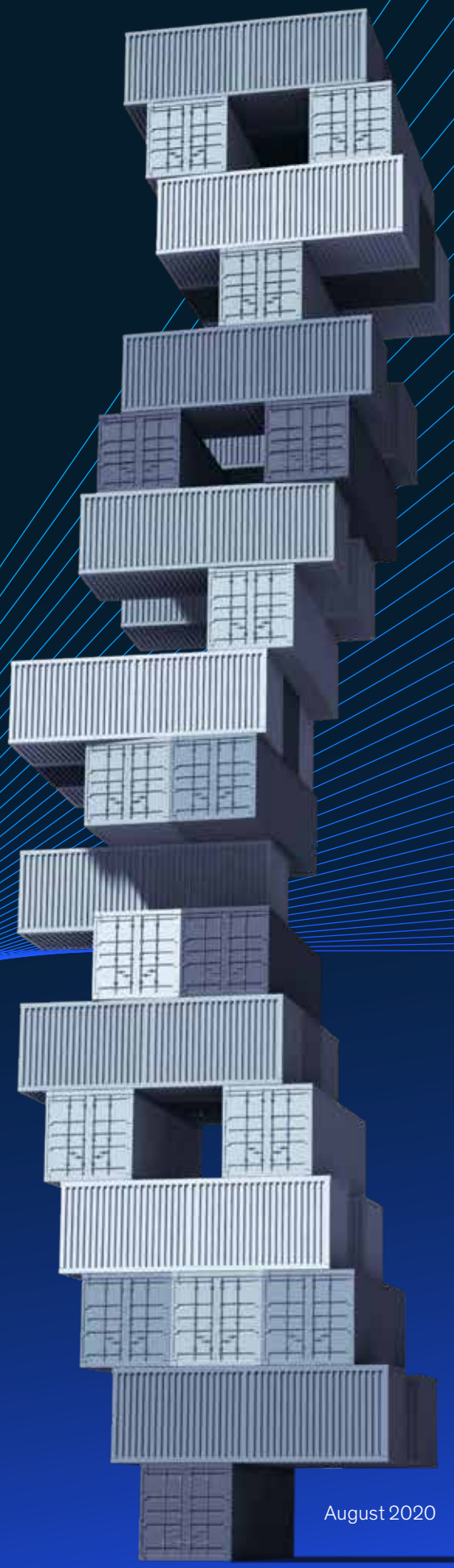
McKinsey Global Institute

Risk, resilience, and rebalancing in global value chains

Executive summary



August 2020

McKinsey Global Institute

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MGI is led by three McKinsey & Company senior partners: co-chairs James Manyika and Sven Smit and director Jonathan Woetzel. Michael Chui, Susan Lund, Anu Madgavkar, Jan Mischke, Sree Ramaswamy, Jaana Remes, Jeongmin Seong, and Tilman Tacke are MGI partners. Mekala Krishnan is an MGI senior fellow, and Sundiatu Dixon-Fyle is a visiting senior fellow. Project teams are led by the MGI partners and a group of senior fellows and include consultants from McKinsey offices around the world. These teams draw on McKinsey's global network of partners and industry and management experts.

The MGI Council is made up of McKinsey leaders and includes Michael Birshan, Andrés Cadena, Sandrine Devillard, André Dua, Kweilin Ellingrud, Tarek Elmasry, Katy George, Rajat Gupta, Eric Hazan, Acha Leke, Gary Pinkus, Oliver Tonby, and Eckart Windhagen. The Council members help shape the research agenda, lead high-impact research, and share the findings with decision makers around the world. In addition, leading economists, including Nobel laureates, advise MGI research.

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Preface

Manufactured goods take lengthy and complex journeys through global value chains as raw materials and intermediate inputs are turned into the final products that reach consumers. But global production networks that took shape to optimize costs and efficiency often contain hidden vulnerabilities—and external shocks have an uncanny way of finding and exploiting those weaknesses. In a world where hazards are occurring more frequently and causing greater damage, companies and policy makers alike are reconsidering how to make global value chains more resilient. All of this is occuring against a backdrop of changing cost structures across countries and growing adoption of revolutionary digital technologies in global manufacturing.

Applying MGI's micro-to-macro methodology, this report considers the issues and investment choices facing individual companies as well as the implications for global value chains, trade, and national economies. It builds on a large multiyear body of MGI research on topics such as global value chains and flows, manufacturing, digitization, and climate risk. This includes major reports such as *Manufacturing the future* (2012), *Global flows in a digital age* (2014), *Digital globalization* (2016), *Making it in America* (2017), *Globalization in transition* (2019), and *Climate risk and response* (2020), among others. This work also draws on McKinsey's on-the-ground experience in operations, supply chain management, and risk across multiple industries.

Our past research highlights important structural changes in the nature of globalization; goods producing value chains have become less trade-intensive, even as cross-border services are increasing. The share of global trade based on labor-cost arbitrage has been declining over the last decade and global value chains are becoming more knowledge-intensive and reliant on high-skill labor. Finally, goods-producing value chains are becoming more regionally concentrated. This report extends that research to better understand supply chain risk and resiliency. While the COVID pandemic has delivered the biggest and broadest value chain shock in recent memory, it is only the latest in a series of disruptions that has exposed value chains and companies to damages.

The research was led by Susan Lund, an MGI partner based in Washington, DC; James Manyika, MGI's co-chair, based in San Francisco; Jonathan Woetzel, an MGI director based in Shanghai; Ed Barriball, a Washington, DC–based partner who specializes in manufacturing, supply chain, and logistics; Mekala Krishnan, an MGI senior fellow, based in Boston; Knut Alicke, a Stuttgart-based partner with expertise in manufacturing and supply chains; Michael Birshan, a London-based senior partner who focuses on strategy and risk; Katy George, a New Jersey–based senior partner with expertise in manufacturing, operations strategy, and operating model design; Sven Smit, MGI's co-chair, based in Amsterdam; and Dan Swan, who leads McKinsey's global supply chain practice. The project team, led by Kyle Hutzler, included Bader Almubarak, Djavaneh Bierwirth, Mackenzie Donnelly, Dhiraj Kumar, Karol Mansfeld, Palak Pujara, and Stephanie Stefanski. Henry Marcil also provided leadership, insight, and support.

Many McKinsey colleagues contributed to this effort, and our research benefited immensely from their industry expertise and perspectives. We are grateful to Ingo Aghte, Emre Akgul, Aykut Atali, Xavier Azcue, Cengiz Bayazit, Stefan Burghardt, Ondrej Burkacky, Ana Calvo, Bob Cantow, Stephen Chen, Jeffrey Condon, Alan Davies, Arnav Dey, Reed Doucette, Hillary Dukart, Elena Dumitrescu, Phil Duncan, Kim Elphinstone, Ankit Fadia, Ignacio Felix, Tacy Foster, Kevin Goering, Arvind Govindarajan, Paul Hackert, Will Han, Philipp Härle, Liz Hempel, Drew Horah, Tore Johnston, Roos Karssemeijer, Pete Kimball, Tim Koller, Vik Krishnan, Randy Lim, Karl-Hendrik Magnus, Yogesh Malik, Adrian Martin, Brenden McKinney, Ricardo Moya-Quiroga, Mike Parkins, Parag Patel, Fernando Perez,

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This report contributes to MGI's mission to help business and policy leaders understand risks our society and the global economy face and how to build resilience against them. As with all MGI research, this work is independent, reflects our own views, and has not been commissioned by any business, government, or other institution. We welcome your comments on the research at MGI@mckinsey.com.

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In brief

Risk, resilience, and rebalancing in global value chains

Intricate supplier networks that span the globe can deliver with great efficiency, but they may contain hidden vulnerabilities. Even before the COVID-19 pandemic, a multitude of events in recent years temporarily disrupted production at many companies. Focusing on value chains that produce manufactured goods, this research explores their exposure to shocks, their vulnerabilities, and their expected financial losses. We also assess prospects for value chains to change their physical footprint in response to risk and evaluate strategies to minimize the growing cost of disruptions.

Shocks that affect global production are growing more frequent and more severe. Companies face a range of hazards, from natural disasters to geopolitical uncertainties and cyberattacks on their digital systems. Global flows and networks offer more "surface area" for shocks to penetrate and damage to spread. Disruptions lasting a month or longer now occur every 3.7 years on average, and the financial toll associated with the most extreme events has been climbing. Shocks can be distinguished by whether they can be anticipated, how frequently they occur, the breadth of impact across industries and geographies, and the magnitude of impact on supply and demand.

Value chains are exposed to different types of shocks based on their geographic footprint, factors of production, and other variables. Those with the highest trade intensity and export concentration in a few countries are more exposed than others. They include some of the highest-value and most sought-after industries, such as communication equipment, computers and electronics, and semiconductors and components. Many labor-intensive value chains, such as apparel, are highly exposed to pandemics, heat stress, and flood risk. In contrast, food and beverage and fabricated metals have lower average exposure to shocks because they are among the least traded and most regionally oriented value chains.

Operational choices can heighten or lessen vulnerability to shocks. Practices such as just-in-time production, sourcing from a single supplier, and relying on customized inputs with few substitutes amplify the disruption of external shocks and lengthen companies' recovery times. Geographic concentration in supply networks can also be a vulnerability. Globally, we find 180 traded products (worth $134 billion in 2018) for which a single country accounts for the vast majority of exports.

Value chain disruptions cause substantial financial losses. Adjusted for the probability and frequency of disruptions, companies can expect to lose more than 40 percent of a year's profits every decade on average. But a single severe event that disrupts production for 100 days—something that happens every five to seven years on average—could erase almost a year's earnings in some industries. Disruptions are costly to societies, too: after disasters claim lives and damage communities, production shutdowns can cause job losses and goods shortages. Resilience measures could more than pay off for companies, workers, and broader societies over the long term.

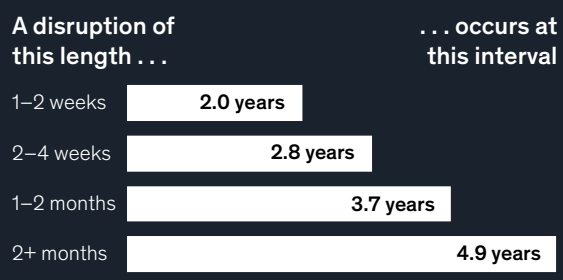
The interconnected nature of value chains limits the economic case for making large-scale changes in their physical location. Value chains often span thousands of companies, and their configurations reflect specialization, access to consumer markets around the world, long-standing relationships, and economies of scale. Primarily labor-intensive value chains (such as apparel and furniture) have a strong economic rationale for shifting to new locations. Noneconomic pressures may prompt movement in others, such as pharmaceuticals. Considering both industry economics and national policy priorities, we estimate that 16 to 26 percent of global goods exports, worth $2.9 trillion to $4.6 trillion, could conceivably move to new countries over the next five years if companies restructure their supplier networks.

Building supply chain resilience can take many forms beyond relocating production. This includes strengthening risk management capabilities and improving transparency; building redundancy in supplier and transportation networks; holding more inventory; reducing product complexity; creating the capacity to flex production across sites; and improving the financial and operational capacity to respond to shocks and recover quickly from them.

Becoming more resilient does not have to mean sacrificing efficiency. Our research highlights the many options for strengthening value chain resilience, including opportunities arising from new technologies. Where companies cannot directly prevent shocks, they can still position themselves to reduce the cost of disruption and the time it takes to recover. Companies have an opportunity to emerge from the current crisis more agile and innovative.

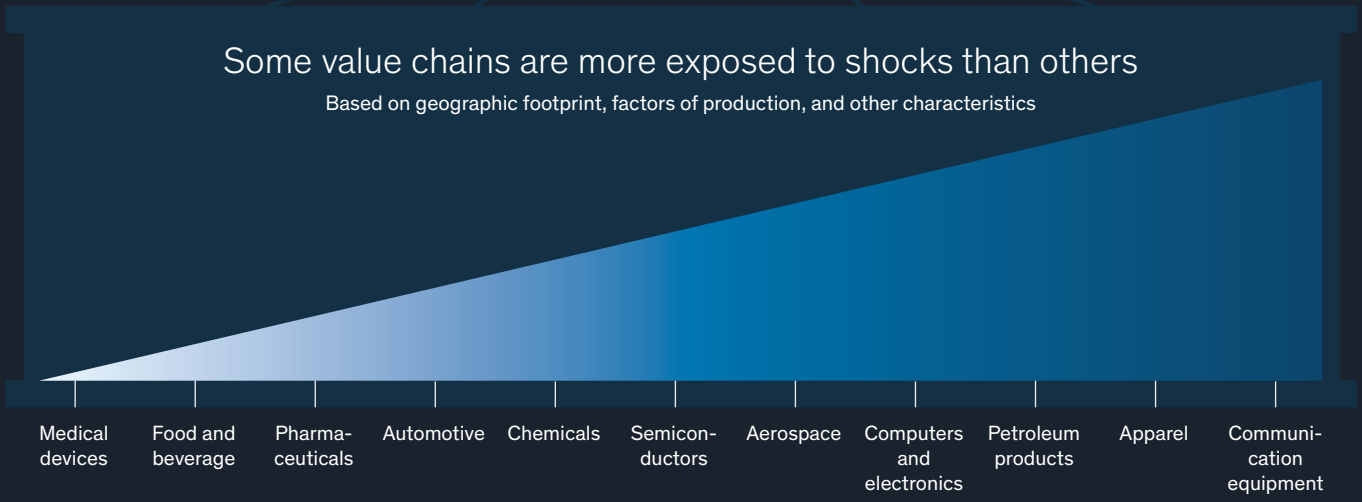
Risk, resilience, and rebalancing in global value chains

Supply chain shocks are becoming more frequent and severe



Some value chains are more exposed to shocks than others

Based on geographic footprint, factors of production, and other characteristics



Supply chain disruptions are costly

Shock exposure × **Vulnerability** = **Value chain risk**

Unexpected events that cause disruption

Force majeure
Macropolitical
Malicious actors
Idiosyncratic

Fragility in key areas

Demand planning and inventory
Supplier network structure
Transportation and logistics
Balance sheet
Product and portfolio complexity

Companies can expect to lose

42%

of one year's EBITDA every decade. Investing to minimize these losses can pay off over the long term

Companies can build resilience by improving supply chain management and transparency, minimizing exposure to shocks, and building their capacity to respond

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Executive summary

In recent decades, value chains have grown in length and complexity as companies expanded around the world in pursuit of margin improvements. Since 2000, the value of intermediate goods traded globally has tripled to more than $10 trillion annually. Businesses that successfully implemented a lean, global model of manufacturing achieved improvements in indicators such as inventory levels, on-time-in-full deliveries, and shorter lead times.

However, these operating model choices sometimes led to unintended consequences if they were not calibrated to risk exposure. Intricate production networks were designed for efficiency, cost, and proximity to markets but not necessarily for transparency or resilience. Now they are operating in a world where disruptions are regular occurrences. Averaging across industries, companies can now expect supply chain disruptions lasting a month or longer to occur every 3.7 years, and the most severe events take a major financial toll.

This report explores the rebalancing act facing many companies in goods-producing value chains as they seek to get a handle on risk. Our focus is not on ongoing business challenges such as shifting customer demand and suppliers failing to deliver, nor on ongoing trends such as digitization and automation. Instead, we consider risks that manifest from exposure to the most profound shocks, such as financial crises, terrorism, extreme weather, and, yes, pandemics.

The risk facing any particular industry value chain reflects its level of exposure to different types of shocks, plus the underlying vulnerabilities of a particular company or in the value chain as a whole. We therefore examine the growing frequency and severity of a range of shocks, assess how different value chains are exposed, and examine the factors in operations and supply chains that can magnify disruption and losses. Adjusted for the probability and frequency of disruptions, companies can expect to lose more than 40 percent of a year's profits every decade, based on a model informed by the financials of 325 companies across 13 industries. However, a single severe shock causing a 100-day disruption could wipe out an entire year's earnings or more in some industries—and events of this magnitude can and do occur.

Recent trade tensions and now the COVID-19 pandemic have led to speculation that companies could shift to more domestic production and sourcing. We examined the feasibility of movement based on industry economics as well as the possibility that governments might act to bolster domestic production of some goods they deem essential or strategic from a national security or competitiveness perspective. All told, we estimate that production of some 16 to 26 percent of global trade, worth $2.9 trillion to $4.6 trillion, could move across borders in the medium term. This could involve some combination of reverting to domestic production, nearshoring, and shifting to different offshore locations.

Moving the physical footprint of production is only one of many options for building resilience, which we broadly define as the ability to resist, withstand, and recover from shocks. In fact, technology is challenging old assumptions that resilience can be purchased only at the cost of efficiency. The latest advances offer new solutions for running scenarios, monitoring many layers of supplier networks, accelerating response times, and even changing the economics of production. Some manufacturing companies will no doubt use these tools and devise other strategies to come out on the other side of the pandemic as more agile and innovative organizations.

With shocks growing more frequent and severe, industry value chains vary in their level of exposure

The COVID pandemic has delivered the biggest and broadest value chain shock in recent memory (see Box E1, "Globalization before and after COVID-19"). But it is actually the latest in a long series of disruptions. In 2011, for instance, a major earthquake and tsunami in Japan shut down factories that produce electronic components for cars, halting assembly lines worldwide. The disaster also knocked out the world's top producer of advanced silicon wafers, on which semiconductor companies rely. Just a few months later, flooding swamped factories in Thailand that produced roughly a quarter of the world's hard drives, leaving the makers of personal computers scrambling. In 2017, Hurricane Harvey, a Category 4 storm, smashed into Texas and Louisiana. It disrupted some of the largest US oil refineries and petrochemical plants, creating shortages of key plastics and resins for a range of industries.

80%

of global trade involves nations with declining political stability scores from the World Bank

This is more than just a run of bad luck. Changes in the environment and in the global economy are increasing the frequency and magnitude of shocks. Forty weather disasters in 2019 caused damages exceeding $1 billion each—and in recent years, the economic toll caused by the most extreme events has been escalating.[1] As a new multipolar world takes shape, we are seeing more trade disputes, higher tariffs, and broader geopolitical uncertainty. The share of global trade conducted with countries ranked in the bottom half of the world for political stability, as assessed by the World Bank, rose from 16 percent in 2000 to 29 percent in 2018. Just as telling, almost 80 percent of trade involves nations with declining political stability scores.[2] Increased reliance on digital systems increases exposure to a wide variety of cyberattacks; the number of new ransomware variations alone doubled from 2018 to 2019.[3] Interconnected supply chains and global flows of data, finance, and people offer more "surface area" for risk to penetrate, and ripple effects can travel across these network structures rapidly.

To understand the full range of potential disruptions and avoid the trap of "fighting the last war," companies must look beyond the latest disaster. Not all shocks are created equal. Some pass quickly, while others can sideline multiple industry players for weeks or even months. Business leaders often characterize shocks in terms of their source. These may include *force majeure* events, such as natural disasters; macropolitical shocks, such as financial crises; the work of malicious actors, such as theft; and idiosyncratic shocks, such as unplanned outages. But characteristics beyond the source of a shock determine its scope and the severity of its impact on production and global value chains.

Exhibit E1 classifies different types of shocks based on their impact, lead time, and frequency of occurrence. In a few cases, we show hypothetical shocks like a global military conflict or a systemic cyberattack that would dwarf the most severe shocks experienced to date. While these may be only remote possibilities, these scenarios are in fact studied and planned for by governments and security experts. The impact of a shock can be influenced by how long it lasts, the ripple effects it has across geographies and industries, and whether a shock hits the supply side alone or also hits demand.

1 *Eye of the Storm*, "Earth's 40 billion-dollar weather disasters of 2019," *Scientific American* blog entry by Jeff Masters, January 22, 2020; and Matteo Coronese et al., "Evidence for sharp increase in the economic damages of extreme natural disasters," *Proceedings of the National Academy of Sciences*, October 2019, Volume 116, Number 43.

2 World Bank, Worldwide Governance Indicators 2018 (political stability and absence of violence/terrorism).

3 Anthony Spadafora, "Ransomware mutations double in 2019," TechRadar, August 20, 2019.

Box E1

Globalization before and after COVID-19

Trade flows ultimately reflect where countless companies decide to invest and make, buy, or sell things—as well as the intermediaries and arrangements they set up to do this as productively as possible. Trade in manufactured goods soared in the 1990s and early 2000s, propelled by China's entry into the WTO and the search by multinational companies for lower-cost inputs and wages. Digital communication lowered transaction costs, enabling companies to do business with suppliers and customers halfway around the world. Overall, goods trade grew at more than twice the rate of global GDP growth over this period. MGI's analysis finds that, over a decade, all types of flows acting together have raised world GDP by 10.1 percent over what would have resulted in a world without any cross-border flows.[1]

The 2008 financial crisis interrupted those trends, causing global trade flows to plummet. When the global economy recovered, they stabilized but did not return to their past growth trajectory. As described in MGI's 2019 research, this was largely because China and other emerging economies reached the next stage of their development.[2] They initially participated in global value chains as assemblers of final goods, but increasingly became the world's major engine of demand growth and started to develop more extensive domestic supply chains, decreasing their reliance on imported inputs. As a result of these developments, a smaller share of the goods produced worldwide is sold across borders.

The latest wave of manufacturing technologies also meant shifting dynamics within global value chains; only 13 percent of overall goods trade in 2018 involved exports from a low-wage country to a high-wage country.[3] In all except the most labor-intensive industries, companies started to base location decisions on other factors, including access to highly skilled talent, supplier ecosystems, infrastructure, business environment, and IP protection. Another long-term evolution is the regionalization of production networks. Long-haul trade between regions took off in the 1990s and early 2000s as global supply chains lengthened. But recently, trade has become more regionally concentrated, particularly within Europe and Asia–Pacific. This has enabled companies to serve major markets quickly and responsively. With rising complexity of global production, as well as concerns over trade disputes pre-COVID, supply chain risk and resilience have also been emerging as increasing considerations on companies' radars.

In the wake of the pandemic, travel, tourism, and migration may take years to return to previous levels. Trade in goods has taken a substantial hit, falling by 13 percent in the first three months of 2020. But much of this is due to a sharp contraction in demand that should eventually reverse when the virus is contained and economies recover. In the meantime, cross-border digital flows continue to take on greater importance as the connective tissue of the global economy.

COVID-19 seems to be accelerating some of the trends that were already manifesting within the world's value chains, including the regionalization of trade and production networks, the growing role of digitization, and the focus on proximity to consumers.[4] The increasing use of automation technologies in manufacturing is lessening the importance of low labor costs—and more automated plants could be more resilient in the face of pandemics and heat waves (although potentially more vulnerable to cyberattacks).

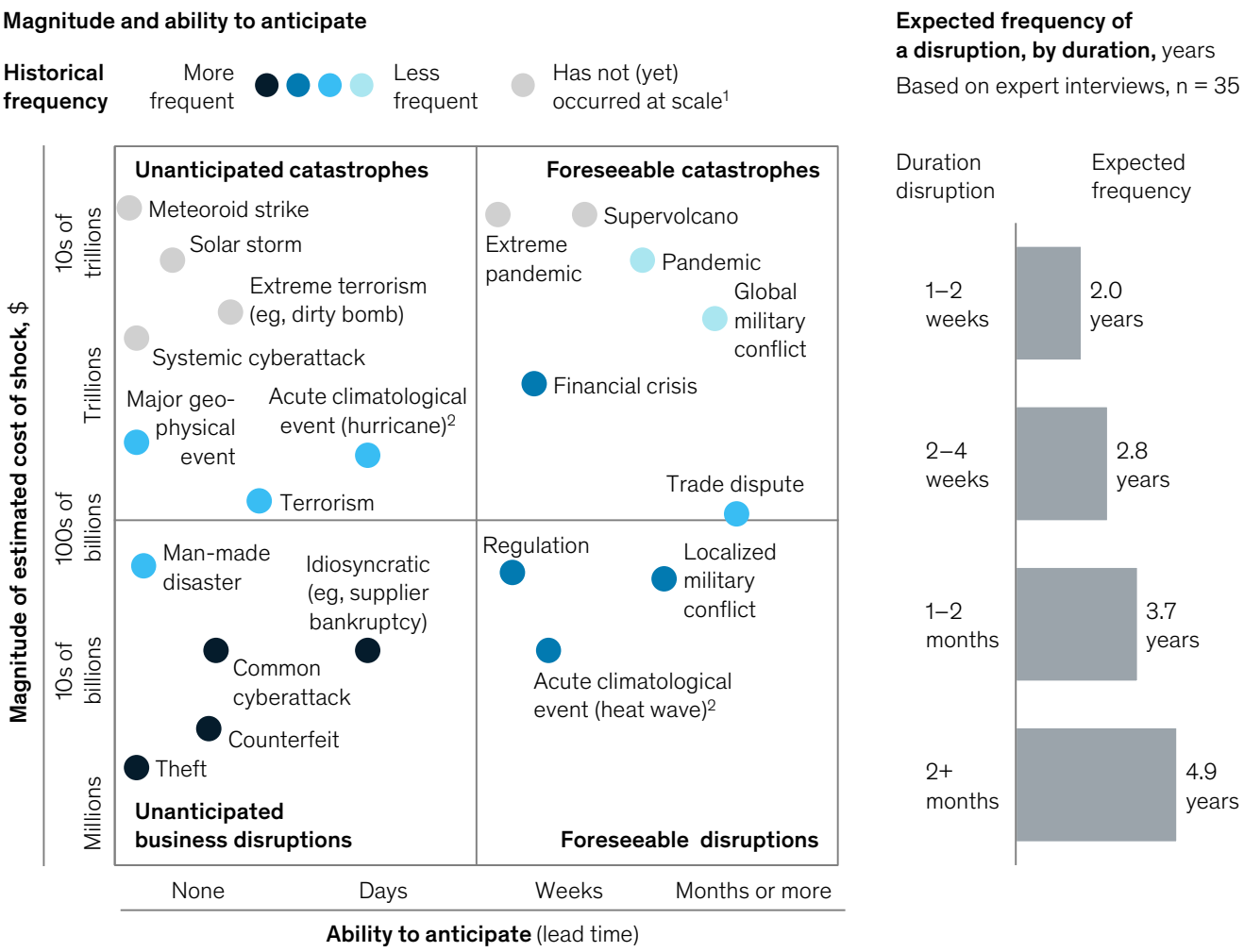
Companies and governments alike are reassessing the way goods flow across borders, and they may still make targeted adjustments to shore up the places where they see fragility. But the pandemic has not reshaped the world's production networks in dramatic ways thus far. After all, global value chains took on their current structures over many years, reflecting economic logic, hundreds of billions of dollars' worth of investment, and long-standing supplier relationships. A major multinational's supplier network may encompass thousands of companies, each with its own specialized contribution.

Tariffs and tax policies are often used by governments to try to shift where things are made. But many considerations go into where companies place manufacturing and where they source. These include growth in consumer demand, speed to market, changing labor and input costs, new technologies, and the availability of specialized workforce skills. Risk and resilience now feature prominently on that list as well—and even though the costs of risk are growing, they do not imply the end of globalization's opportunities.

1 *Digital globalization: The new era of global flows,* McKinsey Global Institute, March 2016.
2 All of the structural trends described here are explored in *Globalization in transition: The future of trade and value chains,* McKinsey Global Institute, January 2019.
3 Defined as exports from a country where GDP per capita is one-fifth that of the importing country or less. Even if we vary the ratio of GDP per capita of the exporter and importer, we continue to see a decline in labor-cost arbitrage in value chains producing labor-intensive goods.
4 See *Globalization in transition: The future of trade and value chains,* McKinsey Global Institute, January 2019.

Exhibit E1

Disruptions vary based on their severity, frequency, and lead time—and they occur with regularity.



1. Shocks that have not occurred either at scale (eg, extreme terrorism, systemic cyberattack, solar storm) or in modern times (eg, meteoroid strike, supervolcano).
2. Based on experience to date; frequency and/or severity of events could increase over time.

Source: McKinsey Global Institute analysis

This analysis reveals four broad categories of shocks. Catastrophes are historically remarkable events that cause trillions of dollars in losses. Some are foreseeable and have relatively long lead times, while others are unanticipated. Shocks that offer at least some degree of advance warning include financial crises, major military conflicts, and pandemics such as the one gripping the world today. Another set of catastrophes includes extreme weather, geophysical natural disasters, and major terrorist attacks. It may be possible to anticipate the frequency and magnitude of these events by looking at larger patterns and probabilities; hurricanes strike in the Gulf of Mexico every year, for example. But the manifestation of a specific event can strike with little to no warning. This includes some calamities that the world has avoided to date, such as a cyberattack on foundational global systems.

Disruptions are serious and costly events, although on a smaller scale than catastrophes. They, too, can be split into those that telegraph their arrival in advance (such as the recent US–China trade disputes and the United Kingdom's exit from the European Union) and unanticipated events such as data breaches, product recalls, logistics disruptions, and industrial accidents. Disruptions do not cause the same cumulative economic toll as catastrophes.

Companies tend to focus much of their attention on managing the types of shocks they encounter most often, which we classify as "unanticipated disruptions." Most companies now consider cybersecurity part of their overall risk management processes, for example. Some other shocks such as trade disputes have made headlines in recent years and, as a result, companies have started to factor them into their planning. But other types of shocks that occur less frequently could inflict bigger losses and also need to be on companies' radars. The COVID pandemic is a reminder that outliers may be rare—but they are real possibilities that companies need to consider in their decision making.

Shocks may emerge within or from outside the affected supply chain ecosystem. Disruptions that are internal to the ecosystem, such as a supplier bankruptcy or unexpected plant shut-down, are often preventable. By contrast, companies cannot hold off external disruptions such as pandemics and natural disasters—but they can assume a posture focused on minimizing their impact. Managing each of these shocks requires companies to analyze their exposure and vulnerability and put different types of resilience measures in place. For example, shocks that come with long lead times may require establishing early warning systems. Those that are difficult to anticipate may require more backup capacity and inventory that can be activated once a shock occurs.

Shocks lasting a month or more occur every

3.7 years

All four types of shocks can disrupt operations and supply chains, often for prolonged periods. We surveyed dozens of experts in four industries (automotive, pharmaceuticals, aerospace, and computers and electronics) to understand how often they occur. Respondents report that their industries have experienced material disruptions lasting a month or longer every 3.7 years on average. Shorter disruptions have occurred even more frequently.

We analyzed 23 industry value chains to assess their exposure to specific types of shocks. The resulting index (Exhibit E2) combines multiple factors, including how much of the industry's current geographic footprint is found in areas prone to each type of event, the factors of production affected by those disruptions and their importance to that value chain, and other measures that increase or reduce susceptibility. For example, heat waves affect some regions more than others. Within them, labor-intensive value chains are at comparatively higher risk—and within that group, those with the highest concentration of workers in outdoor or non-climate-controlled settings are most exposed to disruption.[4]

[4] This is an assessment of value chain *exposure* to shocks; it does not consider vulnerability, or an industry's degree of resilience against the shocks to which it is exposed. For instance, while semiconductor production is common in places that are earthquake prone, engineering standards may mean that factories are built to withstand them.

Exhibit E2

Each value chain's exposure to shocks is based on its geographic footprint and factors of production.

Less exposed — More exposed

Value chain		Overall shock exposure	Rank of exposure (1 = most exposed)					
			Pandemic[1]	Large-scale cyber-attack[2]	Geophysical event[3]	Heat stress[4]	Flooding[5]	Trade dispute[6]
Global innovations	Chemical	11	16	4	6	19	16	8
	Pharmaceutical	19	23	2	17	23	19	4
	Aerospace	8	2	1	18	20	21	5
	Automotive	14	6	9	12	21	18	6
	Transportation equipment	4	5	12	7	13	5	15
	Electrical equipment	16	17	11	9	15	15	10
	Machinery and equipment	18	9	10	20	17	20	7
	Computers and electronics	6	15	5	4	14	14	9
	Communication equipment	1	13	3	2	16	7	2
	Semiconductors and components	9	19	6	1	18	23	1
	Medical devices	23	22	8	22	22	22	3
Labor-intensive	Furniture	13	3	21	14	4	12	17
	Textile	7	7	22	11	3	2	21
	Apparel	2	1	20	15	2	1	11
Regional processing	Fabricated metal products	21	14	18	19	6	17	15
	Rubber and plastic	15	8	17	16	8	13	13
	Food and beverage	19	21	14	13	12	6	22
	Glass, cement, and ceramics	10	11	16	5	5	11	20
Resource-intensive	Agriculture	17	20	19	23	1	4	14
	Petroleum products	3	4	7	10	7	10	18
	Basic metal	12	18	13	8	11	8	12
	Mining	5	10	15	3	10	3	19
	Wooden products	22	12	23	21	9	9	23

1. Based on geographic footprint in areas with high incidence of epidemics and high people inflows. Also considers labor intensity and demand impact. Sources: INFORM; UN Comtrade; UN World Tourism Organization; US BEA; World Input-Output Database (WIOD).
2. Based on knowledge intensity, capital intensity, degree of digitization, and presence in geographies with high cross-border data flows. Sources: MGI Digitization Index; MGI LaborCube; Telegeography; US BLS.
3. Based on capital intensity and footprint in geographies prone to natural disasters. Sources: INFORM; UN Comtrade; WIOD.
4. Based on footprint in geographies prone to heat and humidity, labor intensity, and relative share of outdoor work. Sources: MGI Workability Index; O*Net; UN Comtrade; US BLS.
5. Based on footprint in geographies vulnerable to flooding. Sources: UN Comtrade; World Resources Institute.
6. Based on trade intensity (exports as a share of gross output) and product complexity, a proxy for substitutability and national security relevance. Sources: Observatory of Economic Complexity; UN Comtrade.

Note: Overall exposure averages the six assessed shocks, unweighted by relative severity. Chart considers exposure but not mitigation actions. Demand effects included only for pandemics.

Source: McKinsey Global Institute analysis

Read horizontally, the chart shows each value chain's level of exposure to different types of shocks, which can vary sharply. Aerospace and semiconductors, for example, are susceptible to cyberattacks and trade disputes because of their high level of digitization, R&D, capital intensity, and exposure to digital data flows. However, both value chains have relatively low exposure to the climate-related events we have assessed here (heat stress and flooding) because of the footprint of their production. By contrast, agriculture, textiles, apparel, and, to a lesser extent, food and beverage, are labor-intensive. As a result, these value chains are highly exposed to heat stress. Much of their activity also takes place in regions that face disruption due to flooding.

Read vertically, the index shows which value chains are likely to be touched by specific types of shocks. Pandemics, for example, have a major impact on labor-intensive value chains. In addition, this is the one type of shock for which we assess the effects on demand as well as supply. As we are seeing in the current crisis, demand has plummeted for nonessential goods and travel, hitting companies in apparel, petroleum products, and aerospace. By contrast, while production has been affected in value chains like agriculture and food and beverage, they have continued to see strong demand because of the essential nature of their products. In general, heat stress is more likely to strike labor-intensive value chains (and some resource-intensive value chains) because of their relatively high reliance on manual labor or outdoor work. Perhaps surprisingly, these same value chains are relatively less susceptible to trade disputes, which are increasingly focused on value chains with a high degree of knowledge intensity and high-value industries. Cyberattacks are more likely to affect value chains with a high degree of digitization, such as communication equipment.

Overall, value chains that are heavily traded relative to their output are more exposed than those with lower trade intensity. Some of these include value chains that are the most sought after by countries: communication equipment, computers and electronics, and semiconductors and components. These value chains have the further distinction of being high value and relatively concentrated, underscoring potential risks for the global economy. Heavily traded labor-intensive value chains, such as apparel, are highly exposed to pandemic risk, heat stress (because of their reliance on labor), and flood risk. In contrast, the value chains including glass and cement, food and beverage, rubber and plastics, and fabricated metals have much lower exposure to shocks; these are among the least traded and most regionally oriented value chains.

$4.4 trillion

in global trade flows through the five most exposed value chains

All in all, the five value chains most exposed to our assessed set of six shocks collectively represent $4.4 trillion in annual exports, or roughly a quarter of global goods trade (led by petroleum products, ranked third overall, with $2.4 trillion in exports). The five least exposed value chains account for $2.6 trillion in exports. Of the five most exposed value chains, apparel accounts for the largest share of employment, with at least 25 million jobs globally, according to the International Labor Organization.[5]

Even value chains with limited exposure to all types of shocks we assessed are not immune to them. Despite recent headlines, we find that pharmaceuticals are relatively less exposed than most other industries. But the industry has been disrupted by a hurricane that struck Puerto Rico, and cyberattacks are a growing concern. In the future, the industry may be subject to greater trade tensions as well as regulatory and policy shifts if governments take action with the intent of safeguarding public health. Similarly, the food and beverage industry and agriculture have relatively low exposure overall, as they are globally dispersed. Yet these value chains are subject to climate-related stresses that are likely to grow over time. In addition to disrupting the lives and livelihoods of millions, this could cause the industries to become more dependent on trade or force them to undertake expensive adaptations.[6]

[5] International Labor Organization, "Employment by sex and economic activity—ILO modelled estimates," ILOSTAT, accessed June 20, 2020.
[6] *Will the world's breadbaskets become less reliable?: Case study,* McKinsey Global Institute, May 2020.

In addition to observing variations in exposure across industry value chains, it is important to note that risk exposure varies for individual companies within those value chains. Similarly, each company has unique vulnerabilities, as we discuss below. Some have developed far more sophisticated and effective supply chain management capabilities and preparedness plans than others.

Shocks exploit vulnerabilities within companies and value chains

Shocks inevitably seem to exploit the weak spots within broader value chains and specific companies. An organization's supply chain operations can be a source of vulnerability or resilience, depending on its effectiveness in monitoring risk, implementing mitigation strategies, and establishing business continuity plans. We explore several key areas of vulnerability, including demand planning, supplier networks, transportation and logistics, financial health, product complexity, and organizational effectiveness.[7]

Some of these vulnerabilities are inherent to a given industry; the perishability of food and agricultural products, for example, means that the associated value chains are vulnerable to delivery delays and spoilage. Industries with unpredictable, seasonal, and cyclical demand also face particular challenges. Makers of electronics must adapt to relatively short product life cycles, and they cannot afford to miss spikes in consumer spending during limited holiday windows.

Other vulnerabilities are the consequence of intentional decisions, such as how much inventory a company chooses to carry, the complexity of its product portfolio, the number of unique SKUs in its supply chain, and the amount of debt or insurance it carries.[8] Changing these decisions can reduce—or increase—vulnerability to shocks.

Weaknesses often stem from the structure of supplier networks in a given value chain. Complexity itself is not necessarily a weakness to the extent that it provides companies with redundancies and flexibility. But sometimes the balance can tip. Complex networks may become opaque, obscuring vulnerabilities and interdependencies. A large multinational company can have hundreds of tier-one suppliers from which it directly purchases components. Each of those tier-one suppliers in turn can rely on hundreds of tier-two suppliers. The entire supplier ecosystem associated with a large company can encompass tens of thousands of companies around the world when the deepest tiers are included.[9]

Exhibit E3 applies network analytics to illustrate the complexity of the first- and second-tier supply ecosystems for two Fortune 500 companies in the computer and electronics industry. This is based on publicly available data and may therefore not be exhaustive.[10] These multitiered, multinational networks span thousands of companies and extend to deeper tiers that are not shown here. This illustration also underscores the fact that, even within the same industry, companies may make materially different decisions about how to structure their supply ecosystems, with implications for risk.

[7] Knut Alicke, Ed Barriball, Susan Lund, and Daniel Swan, "Is your supply chain risk blind—or risk resilient?," McKinsey.com, 2020.

[8] SKUs are stock-keeping units, indicating a distinct type of product for sale.

[9] We refer to supply chains when specifically discussing the tiers of vendors that provide inputs and services to create products for a downstream company. We refer to industry value chains when discussing the broader end-to-end journey from producers of raw inputs to distribution channels and, eventually, customers. The latter view is important because companies increasingly consider proximity to customers when deciding where to base production; furthermore, customer product usage data can form the basis of design improvements and after-sales services.

[10] Data from the Bloomberg Supply Chain database, based on regulatory filings and other public disclosures. The database does not capture all supplier relationships, but the results provide a relative overview of connectivity and network structure compared to other companies with similar data availability.

Exhibit E3

Even within the same industry, companies can have very different supply chain structures—and significant overlap.

Companies rely on complex, multitiered. and interconnected networks

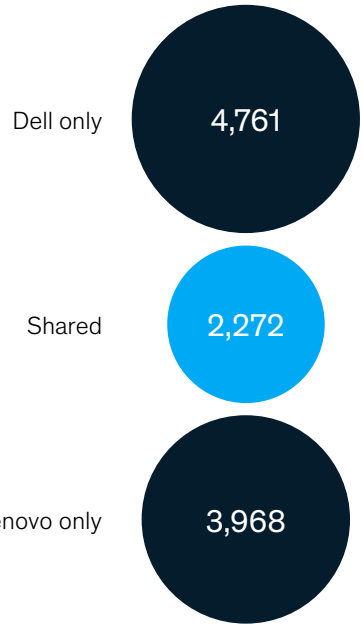
Example: Semiconductors, computers and electronics, and communication equipment

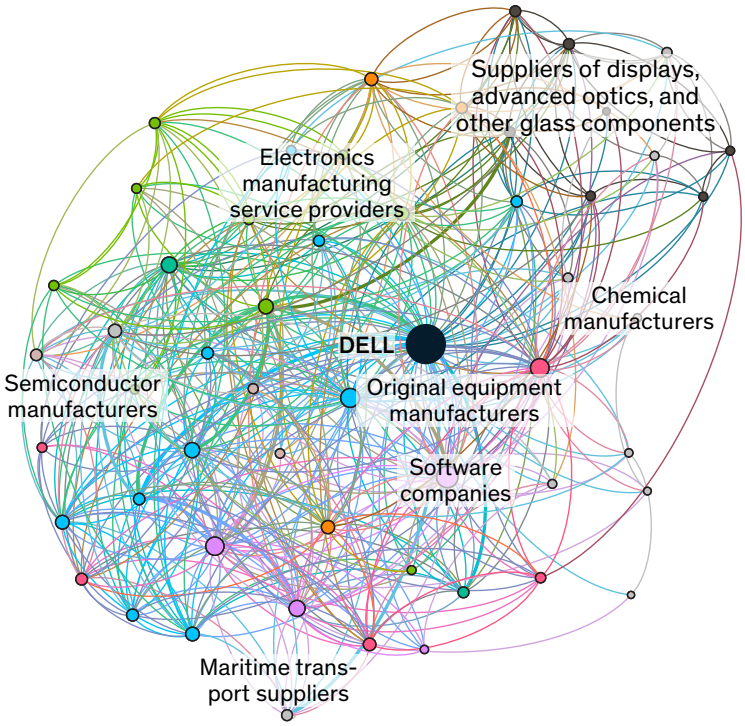
Dell

Revenue, 2019 = $90 billion

Dell's supplier ecosystem is more clustered, meaning it is potentially more exposed to bottlenecks[1]

Known tier 1 and 2 suppliers

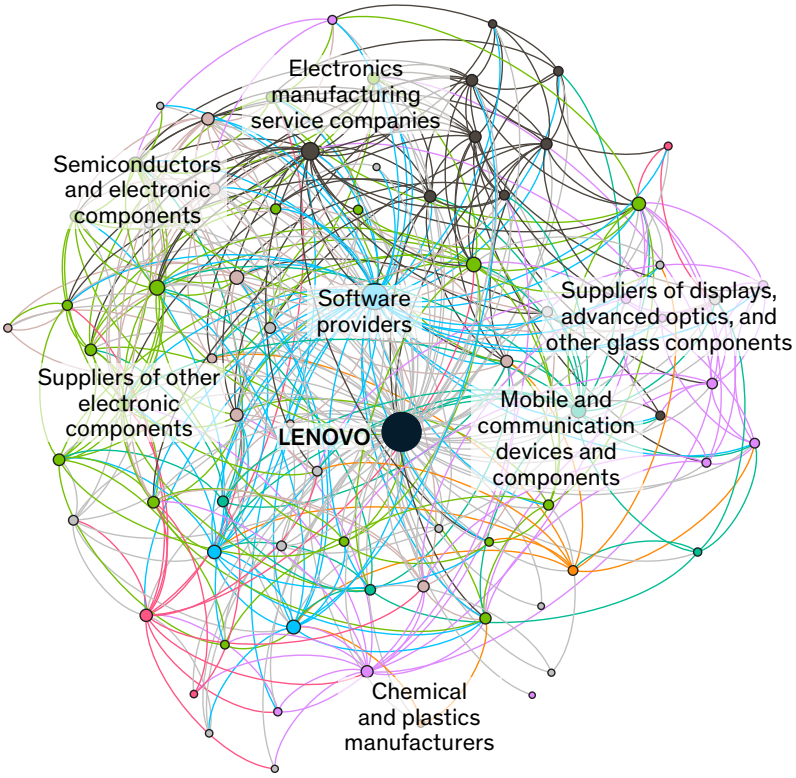




Lenovo

Revenue, 2019 = $51 billion

Lenovo's supplier ecosystem is deeper, meaning it has potentially less visibility[2]



1. Clustering is based on the clustering coefficient, which is calculated with network analysis of all supplier-customer relationships. The clustering coefficient measures the degree to which nodes cluster together and form interconnected subgroups.
2. The level of network depth is measured through the network diameter, using network analysis of all supplier-customer relationships. The network diameter is a measurement of network size that accounts for the overall structure by measuring the longest shortest path in the network.

Source: Bloomberg Supply Chain database; McKinsey Global Institute analysis

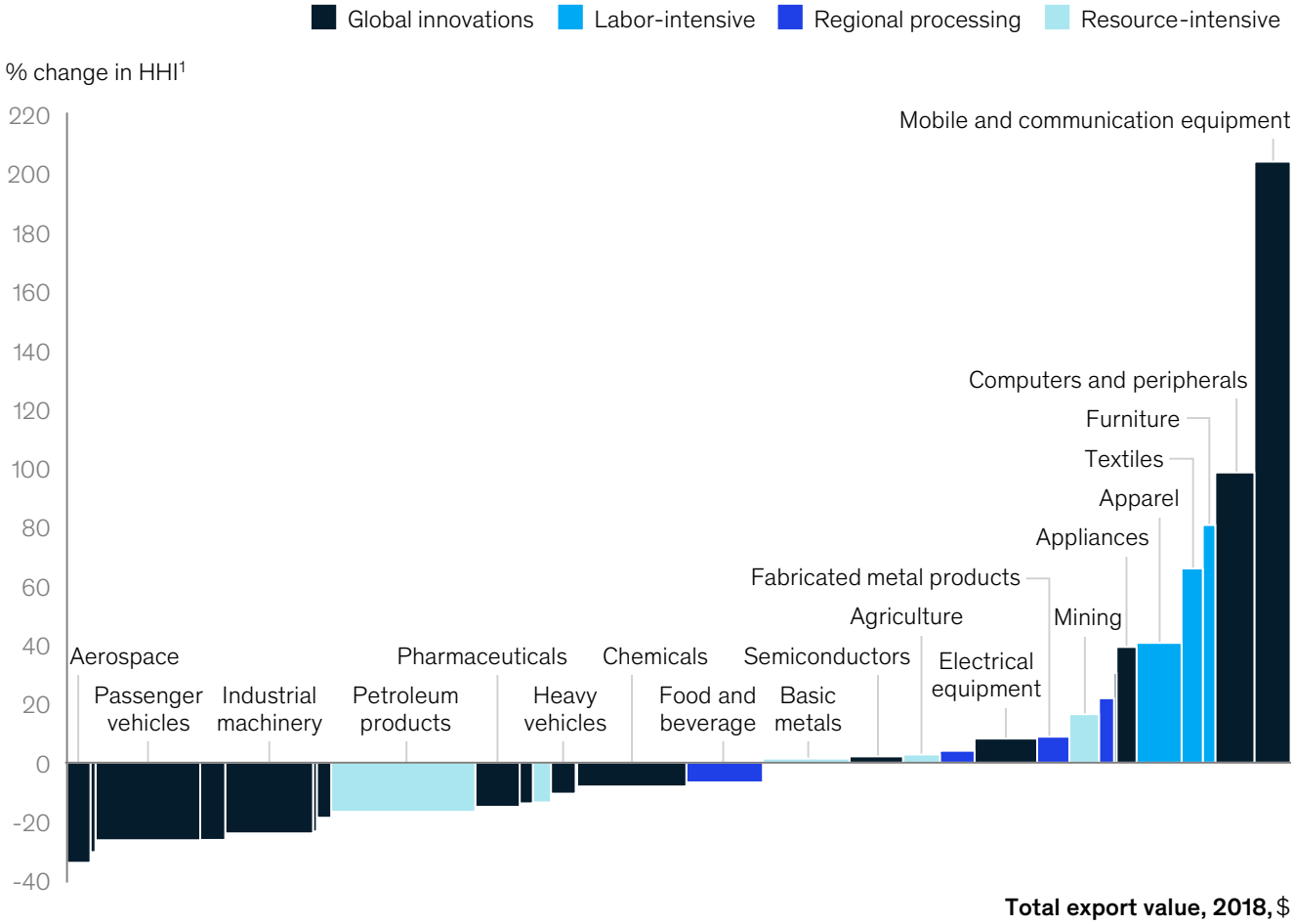
Companies' supplier networks vary in ways that can shape their vulnerability. Spending concentrated among just a few suppliers may make it easier to manage them, but it also heightens vulnerability should anything happen to them. Suppliers frequently supply each other; one form of structural vulnerability is a subtier supplier that accounts for relatively little in spending but is collectively important to all participants. The number of tiers of participating suppliers can hinder visibility and make it difficult to spot emergent risks. Suppliers that are dependent on a single customer can cause issues when demand shocks cascade through a value chain. The absence of substitute suppliers is another structural vulnerability.

In some cases, suppliers may be concentrated in a single geography due to that country's specialization and economies of scale. A natural disaster or localized conflict in that part of the world can cause critical shortages that snarl the entire network. Some industries, such as mobile phones and communication equipment, have become more concentrated in recent years, while others, including medical devices and aerospace, have become less so (Exhibit E4). The aerospace value chain, for example, has diversified in part due to secure market access.

Exhibit E4

Globalization has led to diversification of production across countries in some sectors, but others have grown more concentrated.

Change in geographic concentration by sector, 2000–18, measured by change in Herfindahl-Hirschman Index of exports (HHI)[1]



1. A measure of concentration that is the sum of the square of each country's share of exports.
Note: Data includes 5,444 unique final and intermediate products from 2018 trade data. The weighted average is weighted by the share of trade for each product within each value chain. All other measurements of HHI are calculated using the raw, unweighted score.
Source: UN Comtrade; McKinsey Global Institute analysis

180

products are predominantly exported from a single country, opening the door to bottlenecks

Even in value chains that are generally more geographically diversified, production of certain key products may be disproportionately concentrated. Many low-value or basic ingredients in pharmaceuticals are predominantly produced in China and India, for instance. In total, we find 180 products across value chains for which one country accounts for 70 percent or more of exports, creating the potential for bottlenecks. The chemicals value chain has a particularly large number of such highly concentrated products, but examples exist in multiple industries. Other products may be produced across diverse geographies but have severe capacity constraints, which creates bottlenecks in the event of production stoppages. Similarly, some products may have many exporting countries, but trade takes place within clusters of countries rather than on a global basis. In those instances, importers may struggle to find alternatives when their predominant supplier experiences a disruption. Geographic diversification is not inherently positive, particularly if production and sourcing expands into areas that are more exposed to shocks.

Over the course of a decade, companies can expect disruptions to erase half a year's worth of profits or more

When companies understand the magnitude of the losses they could face from supply chain disruptions, they can weigh how much to invest in mitigation. We built representative income statements and balance sheets for hypothetical companies in 13 different industries, using actual data from the 25 largest public companies in each. This enables us to see how they fare financially when under duress.

We explore two scenarios involving severe and prolonged shocks:

— **Scenario 1.** A complete manufacturing shutdown lasting 100 days that affects raw material delivery and key inputs but not distribution channels and logistics. In this scenario, companies can still deliver goods to market. But once their safety stock is depleted, their revenue is hit.

— **Scenario 2.** The same as above, but in this case, distribution channels are also affected, meaning that companies cannot sell their products even if they have inventory available.

Our choice to model a 100-day disruption is based on an extensive review of historical events. In 2018 alone, the five most disruptive supply chain events affected more than 2,000 sites worldwide, and factories took 22 to 29 weeks to recover.[11]

Our scenarios show that a single prolonged production-only shock would wipe out between 30 and 50 percent of one year's EBITDA for companies in most industries. An event that disrupts distribution channels as well would push the losses sharply higher for some.

Industries in which companies typically hold larger inventories and have lower fixed costs tend to experience relatively smaller financial losses from shocks. If a natural disaster hits a supplier but distribution channels remain open, inventory levels become a key buffer. However, the downstream company will still face a cash drain after the fact when it is time to replenish its drawn-down safety stock. When a disruption outlasts the available safety stock, lower fixed costs become important to withstanding a decline in EBITDA.

[11] Shahzaib Khan and Andrew Perez, *Eventwatch 2018 annual report,* Resilinc, 2019.

Companies can expect to lose almost

45%

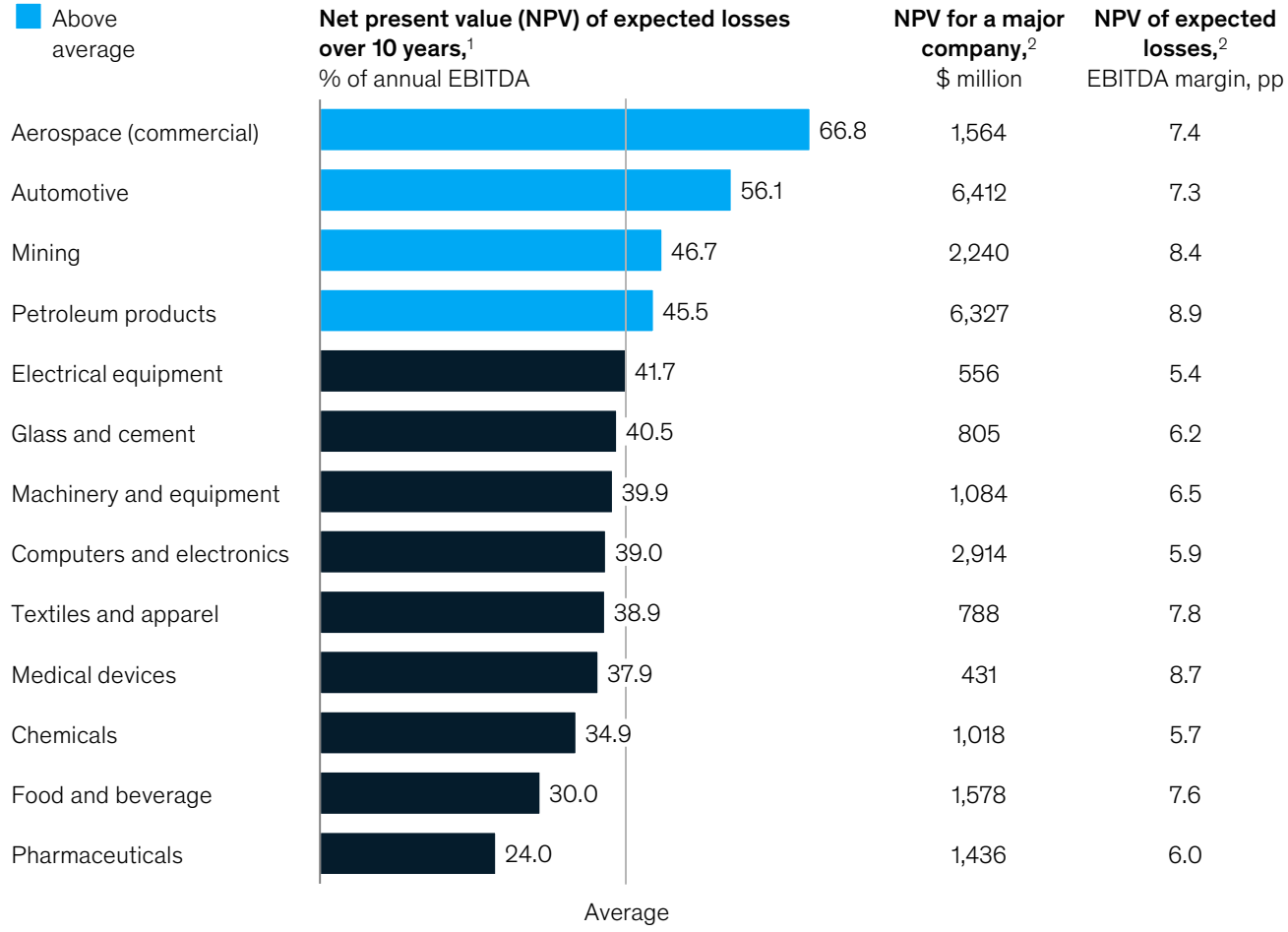
of one year's profits over the course of a decade

Having calculated the damage associated with one particularly severe and prolonged disruption, we then estimated the bottom-line impact that companies can expect over the course of a decade, based on probabilities. We combined the expected frequency of value chain disruptions of different lengths with the financial impact experienced by companies in different industries. On average, companies can expect losses equal to almost 45 percent of one year's profits over the course of a decade (Exhibit E5). This is equal to seven percentage points of decline on average. We make no assessment of the extent to which the cost of these disruptions has already been priced into valuations.

These are not distant future risks; they are current, ongoing patterns. On top of those losses, there is an additional risk of permanently losing market share to competitors that are able to sustain operations or recover faster, not to mention the cost of rebuilding damaged physical assets. However, these expected losses should be weighed in the context of the additional profits that companies are able to achieve with highly efficient and far-reaching supply chains.

Exhibit E5

Expected losses from supply chain disruptions equal 42 percent of one year's EBITDA on average over the course of a decade.



1. Based on estimated probability of a severe disruption twice per decade (constant across industries) and proportion of revenue at risk due to a shock (varies across industries). Amount is expressed as a share of one year's revenue (ie, it is not recurring over modeled 10-year period). Calculated by aggregating cash value of expected shocks over a 10-year period based on averages of production-only and production and distribution disruption scenarios multiplied by probability of event occurring for a given year. Expected cash impact is discounted based on each industry's weighted average cost of capital.
2. Based on weighted average revenue of top 25 companies by market cap in each industry.

Source: S&P Capital IQ; McKinsey Global Institute analysis

Will global value chains shift across countries?

Today much of the discussion about resilience in advanced economies revolves around the idea of increasing domestic production. But the interconnected nature of value chains limits the economic case for making large-scale changes in their physical location. Value chains often span thousands of interconnected companies, and their configurations reflect specialization, access to consumer markets around the world, long-standing relationships, and economies of scale.

We set out to estimate what share of global exports could move to different countries based on the business case and how much might move due to policy interventions. To determine whether industry economics alone support a future geographic shift, we considered a number of factors. One is whether there is already some movement under way. Between 2015 and 2018, for instance, the share of trade produced by the three leading export countries in apparel dropped. In contrast, the top three countries in semiconductors and mobile communications increased their share of trade markedly.

Other considerations include whether the value chain is capital- or knowledge-intensive, or tied to geology and natural resources. All of these make relocation less feasible. Highly capital-intensive value chains are harder to move for the simple reason that they represent hundreds of billions of dollars in fixed investments. These industries have strong economies of scale, making them more costly to shift. Value chains with high knowledge intensity tend to have specialized ecosystems that have developed in specific locations, with unique suppliers and specialized talent. Deciding to move production outside of this ecosystem to a novel location is costly. Finally, value chains with comparatively high levels of extraregional trade have more scope to shorten than those that are already regionalized. We also consider overall growth, the location of major (and rising) consumer markets, trade intensity, and innovation dynamics.

With respect to noneconomic factors, we consider governments' desire to bolster national security, national competitiveness, and self-sufficiency. Some nations are focusing on safeguarding technologies with dual-use (civilian and military) implications, which could affect value chains such as semiconductors and communication equipment (particularly as 5G networks are built out). In other cases, governments are pursuing industrial policies intended to capture leading shares of emerging technologies ranging from quantum computing and artificial intelligence to renewable energy and electric vehicles. This, too, has the potential to reroute value chains. Finally, self-sufficiency has always been a question surrounding energy. Now the COVID pandemic has driven home the importance of self-sufficiency in food, pharmaceuticals, and certain medical equipment as well.

16–26%

of global exports could shift to different countries due to economic and noneconomic factors

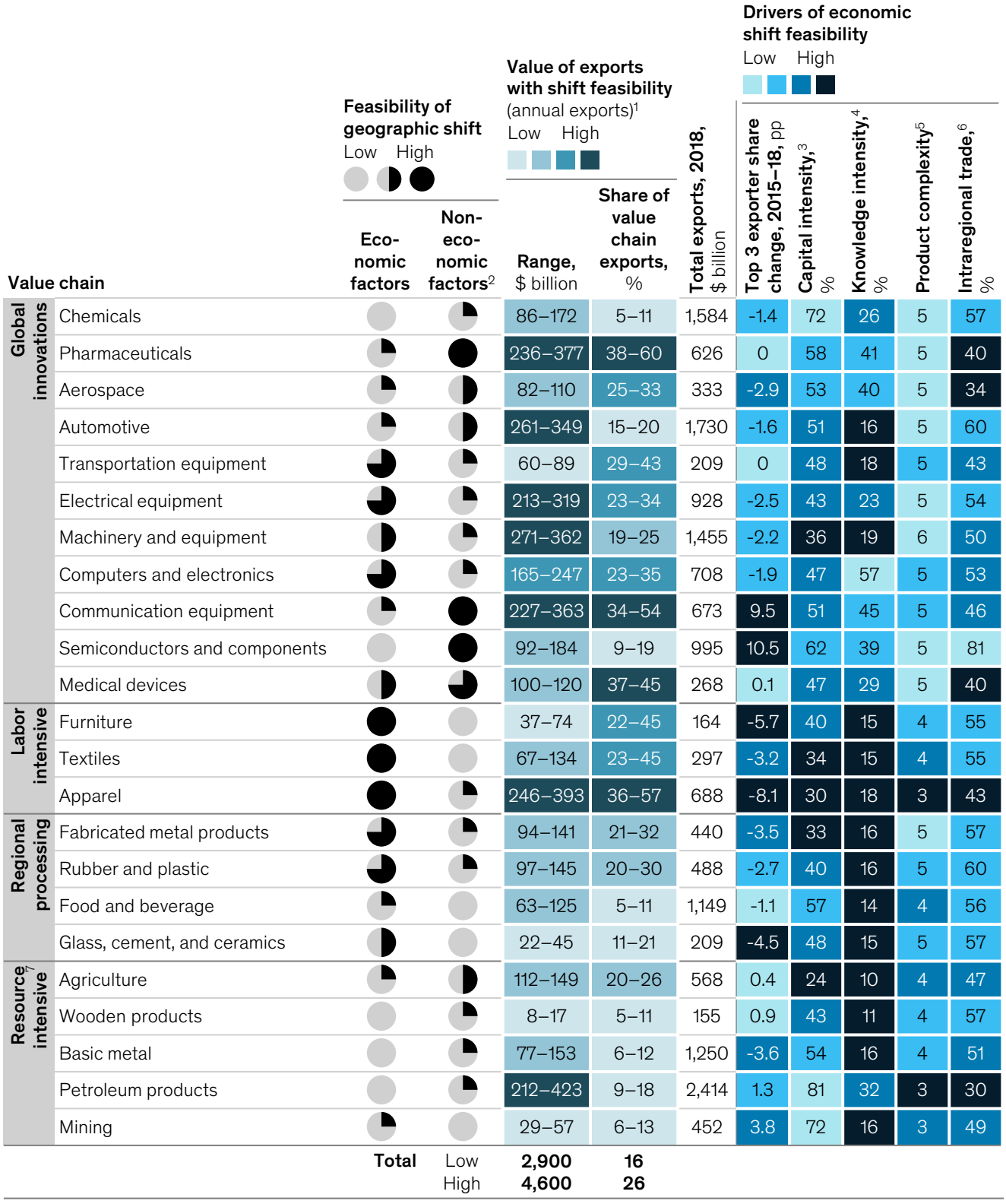
Exhibit E6 compiles these metrics for individual value chains and estimates what proportion of production for export has the potential to move to new countries. We estimate that 16 to 26 percent of exports, worth $2.9 trillion to $4.6 trillion in 2018, could be in play—whether that involves reverting to domestic production, nearshoring, or new rounds of offshoring to new locations. It should be noted that this is not a forecast: it is a rough estimate of how much global trade *could* relocate in the next five years, not an assertion that it *will* actually move.

The value chains with the largest share of total exports potentially in play are pharmaceuticals, apparel, and communication equipment. In dollar terms, the value chains with the largest potential to move production to new geographies are petroleum, apparel, and pharmaceuticals.[12] In all of these cases, more than half of their global exports could potentially move. With few exceptions, the economic and noneconomic feasibility of geographic shifts do not overlap. Thus, countries would have to be prepared to expend considerable sums to induce shifts from what are otherwise economically optimal production footprints.

[12] The potential to move petroleum production is of course limited by the presence of geologic deposits. But if the price of oil rises, exploration and extraction now considered uneconomic in some sites could become viable. New technologies, too, could make it possible to expand into new locations.

Exhibit E6

The potential for value chains to shift across borders over the next five years depends on economic and noneconomic factors.



1. Low-end sizing = global imports from outside importing country's region average of economic and noneconomic feasibility. High-end sizing = global imports from outside importing country's region maximum of economic and noneconomic feasibility. 2. Noneconomic factors take into account goods deemed essential or targeted for national security or economic competitiveness considerations, based on proposed and enacted government policies and definitions of essential goods. 3. Amount of capital compensation as a share of gross output. 4. Defined as share of labor with a tertiary education. 5. Product Complexity Index measures the relative substitutability of production across sites of products in value chain. 6. Percent of total trade that takes place within same region as its importer. 7. Dependent on access to resources that are geographically determined.

Source: Federal Reserve Bank of St. Louis; Observatory of Economic Complexity; UN Comtrade; US Bureau of Economic Analysis; US Bureau of Labor Statistics; World Input-Output Database; McKinsey Global Institute analysis

In general, the economic case to move is most viable for labor-intensive value chains such as furniture, textiles, and apparel. These value chains were already experiencing shifts away from their current top producers, where the cost of labor has risen, to other developing countries. The continuation of this trend could represent a real opportunity for some nations. By contrast, resource-intensive value chains, such as mining, agriculture, and energy, are generally constrained by the location of natural resources that provide crucial inputs. But policy considerations may encourage new exploration and development that can shift value chains at the margins.

The value chains in the global innovations category (semiconductors, automotive, aerospace, machinery, communication, and pharmaceuticals) are subject to the most scrutiny and possible intervention from governments, based on their high value, cutting-edge technologies as well as their perceived importance for national competitiveness. But the feasibility of moving these value chains based on the economics alone is low. For example, the recent decision to site a new semiconductor fabrication plant in the United States was contingent upon significant government subsidies.

Production networks have begun to regionalize in recent years, and this trend may persist as growth in Asia continues to outpace global growth. But multinationals with production facilities in countries such as China, India, and other major emerging economies are typically there to serve local consumer markets, whether or not they also export from those places. As prosperity rises in these countries, they are key sources of global growth that companies will continue to pursue.

Four industry case studies illustrate what could drive the complexity of geographic rebalancing of value chains

Pharmaceuticals. Overall, the pharmaceutical value chain has become less concentrated and more globally dispersed over the past 20 years. But the manufacture of some specific products is highly concentrated. While China and India export a relatively small share (3 percent each) of overall pharmaceutical products by value, they are the world's key producers of active pharmaceutical ingredients and small-molecule drugs. In some categories, such as antibiotics, sedatives, ibuprofen, and acetaminophen, China is the world's dominant producer, accounting for 60 percent or more of exports. India is the world's leading provider of generic drugs, accounting for some 20 percent of global exports by volume, but it relies on China for most of the active pharmaceutical ingredients that go into them. When the flow of these ingredients dried up in the early stages of the COVID pandemic, India temporarily placed export controls on dozens of essential drugs, including antibiotics.

Up to 60%

of global pharma exports could shift to different countries due to economic and noneconomic factors

Based on economics alone, there is little reason to believe that pharmaceutical production will shift unless companies respond to the rise of new consumers in developing countries. But many governments are weighing whether to boost domestic production of some key medicines (as well as medical equipment). As a result, we estimate that 38 to 60 percent of the pharmaceutical value chain could shift geographically in the coming years. However, production of small-molecule drugs would likely need to be highly digitized and automated to be viable in advanced economies; otherwise, the higher cost of doing business might lead to higher drug prices.

Automotive. The auto industry has some of the most intricate value chains in the global economy, and the most regionalized. Most exports of intermediate parts circulate within three broad regions: Asia, Europe, and North America. The US auto industry is integrated with Mexico and Canada; Germany has production networks in Eastern Europe; and Japan and South Korea source from China, Thailand, and Malaysia. Despite the largely regional nature of automotive production, OEMs rely on some imported Chinese parts—and the initial COVID outbreak centered in Hubei Province quickly produced global ripple effects in the industry.

Automotive is a prized industry from the standpoint of jobs, innovation, and competitiveness, and nations have historically enacted tariffs, trade restrictions, and local content requirements to try to attract and retain auto manufacturing. Trade disputes are an ongoing concern, leading companies to build in more flexibility and redundancy. We estimate that a relatively modest share of auto exports, between 15 and 20 percent by value, has the potential to shift in the medium term, driven predominantly by noneconomic factors.

Semiconductors. While the United States designs advanced chips, their manufacturing is highly concentrated in places like South Korea and Taiwan. Overall, Asia accounts for more than 95 percent of outsourced semiconductor assembly and testing capacity. This concentration brings potential risks. MGI research has found that companies sourcing advanced chips from South Korea, Japan, Taiwan, or other hubs in the western Pacific can expect that hurricanes severe enough to disrupt suppliers will become two to four times more likely by 2040.[13] Other dynamics can also invite potential complications. A single firm leads production of lithographic machines, which place circuits on the wafers.

Economies of scale and high barriers to entry leave very little room for semiconductor production to move on its own. A semiconductor fabrication plant can cost $10 billion or more to build, and the industry requires specialized engineers. But geopolitical and trade tensions could reshape the value chain in ways that market forces alone might not. National security and competitiveness concerns could lead governments to take action, potentially shifting an estimated 9 to 19 percent of trade flows.

Textiles and apparel. Apparel and textiles are highly traded, labor-intensive value chains that are already moving. China has long been the dominant player, and it still accounts for some 29 percent of apparel sold globally. But its wages are rising, and Chinese producers can now focus on meeting domestic demand. In 2005, China exported 71 percent of the finished apparel goods it produced. By 2018, that share was just 29 percent.

Relative to all other value chains, textiles and apparel feature the highest proportion of trade that could feasibly shift due to purely economic factors (36 to 57 percent in apparel, and 23 to 45 percent in textiles). While some apparel production may nearshore to US and EU markets, most would likely shift to Southeast Asian countries due to their comparative advantage in labor and overhead costs. As China's exports have plateaued, more apparel manufacturing for export has moved to places such as Bangladesh, Vietnam, and Ethiopia. Turkey is also a major producer of clothing that is exported to Europe. But companies will need to mitigate against natural disasters and future pandemics in these geographies. National needs for PPE could cause some footprint changes as well.

Companies have a range of options for improving resilience

In a McKinsey survey of supply chain executives conducted in May 2020, an overwhelming 93 percent reported that they plan to take steps to make their supply chains more resilient, including building in redundancy across suppliers, nearshoring, reducing the number of unique parts, and regionalizing their supply chains (Exhibit E7). The respondents included supply chain and operations' executives representing diverse value chains, such as pharmaceutical and medical products, automotive, advanced electronics and semiconductors, consumer packaged goods, chemicals, and metals and mining, among others.

When companies understand the magnitude of the losses they could face from supply chain disruptions, they can weigh how much to invest in building resilience. Many options can boost productivity at the same time, providing a win-win.[14]

[13] *Could climate change become the weak link in your supply chain?*, McKinsey Global Institute, August 2020.
[14] For a broader discussion, see Nassim Nicholas Taleb, *Antifragile: Things That Gain from Disorder,* New York, NY: Random House, 2012.

Exhibit E7

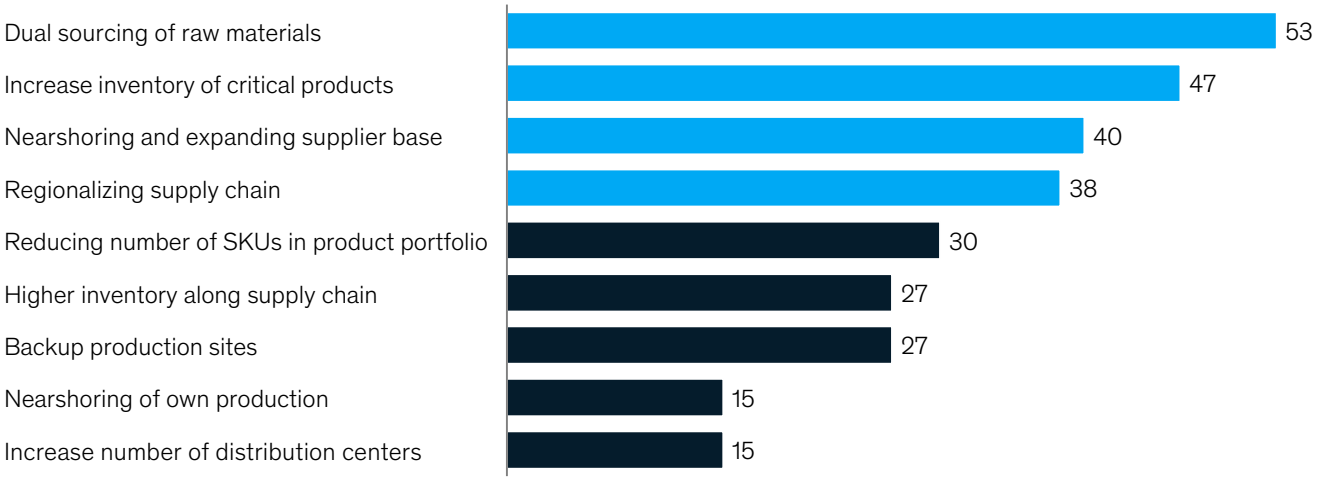
Surveyed business leaders are increasing resilience in supply chains and production through multiple strategies.

93% of global supply chain leaders are planning to increase resilience[1]

44% would increase resilience even at expense of short-term savings[2]

Planned actions to build resilience

% of respondents[1]



1. McKinsey survey of global supply chain leaders, May 2020.
2. McKinsey survey of business executives, May 2020.

Source: McKinsey survey of business executives, May 2020 (n = 605); McKinsey survey of global supply chain leaders, May 2020 (n = 60); McKinsey Global Institute analysis

Strengthen supply chain risk management and improve end-to-end transparency

Global manufacturing has only just begun to adopt a range of technologies, such as analytics and artificial intelligence, the Internet of Things, advanced robotics, and digital platforms. Companies now have access to new solutions for running scenarios, assessing trade-offs, improving transparency, accelerating responses, and even changing the economics of production.[15]

Most companies are still in the early stages of their efforts to connect the entire value chain with a seamless flow of data. Digital can deliver major benefits to efficiency and transparency that are yet to be fully realized. Consumer goods giant Procter & Gamble, for example, has a centralized control tower system that provides a company-wide view across geographies and products. It integrates real-time data, from inventory levels to road delays and weather forecasts, for its own plants as well as suppliers and distributors. When a problem occurs, the system can run scenarios to identify the most effective solution.[16]

Creating a comprehensive view of the supply chain through detailed subtier mapping is a critical step to identifying hidden relationships that invite vulnerability. Today, most large firms have only a murky view beyond their tier-one and perhaps some large tier-two suppliers. Working with operations and production teams to review each product's bill of materials can reveal whether critical inputs are sourced from high-risk areas and lack ready substitutes. Companies can also work with their tier-one suppliers to create transparency. But in cases where those suppliers lack visibility themselves or consider their own sourcing to be proprietary information, risk management teams may have to turn to other

[15] See, for example, Katy George, Sree Ramaswamy, and Lou Rassey, "Next-shoring: A CEO's guide," *McKinsey Quarterly*, January 2014; and Kevin Goering, Richard Kelly, and Nick Mellors, "The next horizon for industrial manufacturing: Adopting disruptive digital technologies in making and delivering," McKinsey.com, November 2018.

[16] Emma Cosgrove, "How P&G created a 'ready-for-anything' supply chain," *Supply Chain Dive*, June 3, 2019.

information sources to do detective work.[17] After mapping upstream suppliers, downstream companies need to understand their production footprint, financial stability, and business continuity plans.

Minimize exposure to shocks

Targeted measures taken before an event occurs can mitigate the impact of a shock or speed time to recovery.[18] As more physical assets are digitized, for example, companies will need to step up investment in cybersecurity tools and teams.

One of the most important steps is building more redundancy into supplier networks.[19] Relying on a single source for critical components or raw materials can be a vulnerability. In fact, even if a company relies on multiple suppliers, they may be concentrated in the same place. Taking the time to identify, prequalify, and onboard backup vendors comes at a cost. But it can provide much-needed capacity if a crisis strikes.[20] Auditing and diversifying the supply chain can have the added benefit of reducing carbon intensity, raising environmental and labor standards, and expanding opportunities for women- and minority-owned businesses.

One way to achieve supply chain resilience is to design products with common components, cutting down on the use of custom parts in different product offerings. Auto manufacturers are perhaps the most advanced in this regard, having implemented modular manufacturing platforms that share components across product lines and production sites.

Physical assets may need to be hardened to withstand natural disasters. In regions that are vulnerable to worsening hurricanes and storm surges, this may involve installing bulkheads, elevating critical machinery and utility equipment, adding more waterproof sealing, and reworking drainage and valves.[21] Many factories that are not air-conditioned today will need cooling systems to prepare for rising temperatures and potential heat waves in some parts of the world. Plants located in earthquake-prone areas may need seismic retrofitting. Companies can also build more redundancies into transportation and logistics.

When a shock does hit, companies need the ability to respond quickly

The shift to just-in-time and lean production systems has helped companies improve efficiency and reduce their need for working capital. But now they may need to strike a different balance between just-in-time and "just in case." Having sufficient backup inventory of key parts and safety stock is a critical buffer that can minimize the financial impact of disrupted supplies. It can also position companies to meet sudden spikes in demand.

The ability to reroute components and flex production dynamically across sites can keep production going in the wake of a shock. This requires robust digital systems as well as the analytics muscle to run scenarios based on different responses. When the COVID pandemic hit, Nike used predictive analytics to selectively mark down goods and reduce production early on to minimize impact. The company was also able to reroute products from brick-and-mortar stores to e-commerce sales, driven in part by direct-to-consumer online sales through its own training app. As a result, Nike sustained a smaller drop in sales than some of its competitors.

When disaster strikes, companies have to be laser focused on cash management. But those at the top of a value chain also have a vested interest in preserving the supplier networks on which they depend. In the aftermath of the global financial crisis, some companies accelerated payments or guaranteed bank loans to give key vendors a lifeline.

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Coming on the heels of Brexit and a flare-up in US–China trade tensions, the COVID pandemic has forced businesses to focus on building resilience in their supply chains and operations. Not everything that can go wrong actually does go wrong, but businesses and governments cannot afford to be caught flat-footed when disaster strikes. Preparing for future hypotheticals has a present-day cost. But those investments can pay off over time—not only minimizing losses but also improving digital capabilities, boosting productivity, and strengthening entire industry ecosystems. Rather than a trade-off between resilience and efficiency, this rebalancing act might deliver a win-win.

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