide, triggering the broadest condemnation of these attacks ever by Australia, the European Union, Japan, New Zealand, and 30 NATO countries. The outcry stopped short of imposing sanctions (Hudson and Nakashima 2021). In May 2021, a ransomware group based in the Russian Federation launched a cyberattack that shut down a pipeline supplying nearly half the oil to the US east coast for 5 days, causing major disruptions to supply chains.

In sum, risks compounding geopolitical and cyber tensions, natural hazards, and the COVID-19 pandemic have generated incentives for economies and firms to invest significantly in enhancing resilience to these risks. These measures have so far resulted in only a limited decline in the PRC's standing as the "factory of the world" and this does not look likely to change in the short term. But it could certainly buttress further GVC decoupling under more extreme inward-oriented geopolitics, fueled by rising protectionism, populism, and hypernationalism. Investments in resilience could also yield a modified but far from obsolescing GVC infrastructure that emerges nimbler and geographically diversified for coping with various types of risk.

## Conclusions and Policy Recommendations

Writing at an inflection point in mid-2021 precludes a firm assessment of whether GVCs are becoming more or less resilient to the risks addressed in this chapter, but this section offers recommendations for reducing all three risk types. As many studies document, and this chapter echoes, GVCs can exacerbate each of those risks. The primary focus here, however, was the reverse causal arrow: why and how these risks affect GVCs. All three risks *from* GVCs are on the rise as are all three risks *to* GVCs. All three risks are becoming more predictable, to varying degrees, as the understanding of their sources and mechanisms improves. All three can be better contained domestically and internationally if handled well, especially because they all can have anthropogenic sources or mechanisms. All fuel unfortunate synergies across them and are increasingly compounded by cyberattacks. Unless appropriate policies are adopted for reducing those risks, the remarkable benefits that GVCs can bring, examined in other chapters of this report, will be at stake.

This chapter's overview of the sources, mechanisms, and effects underlying those risks leads to an overarching recommendation: the optimal strategy is confronting them at their source. Prevention can dramatically reduce the burden of coping with rising risks. Only international collaboration, reciprocity, and transparency will defeat uncontrolled climate change, pandemics, and the unconstrained, unilateral pursuit of relative gains in interstate relations. Geopolitical shocks inspired by extreme inward-oriented strategies generate both direct and indirect risks to GVCs by undermining cooperation geared to dampen environmental and pandemic risk. Further research will improve the ability to identify more specific synergies across the three risk types. The rest of this section distills seven more fine-grained complementary recommendations.



First, GVCs can indeed amplify and compound the effects of all three shocks. Geopolitical tensions enhance uncertainty, decrease investment, create bottlenecks, reduce productive economic exchange, and unleash contagion throughout GVCs. Extreme weather is stretching GVC capacities worldwide. COVID-19 affected trade primarily through GVCs. Notwithstanding those effects, research suggests that reshoring would reduce GDP further without significant increases in resilience. Calls for radical renationalization can overwhelm sober analysis of the net costs of dismantling GVCs, especially in the Beyond Production era. While GVCs may magnify shocks, they can also help mitigate them. Initial export restrictions under COVID-19 exposed the fragility of GVCs in essential goods, knowledge-intensive sectors, health care, and pharmaceutical goods, but subsequent relaxation proved that GVCs were quite resilient. Shortfalls and gridlock remain due to spikes in demand and lingering labor supply disruptions and lockdowns, as well as container shortages, transportation bottlenecks, outdated port and road infrastructure, and surging prices.

Second, enhancing GVC resilience is not equivalent to pursuing extreme self-reliance, a policy that is inefficient, costly, often ineffective, and counterproductive even for the largest countries. Most goods and services not tightly connected to national security do not justify complete self-reliance, subsidies, or import protection that increases consumer prices. Nor do risky shifts to self-reliance guarantee supply, especially when shocks affect domestic production. Limited global geographic diversification heightens vulnerability to shocks whereas dependable outward-oriented strategies foster GVCs with broader access to goods, services, specialization, and innovation. Outward-oriented strategies are also better poised than their alternatives to advance more environmentally sustainable and cooperative policies on a wide range of issues, including pandemic prevention and mitigation.

Third, surveys suggest that all three risk types are underpinning efforts to enhance the resilience of GVCs by adopting ICT, automation and digitalization, diversifying suppliers, expanding inventories, encouraging redundancies and “just in case” operations, regionalization, nearshoring, and striving to reduce dependency on any single economy for production or sourcing. GVCs are also increasing transparency and accurate mapping to facilitate timely substitution and geographic diversification. Automation has been a more typical response than reshoring so far, but increased pressure for accelerating reshoring cannot be discounted.

Fourth, efforts to restore confidence in GVC benefits require hard work at every level and awareness of synergies across those levels. Greater sensitivity to domestic distributional considerations from participating in GVCs can help reduce the impulse toward extreme inward-looking strategies premised on costly and elusive aspirations of self-sufficiency. MNCs capture massive returns from progressively more knowledge-intensive GVCs, deepening income disparities, and eroding public support for GVCs. Strengthening antitrust policies and competition helps minimize economic and political risk. Proper and fair tax reform for MNCs is vital for increasing equity and improving

labor and environmental protections. Agreement on a minimum global corporate tax could be followed by greater transparency in intra-firm income transfers and improved data collection on intangibles in GVCs. Eliminating poverty and reducing inequality also provides stronger foundations for technological upgrading.

Fifth, policies must prioritize renewable energy and decarbonization, making progress and improving on the Paris Agreement goals by combatting illegal deforestation linked to food-related GVCs, eliminating fossil fuel subsidies, adopting minimum carbon pricing and improved carbon emission standards, and other urgent measures toward net zero. UN Secretary-General António Guterres declared in March 2021: “Phasing out coal from the electricity sector is the single most important step to get in line with the 1.5-degree goal” (UN 2021). A more circular economy requires sustainability across all GVC stages. Sustainable, reusable packaging and zero waste are of growing importance to consumers and would help cushion GVCs from future shocks. Adjustments may be costly in the short term, but they are bound to yield a more sustainable environment for GVCs in the longer term.

Sixth, geopolitical tensions and coercive economic statecraft have introduced unprecedented risks to GVC operations, higher than at any time in recent decades. This has magnified generalized uncertainty, reduced trust in the integrity of GVCs, triggered retaliatory downward spirals, and undermined the global movement of people who lubricate GVC operations, especially in services and intangibles and more broadly in science, technology, and innovation. Global interdependence via GVCs entails complex compromises in terms of relative costs and gains that must be weighed against those risks. Inattention to their differential costs and benefits clouds a fitting recognition of GVCs’ contributions to growth, welfare, innovation, productivity, ability to leapfrog, and peaceful international exchange over and beyond the benefits from non-GVC trade. The absence of reciprocity and transparency, and deficient compliance with multilateral commitments, undermine trust and fuel incentives to redress grievances unilaterally. Coercive economic statecraft, in turn, triggers counterproductive blowback and spillback effects, decreased investment, lower exports, rising unemployment, and Pyrrhic victories that hurt senders as much as targets and spill over into other domains in interstate relations. Further research must include not only the quantifiable but also reputational costs of coercive statecraft that can be harder to estimate before their application.

Seventh, strengthened multilateral institutions can help rebuild trust by, for instance, bolstering compliance with nondiscrimination, reciprocity, transparency, and IP rights, all of which are of huge relevance to knowledge-intensive GVC operations and trade in intangibles. A revitalized WTO can be empowered to play important new roles in reducing distortions, such as subsidies; reinforcing fair competition and market-oriented policies; strengthening information and cross-border digital flows and data privacy; and further liberalization of services. As WTO Director-General Ngozi Okonjo-Iweala has put it, the future of trade is services, digital, green, and inclusive (Harding 2021). Initial export restrictions on personal protective equipment hindered the collective ability to

cope with the most devastating pandemic in a century. WTO rules must be especially flexible for COVID-19 vaccine inputs. Much remains to be learned from failures of international policy coordination that might have otherwise improved supply chains and the timely delivery of vaccines worldwide (Bown and Bollyky 2021).

Other multilateral forums must urgently tackle cybersecurity because cyberattacks on GVCs and industrial and economic targets especially relevant to Beyond Production activities have soared to critical levels. Cyberattacks have brought the nontrivial potential that economic statecraft and technological competition spill over into the security realm to dangerous levels. A global compact reducing cyber risks to GVCs would be a stepping-stone toward a deeper and broader international regime curtailing the use of cyber space for nefarious aims. Countries must also converge around an upgraded multilateral early warning system for pandemics that guarantees effective transparency and the timely provision of data and all pertinent information, which WHO can help coordinate. A global blueprint for pandemic preparedness requires significant new funding from international financial institutions, including development banks and the International Monetary Fund, as well as scaled up, geographically diversified end-to-end GVCs for diagnostic tools, therapeutics, vaccines, and personal protective equipment (Group of 20 2021). Guan et al. (2020) provide a prescient insight on the lockdown effects on GVCs. Here, relaxing restrictions gradually (e.g., over 12 months) resulted in significantly lower declines in GVC value added (39.5%) than would have been the case with the quick lifting of restrictions, which would have resulted in recurrent future lockdowns (with declines of 49.5% and 61.5% in alternative scenarios). The study also suggests that a pattern where individual countries adopt disease control measures without consideration of their overall effects on GVCs leads to suboptimal outcomes. Developing a global cost-sharing instrument ahead of the next potential pandemic could enable a fairer distribution of the costs of monitoring, containing, and suppressing emerging diseases, while strengthening incentives for early action.

In the absence of these and other urgent adjustments, the alternatives have only compounded and reproduced perverse synergies across geopolitical, environmental, and pandemic risks. The recommended solutions make more viable the return to virtuous circles between interdependence via GVCs and broader international cooperation. Beyond their contributions to the global economy, the complexity of GVCs engenders novel mechanisms of global interdependence that could raise the costs of conflict, making international cooperation more resilient than 20th century forms of economic exchange. But political will is of the essence, especially because risks are rapidly compounding. Timely cooperation on climate change might not only help soften the rough edges of geopolitical and pandemic risks but also reinforce mutual commitments across all three risk types.

## References

- Abe, M., and L. Ye. 2013. Building Resilient Supply Chains against Natural Disasters: The Cases of Japan and Thailand. *Global Business Review*. 14 (4). pp. 567–586.
- Acemoglu, D., U. Akcigit, and W. Kerr. 2016. Networks and the Macroeconomy: An Empirical Exploration. *NBER Macroeconomics Annual*. 30 (1). pp. 273–335.
- Acemoglu, D., V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi. 2012. The Network Origins of Aggregate Fluctuations. *Econometrica*. 80 (5). pp. 1977–2016.
- Acemoglu, D., and P. Restrepo. 2020. Robots and Jobs: Evidence from US Labor Markets. *Journal of Political Economy*. 128 (6).
- Adachi, D., H. Nakata, Y. Sawada, and K. Sekiguchi. 2016. *Adverse Selection and Moral Hazard in the Corporate Insurance Market: Evidence from the 2011 Thailand Floods*. Tokyo: Research Institute of Economy, Trade and Industry.
- Ahir, H., N. Bloom, and D. Furceri. 2019. New Index Tracks Trade Uncertainty across the Globe. IMFBlog. 9 September. Washington, DC: International Monetary Fund.
- . 2021. Why Global Uncertainty Is Declining. VoxEU. 18 May. <https://voxeu.org/article/why-global-uncertainty-declining>.
- Allison, G. 2017. *Destined for War: Can America and China Escape Thucydides's Trap?* Boston, MA: Houghton Mifflin Harcourt.
- AmCham China (American Chamber of Commerce China). 2020. *2020 China Business Climate Survey Report*. Beijing.
- . 2021a. *China Business Climate Survey Report*. Beijing.
- . 2021b. *American Business in China White Paper*. Beijing.
- AmCham Shanghai (American Chamber of Commerce Shanghai). 2020. *Post-Election Survey*. November. Shanghai.
- AmCham (based in Guangdong, PRC). 2021. *Special Report on the State of Business in (Guangdong; Fujian; Guangxi; Hainan; Hong Kong, China; and Macau, China)*. Guangdong. 25 February.
- Antràs, P. 2020a. De-Globalisation? Global Value Chains in the Post-COVID-19 Age. *NBER Working Paper*. No. 28115. Cambridge, MA: National Bureau of Economic Research.
- . 2020b. Conceptual Aspects of Global Value Chains. *World Bank Policy Research Working Papers*. No. 9114. Washington, DC: World Bank.
- Antràs, P., and S. R. Yeaple. 2014. Multinational Firms and the Structure of International Trade. In *Handbook of International Economics*. Amsterdam: Elsevier.
- Antràs, P., T. C. Fort, and F. Tintelnot. 2017. The Margins of Global Sourcing: Theory and Evidence from US Firms. *American Economic Review*. 107 (9). pp. 2514–2564.
- Autor, D. H., D. Dorn, and G. Hanson. 2013. The China Syndrome: Local Labor Market Effects of Import Competition in the United States. *American Economic Review*. 103 (6). pp. 2121–2168.
- Bacchetta, M., E. Bekkers, R. Piermartini, S. Rubinova, V. Stolzenburg, and A. Xu. 2021. COVID-19 and Global Value Chains: A Discussion of Arguments on Value Chain Organization and the Role of the WTO. *WTO Staff Working Paper*. No. ERSD-2021-3. Geneva: World Trade Organization.

- Baker McKenzie. 2020. Supply Chains Reimagined: Recovery and Renewal in Asia Pacific and Beyond. 17 August. Chicago, IL.
- Baldwin, D. A. 2020. *Economic Statecraft*. Princeton, NJ: Princeton University Press.
- Baldwin, R., and R. Freedman. 2020. Supply Chain Contagion Waves: Thinking Ahead on Manufacturing “Contagion and Reinfection” from the COVID Concussion. VoxEU. 1 April.
- Bamber, P., K. Fernandez-Stark, and D. Taglioni. 2020. Four Reasons Why Globalized Production Helps Meet Demand Spikes: The Case of Medical Devices and Personal and Protective Equipment. Let’s Talk Development. World Bank Blogs. Washington, DC: World Bank.
- Barrot, J. N., and J. Sauvagnat. 2016. Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks. *Quarterly Journal of Economics*. 131 (3). pp. 1543–1592.
- Barwick, P. J., S. Li, J. Wallace, and J. C. Weiss. 2019. Commercial Casualties: Political Boycotts and International Disputes. 10 July. SSRN Papers. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3417194](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3417194).
- Boehm, C. E., A. Flaaen, and N. Pandalai-Nayar. 2019. Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tōhoku Earthquake. *Review of Economics and Statistics*. 101 (1). pp. 60–75.
- Bogoch, I. I., A. Watts, A. Thomas-Bachli, C. Huber, M. U. Kraemer, and K. Khan. 2020. Pneumonia of Unknown Aetiology in Wuhan, China: Potential for International Spread via Commercial Air Travel. *Journal of Travel Medicine*. 27 (2).
- Bown, C. P. 2021. How COVID-19 Medical Supply Shortages Led to Extraordinary Trade and Industrial Policy. *Working Paper*. No. 21-11 (July). Washington, DC: Peterson Institute for International Economics.
- Bown, C. P., and T. J. Bollyky. 2021. How COVID-19 Vaccine Supply Chains Emerged in the Midst of a Pandemic. *Working Paper*. No. 21-12 (August). Washington, DC: Peterson Institute for International Economics.
- Cadestin, C., K. D. Backer, S. Miroudot, L. Moussiegt, D. Rigo, and M. Ye. 2019. Multinational Enterprises in Domestic Value Chains. *OECD Science, Technology and Industry Policy Papers*. Paris: Organisation for Economic Co-operation and Development.
- Carvalho, V. M., M. Nirei, M. Y. Saito, and A. Tahbaz-Salehi. 2021. Supply Chain Disruptions: Evidence from the Great East Japan Earthquake. *Quarterly Journal of Economics*. 136 (2). pp. 1255–1321.
- Caselli, F., M. Koren, M., Lisicky, and S. Tenreyro. 2020. Diversification through Trade. *Quarterly Journal of Economics*. 135 (1). pp. 449–502.
- Colon, C., S. Hallegatte, and J. Rozenberg. 2021. Criticality Analysis of a Country’s Transport Network via an Agent-Based Supply Chain Model. *Nature Sustainability*. 4 (3). pp. 209–215.
- Constantinescu, C., A. Mattoo, and R. Michele. 2020. Policy Uncertainty, Trade and Global Value Chains: Some Facts, Many Questions. *Review of Industrial Organization*. 57. pp. 285–308.

- Costinot, A., D. Donaldson, and C. Smith. 2016. Evolving Comparative Advantage and the Impact of Climate Change in Agricultural Markets: Evidence from 1.7 Million Fields around the World. *Journal of Political Economy*. 124 (1). pp. 205–248.
- Cowan, B. W. 2020. Short-Run Effects of COVID-19 on US Worker Transitions. *NBER Working Paper*. No. 27315. Cambridge, MA: National Bureau of Economic Research.
- Cristea, A., D. Hummels, L. Puzello, and M. Avetisyan. 2013. Trade and the Greenhouse Gas Emissions from International Freight Transport. *Journal of Environmental Economics and Management*. 65 (1). pp. 153–173.
- Dasgupta, P. 2021. *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.
- Dell, M., B. F. Jones, and B. A. Olken. 2012. Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*. 4 (3). pp. 66–95.
- Dellink, R., H. Hwangi, E. Lanzi, and J. Chateau. 2017. International Trade Consequences of Climate Change. *OECD Trade and Environment Working Papers*. No. 2017/01. Paris: Organisation for Economic Co-operation and Development.
- Department of Justice, Government of the United States. 2020. Seven International Cyber Defendants, including “Apt41” Actors, Charged in Connection with Computer Intrusion Campaigns against More than 100 Victims Globally. 16 September. <https://www.justice.gov/opa/pr/seven-international-cyber-defendants-including-apt41-actors-charged-connection-computer>.
- di Giovanni, J., A. A. Levchenko, and I. Mejean. 2018. The Micro Origins of International Business-Cycle Comovement. *American Economic Review*. 108 (1). pp. 82–108.
- Engel, J., and D. Taglioni. 2017. The Middle-Income Trap and Upgrading along Global Value Chains. In *Global Value Chain Development Report 2017: Measuring and Analyzing the Impact of GVCs on Economic Development*. Washington, DC: World Bank.
- Escaith, H., and S. Inomata. 2013. Geometry of Global Value Chains in East Asia: The Role of Industrial Networks and Trade Policies. In D. K. Elms and P. Low, eds. *Global Value Chains in a Changing World*. Geneva: World Trade Organization.
- Espitia, A., A. Mattoo, N. Rocha, M. Ruta, and D. Winkler. 2021. Pandemic Trade: COVID-19, Remote Work and Global Value Chains. *World Economy*. 17 February. <https://doi.org/10.1111/twec.13117>.
- Farzanegan, M. R., M. Feizi, and H. F. Gholipour. 2020. Globalization and Outbreak of COVID-19: An Empirical Analysis. *Journal of Risk and Financial Management*. 14 (105). pp. 1–10.
- Forti, V., C. P. Baldé, R. Kuehr, and B. Garam. 2020. *The Global E-Waste Monitor 2020: Quantities, Flows and the Circular Economy Potential*. United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, International Solid Waste Association.
- Freund, C., A. Mattoo, A. Mulabdic, and M. Ruta. 2021. Natural Disasters and the Reshaping of Global Value Chains. *Policy Research Working Paper*. No. 9719. Washington, DC: World Bank.



- Friedt, F. L. 2021. Natural Disasters, Aggregate Trade Resilience, and Local Disruptions: Evidence from Hurricane Katrina. *Review of International Economics*. 16 March.
- Gao, Y., B. Meng, G. Suder, and J. Ye. 2021. Who Dominates Global Value Chains? Multinationals vs Domestic Firms. *IDE Discussion Paper*. No. 825. Chiba, Japan: Institute of Developing Economies – Japan External Trade Organization.
- Gereffi, G. 2020. What Does the COVID-19 Pandemic Teach Us about Global Value Chains? The Case of Medical Supplies. *Journal of International Business Policy* 3 (3). pp. 287–301.
- Gereffi, G., and X. Luo. 2014. Risks and Opportunities of Participation in Global Value Chains. *Policy Research Working Paper*. No. 6847. Washington, DC: World Bank.
- Gleick, P. H. 2014. Water, Drought, Climate Change, and Conflict in Syria. *Weather, Climate, and Society*. 6 (3). pp. 331–340.
- Gowa, J., and E. D. Mansfield. 1993. Power Politics and International Trade. *American Political Science Review* 87 (2). pp. 308–20.
- Grossman, G. M., and E. Helpman. 2020. When Tariffs Disturb Global Supply Chains. *NBER Working Paper*. No. 27722. Cambridge, MA: National Bureau of Economic Research.
- Group of 20. 2021. *A Global Deal for Our Pandemic Age*. Report of the G20 High Level Independent Panel on Financing the Global Commons for Pandemic Preparedness and Response. June.
- Guan, D., D. Wang, S. Hallegatte, S. J. Davis, J. Huo, S. Li, Y. Bai, et al. 2020. Global Supply-Chain Effects of COVID-19 Control Measures. *Nature Human Behaviour*. 4. pp. 577–587. <https://doi.org/10.1038/s41562-020-0896-8>.
- Harding, L. 2021 WTO Director-General Says Trade Critical in Solving Pandemic and Climate Change. Yahoo!Finance. 8 September.
- Hirschman, A. 2018. *National Power and the Structure of Foreign Trade*. Berkeley, CA: University of California Press.
- Hoegh-Guldberg, O., D. Jacob, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, et al. 2018. *Impacts of 1.5 C Global Warming on Natural and Human Systems*. An IPCC Special Report. World Meteorological Organization Technical Document. Geneva.
- Hudson, J., and E. Nakashima. 2021. US, Allies Accuse China of Hacking Microsoft and Condoning Other Cyberattacks. *Washington Post*. 19 July.
- Huneus, F. 2018. *Production Network Dynamics and the Propagation of Shocks*. Princeton, NJ: Princeton University.
- ILO (International Labour Organization). 2021. ILO Monitor: COVID-19 and the World of Work. 7th edition. Geneva. [https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/documents/briefingnote/wcms\\_767028.pdf](https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/documents/briefingnote/wcms_767028.pdf).
- IMF (International Monetary Fund). 2021a. 2021 Comprehensive Surveillance Review: Background Paper on the Surveillance Priority Confronting Risks and Uncertainties. *IMF Policy Paper*. May. Washington, DC.
- . 2021b. Transcript of April 2021 Asia and Pacific Department Press Briefing. 14 April. Washington, DC.

- Inomata, S., and D. Taglioni. 2019. Technological Progress, Diffusion, and Opportunities for Developing Countries: Lessons from China. In *Global Value Chain Development Report 2019*. Geneva: World Trade Organization. pp. 83–102.
- Inoue, H., and Y. Todo. 2019. Firm-Level Propagation of Shocks through Supply-Chain Networks. *Nature Sustainability*. 2 (9). pp. 841–847.
- . 2020. The Propagation of Economic Impacts through Supply Chains: The Case of a Mega-City Lockdown to Prevent the Spread of COVID-19. *PLoS ONE*. 15 (9). <https://doi.org/10.1371/journal.pone.0239251>.
- Interos. 2021. *Interos Annual Global Supply Chain Report*. Arlington, VA. <https://www.interos.ai>.
- IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press.
- . 2021. *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press.
- Jamilov, R., H. Rey, and A. Tahoun. 2021. The Anatomy of Cyber Risk. VoxEU. 5 July.
- JETRO (Japan External Trade Organization). 2021. *Survey on the International Operations of Japanese Firms*. March. Tokyo. [https://www.jetro.go.jp/ext\\_images/en/reports/survey/pdf/jafirms2020.pdf](https://www.jetro.go.jp/ext_images/en/reports/survey/pdf/jafirms2020.pdf).
- John, G., and K. Raman. 2020. Weathering the Storm: Supply Chain Resilience in an Age of Disruption. Gartner Research. ID G00467851. Stamford, CT.
- Jones, C. I. 2011. Intermediate Goods and Weak Links in the Theory of Economic Development. *American Economic Journal: Macroeconomics*. 3 (2). pp. 1–28.
- Kahn, M. E., K. Mohaddes, R. N. Ng, M. H. Pesaran, M. Raissi, and J-C. Yang. 2019. Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis. *NBER Working Paper*. No. 26167. Cambridge, MA: National Bureau of Economic Research.
- Kashiwagi, Y., Y. Todo, and P. Matous. 2018. Propagation of Shocks by Natural Disasters through Global Supply Chains. *RIETI Discussion Paper Series*. No. 18-E-041. Tokyo: Research Institute of Economy, Trade and Industry.
- Kastner, S. L. 2007. When Do Conflicting Political Relations Affect International Trade? *Journal of Conflict Resolution*. 51 (4). pp. 664–688.
- Kaza, S., L. C. Yao, P. Bhada-Tata, and V. W. Frank. 2018. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Urban Development Series. Washington, DC: World Bank.
- Keohane, R. O. 1984. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton, NJ: Princeton University Press.
- Kiran, S., H. Warrell, and H. Murphy. US Accuses China of Masterminding Cyber-Attacks Worldwide. *Financial Times*. 7 July.
- Kissler, S. M., C. Tedijanto, M. Lipsitchand, and Y. Grad. 2020. Social Distancing Strategies for Curbing the Covid-19 Epidemic. *medRxiv*. 1. pp. 1–10.

- Koehl, C. 2021. Neighbouring Countries Feel German Flood-Induced Supply Chain Impairments. EuroMetal. 30 July. <https://eurometal.net/neighbouring-countries-feel-german-flood-induced-supply-chain-impairments/>.
- Koren, M., and S. Tenreyro, S. 2013. Technological Diversification. *American Economic Review*. 103 (1). pp. 378–414.
- Kumagai, S., T. Gokan, K. Tsubota, I. Isono, K. Hayakawa, and S. Keola. 2020. Impact of the 2019 Novel Coronavirus on the Chinese and Asian Economies: Analysis Using IDE-GSM. *IDE Policy Brief*. No. 10. Chiba, Japan: Institute of Developing Economies – Japan External Trade Organization.
- Lafferty, K. D. 2009. The Ecology of Climate Change and Infectious Diseases. *Ecology*. 90 (4). pp. 888–900.
- Lange, S., J. Volkholz, T. Geiger, F. Zhao, I. Vega, T. Veldkamp, and K. Frieler. 2020. Projecting Exposure to Extreme Climate Impact Events across Six Event Categories and Three Spatial Scales. *Earth's Future*. 8 (12).
- Längle, K., A. Xu, and R. Tian. 2021. Assessing the Supply Chain Effect of Natural Disasters: Evidence from Chinese Manufacturers. *WTO Staff Working Paper*. No. ERSD-2021-13. Geneva: World Trade Organization.
- Lau, H., V. Khosrawipour, P. Kocbach, A. Mikołajczyk, Schubert, J. Bania, and T. Khosrawipour. 2020. The Positive Impact of Lockdown in Wuhan on Containing the COVID-19 Outbreak in China. *Journal of Travel Medicine*. 27 (3). pp 1–7.
- le Moigne, M., and R. Ossa. 2021. *Buy Green Not Local: How International Trade Can Help Save Our Planet*. Zurich: Kühne Center for Sustainable Globalization.
- Lenzen, M., D. Moran, K. Kanemoto, B. Foran, L. Lobefaro, and A. Geschke. 2012. International Trade Drives Biodiversity Threats in Developing Nations. *Nature*. 486 (7401). pp. 109–112.
- Li, X., and A.Y. Liu. 2019. Business as Usual? Economic Responses to Political Tensions Between China and Japan. *International Relations of the Asia-Pacific*. 19 (2). pp. 213–236.
- Linka, K., M. Peirlinck, F. Sahli Costabal, and E. Kuhl. 2020. Outbreak Dynamics of COVID-19 in Europe and the Effect of Travel Restrictions. *Computer Methods in Biomechanics and Biomedical Engineering*. 23 (11). pp. 710–717.
- Luo, Z., and Y. Zhou. 2019. Decomposing the Effects of Consumer Boycotts: Evidence from the Anti-Japanese Demonstration in China. *Empirical Economics*. 58 (6). pp. 2615–2634.
- Lund, S., J. Manyika, J. Woetzel, E. Barriball, M. Krishnan, K. Alicke, M. Birshan, et al. 2020. *Risk, Resilience, and Rebalancing in Global Value Chains*. McKinsey Global Institute.
- Mariasingham, M. J., K. Baris, J. P. de Vera, K. V. Garay, P. G. Gonzalez, A. B. Lumba, K. S. Reyes, and C. Yang. 2020. Measuring Global Value Chain Activities: Beyond Production. Background paper for the *Global Value Chain Development Report 2021*.
- Maliszewska, M., A. Mattoo, and D. van der Mensbrugghe. 2020. The Potential Impact of Covid-19 on GDP and Trade : A Preliminary Assessment. *Policy Research Working Paper*. No. 9211. Washington, DC: World Bank.
- Mas-Coma, S., M. K. Jones, and A. M. Marty. 2020. Covid-19 and Globalization. *One Health*. 9 June. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7184197/>.

- McKinsey & Company. 2020. How COVID-19 Has Pushed Companies over the Technology Tipping Point—and Transformed Business Forever. 5 October.
- Meier, M. 2020. Supply Chain Disruptions, Time to Build, and the Business Cycle. *Discussion Paper*. No 160. Mannheim: University of Mannheim.
- Menachery V. D., B. L. Yount Jr., K. Debbink, S. Agnihothram, L. E. Gralinski, J. A. Plante, R. L. Graham, et al. 2015. A Sars-Like Cluster of Circulating Bat Coronaviruses Shows Potential for Human Emergence. *Nature Medicine*. 21 (12). pp. 1508–1513.
- Meng, B., G. Peters, Z. Wang, and M. Li. 2018. Tracing CO<sub>2</sub> Emissions in Global Value Chains. *Energy Economics*. 73. pp. 24–42.
- Meng, B., and M. Ye. Forthcoming. Smile Curves in Global Value Chains: Foreign- vs. Domestic-owned Firms; the U.S. vs. China. *Structural Change and Economic Dynamics*.
- Meng, B., M. Ye, and S.-J. Wei. 2020. Measuring Smile Curves in Global Value Chains. *Oxford Bulletin of Economics and Statistics*. 82 (5). pp. 988–1016.
- Miroudot, S. 2020. Resilience versus Robustness in Global Value Chains: Some Policy Implications. In R. E. Baldwin and S. J. Evenett, eds. *COVID-19 and Trade Policy: Why Turning Inward Won't Work*. London: Centre for Economic Policy Research.
- Mutz, D. C. 2021. How Americans Think About Trade: Winners, Losers, and the Psychology of Globalization. *Foreign Affairs*. 30 July.
- Nag, R. M. 2011. Realizing the Asian Century. Speech at the Lee Kuan Yew School of Public Policy. Singapore. 18 October.
- North, D. 1981. *Structure and Change in Economic History*. New York: W. W. Norton.
- Nye, J. S. 2017. The Kindleberger Trap. Project Syndicate.
- OECD (Organisation for Economic Co-operation and Development). 2020. COVID-19 and Global Value Chains: Policy Options to Build More Resilient Production Networks. OECD Policy Responses to Coronavirus (COVID-19). Paris.
- . 2021. Global Value Chains: Efficiency and Risks in the Context of COVID-19. OECD Policy Responses to Coronavirus (COVID-19). Paris.
- O'Marah, K. 2017. Blind to Risk: Supply Chain Underestimates the Threat of War. 21 April. <https://blogs.gartner.com/beyond-supply-chain-blog/blind-risk-supply-chain-underestimates-threat-war/>.
- Patton, D. 2021. From Coal to Cars, Chinese Floods Tangle Supply Chains. Thomson Reuters. 22 July. <https://www.reuters.com/business/sustainable-business/coal-cars-chinese-floods-tangle-supply-chains-2021-07-22/>.
- Posen, A. 2021. The Price of Nostalgia: America's Self-Defeating Economic Retreat. *Foreign Affairs*. May/June.
- PwC (PricewaterhouseCoopers) and AMCham (American Chamber of Commerce in China). 2020. Supply Chain Strategies Under the Impact of Covid-19 of Large American Companies Operating in China. April.
- Qiang, C. Z., Y. Liu, and V. Steenbergen. 2021. *An Investment Perspective on Global Value Chains*. Washington, DC: World Bank. doi: 10.1596/978-1-4848-1683-3.
- Regalado, F. 2021. Japan Chip Suppliers Reap Benefits of “China Exit” Subsidy. *Nikkei Asia*. 25 January.

- Saurav, A., P. Kusek, R. Kuo, and B. Viney. 2020. The Impact of COVID-19 on Foreign Investors: Evidence from the Second Round of a Global Pulse Survey. World Bank Blogs. 6 October. Washington, DC: World Bank.
- Sforza, A., and M. Steininger. 2020. Globalization in the Time of Covid-19. *CESifo Working Paper Series*. No. 8184. Munich: Center for Economic Studies.
- Shih, V. 2021. Constructing a Chinese AI Global Supply Chain in the Shadow of “Great Power Competition.” In E. Solingen, ed. *Geopolitics, Supply Chains, and International Relations in East Asia*. Cambridge, United Kingdom: Cambridge University Press.
- Silverthorne, S. 2020. Has COVID-19 Broken the Global Value Chain? Research & Ideas. 16 April. Boston, MA: Harvard Business School.
- Solingen, E. 2007. Pax Asiatica versus Bella Levantina: The Foundations of War and Peace in East Asia and the Middle East. *American Political Science Review*. 101 (4). pp. 757–780.
- . 2012. *Sanctions, Statecraft, and Nuclear Proliferation*. Cambridge, United Kingdom: Cambridge University Press.
- . ed. 2021. *Geopolitics, Supply Chains, and International Relations in East Asia*. Cambridge, United Kingdom: Cambridge University Press.
- Solingen, E., and S. Inomata. 2021. GVC Interdependence and Geopolitics: What Is at Risk? Background Paper for the 2021 GVC Development Report Workshop. 9 October 2020.
- Strange, R. 2020. The 2020 Covid-19 Pandemic and Global Value Chains. *Journal of Industrial and Business Economics*. 47. pp. 455–465.
- Todo, Y., and H. Inoue. 2021. Geographic Diversification of the Supply Chains of Japanese Firms. *Asian Economic Policy Review*. 16 (2). pp. 304–322.
- Todo, Y., K. Nakajima, and P. Matous. 2015. How Do Supply Chain Networks Affect the Resilience of Firms to Natural Disasters? Evidence from the Great East Japan Earthquake. *Journal of Regional Science*. 55 (2). pp. 209–229.
- Tokui, J., K. Kawasaki, and T. Miyagawa. 2017. The Economic Impact of Supply Chain Disruptions from the Great East Japan Earthquake. *Japan and the World Economy*. 41 (C). pp. 59–70.
- UN (United Nations). 2021. UN Chief Calls for Immediate Global Action to Phase Out Coal. 2 March. <https://unfccc.int/news/un-chief-calls-for-immediate-global-action-to-phase-out-coal>.
- UNCTAD (United Nations Conference on Trade and Development). 2020. Impact of the Covid-19 Pandemic on Global FDI and GVCs. Global Investment Trends Monitor. 35 (Special issue March). Geneva.
- . 2021. Global Foreign Direct Investment Fell by 42% in 2020, Outlook Remains Weak. 24 January. Geneva.
- UNDRR (United Nations Office for Disaster Risk Reduction). 2020. *Hazard Definition and Classification Review: Technical Report*. Geneva.
- UNIDO (United Nations Industrial Development Organization). 2020. The Economic Impact of COVID-19 Pandemic. UNIDO News. 5 January. Vienna.
- US-China Business Council. 2019. *Member Survey*. Washington, DC.



- . 2020. *Member Survey*. Washington, DC.
- Vasquez, J. A. 1999. *The Power of Power Politics: From Classical Realism to Neotraditionalism*. Cambridge, United Kingdom: Cambridge University Press.
- Verbeke, A. 2020. Will the Covid Pandemic Really Change the Governance of Global Value Chains? *British Journal of Management*. 31 (3). pp. 444–446.
- Waldron, A. 2017. There is No Thucydides Trap. *SupChina*. 12 June. <https://supchina.com/2017/06/12/no-thucydides-trap/>.
- Walls, A. C., Y. J. Park, M. A. Tortorici, A. Wall, A. T. McGuire, and D. Veessler. 2020. Structure, Function, and Antigenicity of the SARS-CoV-2 Spike Glycoprotein. *Cell*. 181 (2). pp. 281–292.
- Wang, Z., S.-J. Wei, X. Yu, and K. Zhu. 2018. Re-examining the Effects of Trading with China on Local Labor Markets: A Supply Chain Perspective, *NBER Working Paper*. No. 24886. Cambridge, MA: National Bureau of Economic Research.
- White House. 2021. *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth, 100-Day Reviews under Executive Order 14017. A Report by the White House*. Washington, DC.
- White, E., and C. Shepherd. 2021. China Hits Back at US-Led Accusations over Cyber-Attacks. *Financial Times*. 21 July.
- Whyte, A. V., and I. Burton. 1980. *Environmental Risk Assessment*. Chichester, United Kingdom: John Wiley & Sons.
- Williamson, O. E. 1985. *The Economic Institutions of Capitalism*. New York: The Free Press.
- World Bank. 2020. *World Development Report 2020: Trading for Development in the Age of Global Value Chains*. Washington, DC.
- WEF (World Economic Forum). 2021. *The Global Risks Report 2021*. Geneva.
- Wu, Z., G. Hou, and B. Xin. 2020. The Causality between Participation in GVCs, Renewable Energy Consumption and CO2 Emissions. *Sustainability*. 12 (3). 1237.
- Xiao, H., B. Meng, J. Ye, and S. Li. 2020. Are Global Value Chains Truly Global? *Economic Systems Research*. 32 (4). pp. 540–564.
- Xing, Y. 2021a. Global Value Chains and the US-China Trade War. In E. Solingen, ed. *Geopolitics, Supply Chains, and International Relations in East Asia*. Cambridge, United Kingdom: Cambridge University Press.
- . 2021b. *Decoding China's Export Miracle: A Global Value Chain Analysis*. World Scientific Publishing.
- Xu, A., and A. R. Kouwoaye. 2019. How Do Natural Disasters Affect Services Trade? *WTO Staff Working Paper*. Geneva: World Trade Organization.
- Yeyati, E. L., and F. Filippini. 2021. Social and Economic Impact of COVID-19. *Brookings Global Working Papers*. Washington, DC: Brookings Institution.
- Yilmazkuday, H. 2019. Estimating the Trade Elasticity over Time. *Economics Letters*. 183.
- Zhang, H. 2021. The US-China Trade War: Implications for Japan's Global Value Chains. In E. Solingen, ed. *Geopolitics, Supply Chains, and International Relations in East Asia*. Cambridge, United Kingdom: Cambridge University Press.
- Zhang, Z., D. Guan, R. Wang, J. Meng, H. Zheng, K. Zhu, and H. Du. 2020. Embodied Carbon Emissions in the Supply Chains of Multinational Enterprises. *Nature Climate Change*. 10 (12). pp. 1096–1101.



Zhou, C. 2020. China Increasingly Worried about “Losing Face” as Japan Bankrolls Exodus of Firms. 5 August.

———. 2021. Global Supply Chain Continues to Shift Away from China, But It Remains the Top Sourcing Location. 30 April.

Zhu, L., K. Ito, and E. Tomiura. 2016. Global Sourcing in the Wake of Disaster: Evidence from the Great East Japan Earthquake. *RIETI Discussion Paper*. No. 16-E-089. Tokyo: Research Institute of Economy, Trade and Industry.