Written Testimony of Gary Gereffi, Ph.D.
Emeritus Professor and Founding Director, Global Value Chains Center
Duke University, Durham, NC

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I. Introduction

Madam Chair Cantwell, Ranking Member Wicker, and Members of the Committee, I am honored to appear before you today to offer testimony on the hearing topic, "Implementing Supply Chain Resiliency." My name is Gary Gereffi, and I am the Founding Director of the Global Value Chains Center at Duke University. I have spent much of my academic career looking at the structure and dynamics of global industries, and how and why U.S. companies decided to set up international production and sourcing networks. This research has involved extensive fieldwork in a wide variety of industries and countries around the world, including in-depth interviews with the companies, business and labor groups, policymakers, and other industry stakeholders in each setting.

In light of this experience, I am very gratified to see the excellent White House report on "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth" released in June 2021 that outlines steps to strengthen critical U.S. supply chains. In my remarks today, I draw upon my background as both a researcher and a policy adviser. I will organize my remarks around three main themes: (1) a brief review of the rise of global supply chains as a research field; (2) a short list of building blocks of resilient supply chains that derive from this research; and (3) a few recommendations for actions that the U.S. federal government can take to implement supply chain resiliency.

Recent disruptions associated with the COVID-19 pandemic have brought both the significance and risks of supply chains to the American consciousness as never before. COVID-19 has been a unique and terrifying event because of its swift global spread and its devastating and lingering impact on the health and security of the American people and the global community. It has resulted in unprecedented supply shortages and demand fluctuations that have affected virtually all U.S. industries, from medical supplies to food products and toilet paper, and from the transportation and service sectors to critical intermediate goods like semiconductors, active pharmaceutical ingredients, and rare-earth minerals. These dislocations can provide important lessons for the future.

Supply-chain disruptions are a recurrent risk for many businesses. They can be caused by natural events, such as tropical storms, earthquakes, or extended droughts, as well as cyclical fluctuations like business cycles or financial crises (e.g., the 2008-09 global recession). Government policies can also disrupt supply chains, such as trade restrictions that impede the cross-border flows of imports and exports or local-content requirements that mandate the domestic procurement of goods and services. While COVID-19 disruptions were a different order of magnitude because of their speed and global impact, a supply-chain perspective that links firm strategies, industry dynamics and government policies can help address short-term supply-chain discontinuities in the U.S. economy, and inform plans for long-term resilience as a basis for dynamic, inclusive and sustainable economic growth.

II. Supply Chain Research: A Recent Field

Although supply chains may sound like a rather arcane or technical topic, supply-chain research has flourished in recent decades, especially as supply chains have gone global. In contrast to the more familiar field of industry studies or intriguing case histories of well-known products (such as Barbie dolls or iPhones), supply-chain research encompasses the full structure of an industry, including its *pre-production* (R&D and design) phases, the often complex *production* process (raw and processed materials, manufactured components and other inputs, and the assembly, testing and packaging of final products), and *post-production* stages (e.g., distribution and logistics, marketing, and in some cases recycling).

During the origins of American big business (19th and early 20th centuries), most supply-chain activities were carried out inside large vertically integrated corporations where the "visible hand" of management replaced Adam Smith's famous invisible hand of the market.[1] However, in the post-World War II era, as businesses became more specialized and global through the twin processes of "outsourcing" (obtaining goods or services from outside suppliers) and "offshoring" (moving portions of the production process to overseas locations), the *global factory model* became more common where the assembly of goods and later the full range of production activities were spread across multiple countries for a combination of cost, capability and market reasons.[2] Thus, a growing proportion of international trade was made up of intermediate goods rather than finished products. As this globalization process gained momentum from the mid-1960s through the 1990s, American manufacturing especially of relatively labor-intensive consumer goods moved offshore, imports accounted for a growing portion of consumer items sold in the United States, and the number of companies and employees in the U.S. manufacturing sector fell precipitously.

Supply chain studies to analyze this globalization process and its impact on the U.S. economy were promoted by various U.S. foundations. The Alfred P. Sloan Foundation in New York launched an Industry Studies program (1990-2010) to foster a closer interaction between academia and industry, which grew to include around two dozen centers at U.S. universities. The Rockefeller Foundation supported a Global Value Chains Initiative (2000-2008) that funded an

international network of scholars with the goal of creating a paradigm linking global, national, and local levels of analysis to address both the knowledge gaps and policy gaps created by globalization. What the global value chain (GVC) framework added to earlier supply chain studies was an explicit effort to understand and measure how and where value is created and captured along global supply chains, as well as the main trajectories of economic, social and environmental upgrading (or downgrading) associated with these changes at the global, national, regional and community levels.[3]

Supply-chain researchers are very interdisciplinary and their work is featured at a variety of annual conferences, such as Industry Studies Association (ISA), Regional Studies Association (RSA), Society for the Advancement of Socio-Economics (SASE), and Academy of International Business (AIB). Traditionally, the supply-chain literature has relied heavily on industry case studies and cross-industry comparisons, but the Organisation for Economic Co-operation and Development (OECD) in conjunction with the World Trade Organization has created a Trade in Value Added database that permits a detailed trade mapping of how countries participate in GVCs by calculating the value-added of exports (domestic content minus imported inputs), which permits modeling of how domestic manufacturing contributes to economic growth. The World Bank, in collaboration with other multilateral development agencies, created the World Integrated Trade Solution software package that allows users to download detailed trade information on commodities and over 170 partner countries to assist policymakers and practitioners involved in the international trading system.

Academic researchers also build their own unique databases to measure supply-chain relationships. For example, a study of the aerospace industry collected data on buyer-supplier and partnership linkages among more than 2,800 firms across 52 aerospace clusters in North America and Europe during 2002-2014,[4] and another study utilized a dataset of over 57,000 sourcing transactions of automotive parts manufacturers in Europe and North America between 1993 and 2012 to test propositions derived from GVC governance theories.[5] Thus, mixed methodologies continue to characterize the field.

International organizations have increasingly adopted the GVC framework as a way to understand how countries at different levels of development participate in the global economy, and what kinds of policy advice could promote dynamic, inclusive and sustainable economic growth.[6] This was the focus of a Duke GVC Summit in October, 2014 that invited representatives from 30 international organizations, national development agencies, non-governmental organizations (NGOs) and universities as well as leading supply-chain researchers to discuss how and why they use the GVC approach, and to provide suggestions on how it can be improved. This type of policy impact is very unusual for most academic research paradigms, and it is a significant catalyst for ongoing work in the field.[7]

III. Building Blocks of Resilient Supply Chains

Drawing from recent research on global supply chains, I will outline six broad themes that intersect with the goals and recommendations of the White House's "Building Resilient Supply Chains" report,[8] and also address the Department of Commerce's concerns to identify concrete steps it can adopt to ensure the resiliency of the nation's critical supply chains. These central concepts, findings and trends reflect work on supply chains that cuts across the global, national, regional and local levels, and they inform my recommendations for U.S. supply chain initiatives such as those carried out by the Department of Commerce to advance a broad-based, inclusive and sustainable economic agenda.

1) Resilience for Whom? Firms, Supply Chains and Countries

In the aftermath of the disruptions caused by COVID-19, there has been an intense debate on whether U.S. supply chains are too rigid and dependent on a small number of offshore locations in pursuit of cost-based global efficiency.[9] The notion of "resilience" is often proposed as an alternative principle to guide recovery from recurrent disruptions. However, resilience has different meanings for companies, supply chains, and countries:

- For *companies*, resilience refers to the ability to adjust and respond to disruptions in their supply chains through strategies and capabilities that balance operational efficiency and flexibility via appropriate forms of risk management and redundancy.
- For *supply chains* that extend beyond individual firms, resilience entails adaptation via modes of governance established by lead firms that maximize system-level efficiencies and cushion against vulnerabilities, taking into account the organizational and geographic configurations of each supply chain.
- At the *country* level, building resilience in the face of supply-chain disruptions involves proposals for reshoring, country and supplier diversification, near-shoring, and reliance on trusted partners, as well as the buildup and maintenance of national stockpiles and strategic reserves that will be driven by national security considerations as well as broader economic and social goals related to jobs, investment, trade, sustainability, and innovation.

Understanding resilience as a multidimensional concept means that coordination and tradeoffs are inevitable to develop robust and comprehensive supply chain policies. Resilience strategies may not easily align across these different levels, but awareness of the interdependencies is a necessary step to ameliorate disruptions in a more effective way.

2) Supply Chains Have Multiple Governance Structures

A core finding and premise of the GVC framework is that global supply chains have *governance structures* that are established by the lead firms that set up and orchestrate the activities of the multi-tiered suppliers in the chain. An initial seminal distinction was between producer-driven

and buyer-driven supply chains: (a) the lead firms in *producer-driven chains* were integrated manufacturers that typically controlled the capital and technology used to establish new industries (e.g., automobiles, aircraft, computers, pharmaceuticals); and (b) conversely, in *buyer-driven chains* the lead firms were large retailers (e.g., Walmart, JC Penney, Costco, Tesco) and brand-name firms (e.g., Nike, Adidas, Liz Claiborne, Disney) that orchestrated but did not own vast networks of global suppliers in consumer-goods industries, such as apparel, footwear, sporting goods, toys, and food products. Whether led from the supply side or the demand side, lead firms tend to set the rules of the game in terms of price, quality, product standards and delivery schedules for other firms in the chain.[10] Subsequent governance typologies were introduced that cover a wider range of structures, such as hierarchical, captive, relational, modular, and market forms of governance.[11]

Within key industries like semiconductors, multiple governance structures may be set up by lead firms that adopt distinct production models. For example, the integrated device manufacturers (IDMs), such as U.S.-based Intel and Texas Instruments and South Korea-based Samsung, do the entire production process for finished chips themselves, whereas in the alternative "fabless" or foundry model, the three broad steps for making finished semiconductors – design, manufacturing, and assembly, testing and packaging (ATP) – are carried out by specialized companies. While U.S. firms are dominant IDM players, accounting for over half of global IDM revenues in 2020, the fabless/foundry model relies very heavily on chip output from Taiwanese-based TSMC (Taiwan Semiconductor Manufacturing Company), which accounts for 53% of the contract foundry market, including the most technologically advanced chips.[12]

3) Supply Chains Have Shifting Geographies

The geographic footprint of most supply chains evolves quite significantly over time. The apparel industry, which epitomized the fragmented and globally dispersed production networks associated with buyer-driven GVCs, became much more consolidated when quotas allowed by the Multi-Fiber Arrangement were eliminated by the World Trade Organization (WTO) in 1995. Today, just three countries – China, Bangladesh and Vietnam – account for nearly half of world apparel exports. In other industries, supply chains are more regionally based, such as the North American automotive industry, the European aerospace sector, and East Asia's ecosystem of consumer electronics suppliers. Regional chains are often a by-product of regional trade pacts, such as the North American Free Trade Agreement (NAFTA) and the European Union (EU).[13]

Supply chains can also be examined at the national level, but measurement and boundaries raise difficult challenges. National statistics typically use standard industry classifications. If we take the U.S. semiconductor industry, for example, which is analyzed in the recent White House supply-chain report, we can define the size of the industry using various metrics: annual sales ($208 billion in 2020, which is nearly half of the world market); value added ($35 billion in 2019, 1.4% of U.S. manufacturing value added); employment (207,400 workers in 2019, 1.6% of U.S. manufacturing employment); number of firms (733 companies in semiconductor device

manufacturing and 140 semiconductor equipment manufacturers); and the breadth of activities across the country (18 U.S. states have major semiconductor manufacturing operations).[14]

However, these industry figures fall far short of indicating the true size and scope of the semiconductor supply chain in the United States, which would include the multitude of suppliers (domestic and international) to U.S. semiconductor firms. In addition, since semiconductors are a critical intermediate component used in many industries, the semiconductor supply chain would also extend to the main sectors that use these chips, which include (based on worldwide demand in 2019): mobile phones (26%), information and communication infrastructure (24%); computers (19%); industrial (12%); automotive (10%); and consumer electronics (10%).[15]

4) Asia Is a Pre-eminent Global Production Hub, and China Is Its Epicenter

In the last couple of decades, Asia has emerged as a dominant production hub for many global supply chains. Asia offers a unique combination of low-cost production, economies of scale, and a broad array of technologically sophisticated and specialized suppliers that serve both global and increasingly Asian consumer markets. The cost advantages associated with Asia-based sourcing are attractive not only to the lead firms in global supply chains, but also to cost-conscious institutional clients like U.S. hospital systems and medical agencies that wish to couple just-in-time (JIT) purchasing of medical supplies with the JIT low-inventory model favored by industry leaders.

China has become the world's top exporter ($2.6 trillion in 2020), well ahead of the United States and Germany (each around $1.4 trillion).[16] However, given rising wages in China and growing shortages of factory workers in many parts of the country, other relatively low-wage economies within Asia, such as Vietnam, Bangladesh, India, Indonesia and the Philippines, are becoming prominent exporters from the region. The most technologically advanced Asian economies, such as Japan, South Korea, Singapore and Taiwan, provide specialized components and equipment, which combine to make Asia a formidable global production and export hub.

As an economic power, China is a significant adversary. It has supplemented its export-oriented development strategy from the 1990s and 2000s with a technology-driven and domestic-economy-oriented approach since the early 2010s, as typified by its Made in China 2025 and indigenous innovation programs. China is also poised to expand its regional influence through its massive Belt and Road Initiative that will increase its external investments and trade in Central and Southern Asia, sub-Saharan Africa, and South America. Although still lagging in key technologies like semiconductors, China has placed an emphasis on forward-looking industries like electric cars, high-speed rail, artificial intelligence, automation, and e-commerce services like mobile banking and digital platform-based factory networks.

There are many valid concerns about China's troubling policies and practices involving state control of the economy, intellectual property theft, human rights abuses, and political repression at home and abroad, among other issues. New U.S. supply chain initiatives are needed to meet

the technological and economic challenges posed by China. However, in pursuing its agenda, the United States would do well to align its efforts to address the threats posed by China with U.S. strategic partners and allies who share many of our concerns and objectives. A rapid decoupling from China poses many practical difficulties and it could reduce U.S. leverage in terms of broader geopolitical and economic interests.

5) Building Resilient Supply Chains in the United States

While much work on supply chains tends to highlight the international dimension and looks at global industries from the "top down," it is equally important to view supply chains from the "bottom up" by emphasizing their potential contributions to national and local growth. A good illustration of this bottom-up approach is the project on "North Carolina in the Global Economy," which was launched at Duke University to understand how globalization affected seven of the state's principal industries: tobacco, textiles and apparel, furniture, hog farming, information technology, biotechnology, and banks and finance.[17] Like many U.S. states, North Carolina's key industries reflect a mix of resource-based, manufacturing and service sectors, and it faces a range of investment, employment, skills training, small business development, and innovation challenges. The NC-Global Economy website was built using publicly available state-level and national economic statistics for a 20-year period (1992-2012), supplemented by online data searches at the company and industry levels, to provide a longitudinal portrait of how North Carolina's industries and companies have fared in an era of globalization, and what policies and strategies at the state and local levels might foster resilient growth.

Among the insights gleaned from the NC-Global Economy project is that traditional industries like textiles and furniture have adapted in striking ways to recent political, economic and technological shifts. While North Carolina's textile firms accomodated NAFTA by continuing to supply apparel customers that moved to Mexico and Central America, the industry also embraced technological change via the growth of nonwoven and "technical" textiles in the state's output and exports. These new products shifted the industry's end markets from its traditional apparel, home furnishing and automotive customers to sectors like aerospace, medical, marine, military and geotextiles.[18] North Carolina's furniture industry also showed resilience in adapting to change, as local manufacturers were hit by export slowdowns and rapidly rising furniture imports from Asia and Mexico. However, the annual High Point, NC furniture market served as a lifeline to keep wholesale buyers coming to the state as local manufacturers slowly recovered.[19]

A supply-chain methodology can also prove very useful in tracking opportunities created by new high-tech sectors in the United States. For example, following a study on the U.S. smart grid (the "energy internet") that assessed the potential of 125 leading smart grid firms to create clean energy-related jobs, the Research Triangle Region of North Carolina emerged as one of the U.S. "hot spots" for future growth.[20] A separate study was commissioned by a local development agency to assess how this North Carolina cluster of smart grid firms could build on its competencies and expand its opportunities to invent, make and sell their products in the U.S. as

well as abroad.[21] A main objective of both studies was to "map" the smart grid value chain to show more clearly the technological synergies linking the national and state-level economies.

Value-chain studies have proven particularly useful to show the connections between so-called "clean technologies" and U.S. jobs. One of the initial clients of the Duke GVC Center was the Environmental Defense Fund (EDF), which commissioned a series of product-level studies to show how the transition to a low-carbon economy positively impacted the U.S. manufacturing sector. The initial report focused on five carbon-reducing products – LED lighting, high-performance windows, auxiliary power units for trucks, concentrated solar power, and a "super soil" system for hog-waste management – and value chain maps for each product helped to show how and where manufacturing jobs were being produced in the United States.[22] Subsequently, EDF commissioned over a dozen additional product and company case studies to illustrate the tangible connections between the green economy and U.S. blue-collar jobs.[23] A similar supply-chain methodology was employed in a new study focusing on expanding utility-scale, lithium-ion battery-storage capacity in North Carolina as a foundation for all forms of clean energy, thus enhancing North Carolina's potential to be a national leader in clean energy.[24]

This "bottom up" approach to building supply-chain resiliency focusing on particular states and products is broadly applicable across the entire U.S. economy. Virtually all U.S. states rely on a handful of key industries linked to national and global markets that account for the bulk of their investment, output and employment. The tools of value-chain analysis, as exemplified in the NC-Global Economy and EDF projects highlighted above, are suitable for various monitoring, planning and innovation objectives that could be spearheaded by the Department of Commerce, including:

- tracking how both large and smaller companies in a state's key industries are performing over time, and how the state compares to its main U.S. competitors in relevant industries
- attracting investors to supplement or fill critical supply-chain needs, especially as multiple U.S. states seek to lure top firms and talent in similar industries
- supporting university, community college and corporate research and training capabilities
- assisting local workforce development efforts to identify and add critical skills needed by priority sectors

Similar dynamics are unfolding in major U.S. cities. A number of American cities stand out as hubs or centers of excellence in key U.S. industries, such as Seattle (aerospace, software and digital economy, with Boeing, Microsoft and Amazon), Houston (oil and gas; medical), Phoenix (semiconductors), Pittsburgh (steel and biomedical), and Boston (high-tech; defense), to name just a few. Cities like these are production and innovation nodes in critical U.S. and global supply chains. To enhance their resiliency, U.S. supply-chain initiatives should strengthen and deepen the supporting activities (infrastructure, hardware, software and services) these urban hubs rely on, and facilitate their connections to other regions and smaller cities that are part of the same value chain.

As U.S. technology giants like Google, Apple and Amazon make major investments in machine learning, artificial intelligence, software engineering, and quantum and cloud computing in mid-sized cities like those in North Carolina[25] and elsewhere across the country, it is clear that vibrant U.S. supply chains rely on urban knowledge and production networks that can create and retain value and spread benefits to surrounding communities.

6) The Role of Universities in Supply-Chain Research

Somewhat surprisingly, perhaps, universities play a very uneven role in supply-chain research. U.S. foundations have been an important source of financial support, but even in the most positive cases, assistance has been temporary. The Sloan Foundation's Industry Studies program set up industry-specific centers in 26 U.S. universities, but the program was terminated in 2010. A by-product of the Sloan program was the formation of the Industry Studies Association in 2009, which has annual conferences but offers no funding for industry research or university-based industry centers. The Rockefeller Foundation, which helped to launch the Global Value Chain Initiative with an international group of scholars,[26] encouraged the formation of the Duke GVC Center (previously the Center on Globalization, Governance & Competitiveness) in 2005 to provide a university base to facilitate the future networking of GVC scholars, but research support was guaranteed by neither Rockefeller nor Duke University. Project funding was client driven and therefore highly uncertain.

This situation reflects the business model of most U.S. research universities. Their core mission is to foster high-quality independent research by faculty that secure long-term funding (primarily from large U.S. government agencies like the National Science Foundation (NSF) or National Institutes of Health) and publish in prestigious peer-reviewed academic journals. Supply-chain research is not an ideal fit for U.S. universities because industry-oriented researchers are both interdisciplinary and international, and acquiring industry-specific knowledge does not necessarily lend itself to academic publications, which tend to privilege theoretical and methodological rigor, and in the social sciences this often translates into quantitative (rather than case-based) analysis.

Given the significant real-world impact of good supply-chain research, a growing number of universities support programs linked to supply chains and economic development (*not* including supply-chain management programs in many business schools). In the United States, along with the Duke GVC Center, the Massachusetts Institute of Technology's Industrial Performance Center is a highly regarded and relatively well-funded unit. Many overseas universities have research groups in GVC analysis or related fields like global production networks, including the University of Manchester (UK) and Oxford Business School (UK), Copenhagen Business School (Denmark), University of Padova (Italy), the National University of Singapore, and the University of International Business and Economics (Beijing, China).

IV. Implementing Supply-Chain Resiliency: A Few Recommendations

Based on this overview of various concepts, findings and trends in recent supply-chain research, I will highlight several final topics that may be relevant in the Department of Commerce's efforts to design and implement projects to strengthen supply-chain resiliency.

Supply Chains Are Product-Specific

Although it is tempting to think of supply chains in broad industry categories, such as automotive, aerospace or semiconductors, in fact supply chains are often quite product-specific and we overgeneralize at our peril. For example, during the COVID-19 pandemic, it was common to analyze disruptions in COVID-19-related medical supplies as though they fit a standard pattern. Particular concern was given to shortages of personal protective equipment (PPE) such as sterile rubber gloves and face masks to limit the spread of the novel coronavirus in the general population, as well as ventilators used by medical personnel to treat seriously ill patients. But recent supply-chain research shows that PPE shortages required different solutions, depending on how the supply chains were organized:

- *Rubber gloves*: Production was concentrated in Southeast Asia, and Malaysia is the dominant supplier with two-thirds of global exports. Although some shortages persist, the U.S. resolved its main supply shortfalls via increased imports of sterile gloves from Malaysia and Thailand.[27]

- *Face masks:* China accounted for about 60% of U.S. face mask imports prior to the pandemic, but China suspended its exports of face masks worldwide as it dealt with its own outbreak of COVID-19 cases in early 2020. In late March 2020, the U.S. government began to encourage large U.S. face mask producers like 3M and Honeywell along with smaller domestic suppliers to ramp up production, but it took several months before the supply gap was substantially narrowed by late August.[28]

- *Ventilators:* The United States confronted acute shortages of ventilators in late March and April, 2020, a life-saving device for many COVID-19 patients treated in the intensive-care units (ICU) of hospitals. Ventilators were much more complex than other PPE items, and the Defense Production Act was invoked to facilitate production partnerships between U.S. auto companies like General Motors and Ford with much smaller medical equipment firms. Although U.S. ventilator output dramatically increased, domestic supply soon exceeded demand. The number of ventilators in the U.S. strategic stockpile surged from 10,000 in April to over 95,000 by mid-August 2020, but only a very small number of these machines were actually used to treat COVID-19 patients. With improved hospital care, far fewer patients were sent to ICUs, demand for ventilators plummeted, and the U.S. ventilator shortage became a glut.[29]

Lessons the Department of Commerce can take away from these COVID-19 product case studies include:

(1) Related products with different supply-chain structures may require distinct policy solutions (e.g., reliance on trade ties for rubber gloves; use of the Defense Production Act in both face masks and ventilators to increase domestic production; anticipate the risks in overbuilding strategic stockpiles).
(2) An up-to-date and regularly revised inventory of the main suppliers (domestic and foreign) in key U.S. supply chains will facilitate a much quicker policy response.
(3) Public-private collaboration is required for effective interventions, including cross-industry production partnerships, and appropriate committees and decision-making units should be created based on what we learned from previous experiences.

Beware of Technological Lock-In

The pace of technological change in global supply chains can be startlingly fast. In the semiconductor industry, this is illustrated by what is referred to as "Moore's Law" → the number of transistors on a semiconductor doubles every two years; this is supplemented by "Moore's Second Law" → the cost of constructing a semiconductor fabrication facility doubles every four years.[30] Because of such rapid change, the potential for technological lock-in is particularly high in R&D and design-intensive fields, such as aerospace and semiconductors. Since it costs $12-$20 billion to build a new state-of-the-art chip fabrication facility, caution in planning such investments and spreading the risks across strategic production partners (both inside the United States and abroad) are prudent supply-chain practices.

The mobile telecom industry, which is the largest end-market for semiconductors, illustrates the rapidly evolving landscape in technology-intensive GVCs. The leading smartphone brands in 2019 were: Samsung (19.2%), Huawei (15.6%) and Apple (12.6%). Previous industry leaders like Nokia (Finland), Motorola (U.S.), Ericsson (Sweden), and Blackberry (Canada) have disappeared from the market. Current market pacesetters each have a different business model:

- *Samsung* is a highly integrated global producer, but relies on open-source software.
- *Apple* is a global innovator that relies almost exclusively on proprietary technology.
- *Huawei* has emerged as a "national champion" within China using a mix of open-source and own technology, but it is hindered by the Chinese government's strict controls on domestic Internet access for foreign firms and by U.S.-led sanctions that restrict Huawei's access to buying parts and components from U.S. companies.
- *Google* is now entering the smartphone GVC primarily on the basis of its software (its Android OS platform) and capitalizing on its many users from other services it owns (such as Gmail, Google Maps, and YouTube), demonstrating the disruptive potential of digital platform pioneers.[31]

Because the path to innovation in the mobile telecom industry depends on so many industries – including semiconductors, digital services, hardware devices, and telecom providers, among

others – the result is a "massively modular system" that remains vulnerable to short-term disruption.[32] Trying to reshore supply chains in an industry such as this with an ecosystem of hundreds of globally distributed and specialized firms and numerous critical inputs poses significant national security risks and a plethora of practical and policy difficulties.

Be Mindful of Unintended Consequences

Another concern for supply chain resiliency are the unintended consequences of policy in a hyper-connected world. This is most clearly evident with trade restrictions, such as the recent U.S.-China "trade war" as well as U.S. tariffs on imported goods from neighboring trade partners like Mexico and Canada. Such policies are intended to support U.S. firms and save American jobs, but given the dense inter-firm networks in global supply chains, restrictions on U.S. imports often have a deleterious impact on U.S.-based companies.

The North American automotive industry provides a striking example. U.S. automotive imports from Mexico contain 40% U.S. content (i.e., parts made by U.S.-based firms that are incorporated in Mexico's exports back to the U.S.) and imports from Canada are 25% U.S. content by value, whereas goods imported from China contain just 4% U.S. content.[33] Thus, tariffs on imports from Mexico and Canada can hurt U.S. suppliers rather than help them.

Trade policies created a different set of unintended consequences in the 1980s when the U.S. government imposed voluntary export restraints (VERs) on Japanese carmakers to limit the quantity of their exports to the American market. Although the VERs were successful in limiting Japanese exports, they induced a wave of foreign direct investment by Japanese carmakers and parts suppliers in the United States to sidestep the VERs. Subsequently, Korean and European automakers followed suit, and foreign auto "transplant" firms are now roughly equivalent to their American competitors in automotive output and employment in the U.S. market.[34]

Long-Term Funding for Supply-Chain Research

Last month, the U.S. Senate passed the U.S. Innovation and Competition Act by a final vote of 68-32, which strengthened the role of the NSF and other leading federal agencies to coordinate in scientific and technological innovation related to key U.S. supply chains.[35] This is a very significant and positive step, especially the proposed creation of an NSF technology directorate that could help focus technology research in areas of critical national importance. However, more specific attention should be devoted to the aforementioned challenges confronted by universities in supply-chain research.

One issue is to supplement the previous temporary support provided by U.S. foundations like Alfred P. Sloan and Rockefeller, which initiated a process of institution-building involving U.S. universities, but it was never designed as a long-term solution to enhancing the resilience of American industries by overcoming short-term disruptions or promoting broad-based and sustainable economic growth. For more decentralized U.S. supply-chain projects, like North

Carolina in the Global Economy, a state-level focus did not guarantee local funding. The North Carolina Department of Commerce provided no financial support for this Duke GVC Center initiative, despite utilizing many of the materials from the NC-Global Economy website for internal and overseas presentations and brochures.

Additional project-based funding by NGOs such as Environmental Defense Fund and Oxfam America has certainly boosted the knowledge capacities of university-based research centers and independent scholars, but several related difficulties remain. These include:

- providing incentives for universities to build and sustain *industry-oriented research communities* over time;
- facilitating the ongoing *data-collection efforts* needed to allow supply-chain datasets to meet the criteria of top-level peer-reviewed scientific journals as well as policy relevance; and
- building inter-university, cross-regional and international *research networks* that allow for robust efforts to develop analytical frameworks, generate testable propositions, and collaborate with policymakers and practitioners.

In conclusion, given the Department of Commerce's central role in ensuring the resiliency of critical U.S. supply chains, my testimony has sought to highlight the connections between firm strategies, GVC structures, and diverse government policy objectives. The opportunity to revitalize American industries from the "bottom up" seems particularly timely. Broad-based economic growth is often decentralized, and thus we need comprehensive frameworks to promote and evaluate how U.S. companies, states and communities compete across different places and within global industries. Tools like value-chain mapping and using new technologies to build resiliency within local clusters or hubs hopefully can assist this essential mission.

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[1] Alfred D. Chandler, Jr., *The Visible Hand: The Managerial Revolution in American Business* (Belknap Press, 1977).

[2] Joseph Grunwald and Kenneth Flamm, *The Global Factory: Foreign Assembly in International Trade* (Washington, DC: Brookings Institution, 1985).

[3] Gary Gereffi, *Global Value Chains and Development: Redefining the Contours of 21st Century Capitalism* (Cambridge University Press, 2018); Stefano Ponte, Gary Gereffi and Gal Raj-Reichert (eds.), *Handbook on Global Value Chains* (Edward Elgar Publishing, 2019); World Bank, *Trading for Development in the Age of Global Value Chains*, World Development Report 2020 (World Bank Group, 2020).

[4] Ekaterina Turkina, Ari Van Assche and Raja Koli, "Structure and evolution of global cluster networks: Evidence from the aerospace industry," *Journal of Economic Geography* 16 (2016): 1211-1234.

[5] Johannes Van Biesebroeck and Alexander Schmitt, "Testing predictions on supplier governance from the global value chains literature," *Industrial and Corporate Change* (2021), https://doi.org/10.1093/icc/dtab034.

[6] Olivier Cattaneo, Gary Gereffi and Cornelia Staritz (eds.), *Global Value Chains in a Postcrisis World: A Development Perspective* (World Bank, 2010); UNCTAD, *World Investment Report 2013 – Global Value Chains: Investment and Trade for Development* (United Nations Conference on Trade and Development, 2013); UNIDO, *Global Value Chains and Development: UNIDO's Support towards Inclusive and Sustainable Industrial Development* (United Nations Industrial Development Organization, 2015).

[7] Gary Gereffi, "Global value chains and international development policy: Bringing firms, networks and policy-engaged scholarship back in," *Journal of International Business Policy* 2(3) (2019): 195-210.

[8] The White House, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Economic Growth," 100-Day Reviews Under Executive Order 14017, June 2021.
[9] Lizzy O'Leary, "The modern supply chain is snapping," *The Atlantic*, March 19, 2020; Willy C. Shih, "Bringing manufacturing back to the U.S. is easier said than done," *Harvard Business Review*, April 15, 2020; Aaron Friedberg, "The United States needs to reshape global supply chains," *Foreign Policy*, May 8, 2020; Robert E. Lighthizer, "The era of offshoring U.S. jobs is over," *New York Times*, May 11, 2020.
[10] Gary Gereffi, "The organization of buyer-driven global commodity chains: How U.S. retailers shape overseas production networks," in Gary Gereffi and Miguel Korzeniewicz (eds.), *Commodity Chains and Global Capitalism* (Praeger, 1994), pp. 95-122.
[11] Gary Gereffi, John Humphrey and Timothy Sturgeon, "The governance of global value chains," *Review of International Political Economy* 12(1) (2005): 78-104
[12] White House (2021), op. cit., pp. 34-35.
[13] Gary Gereffi, Hyun-Chin Lim and Joonkoo Lee, "Trade policies, firm strategies, and adaptive reconfigurations of global value chains," *Journal of International Business Policy* (2021), https://link.springer.com/article/10.1057%2Fs42214-021-00102-z.
[14] White House (2021), op. cit., p. 24.
[15] Ibid., pp. 24-25.
[16] World's Top Export Countries, https://www.worldstopexports.com/worlds-top-export-countries/, accessed on July 6, 2021.
[17] See the North Carolina in the Global Economy website at http://ncglobaleconomy.com.
[18] http://www.ncglobaleconomy.com/textiles/overview.shtml
[19] Bill Lester and Lukas Brun, "The economic impact of the High Point market," Duke Center on Globalization, Governance & Competitiveness (CGGC), Durham, N.C., October 2013, available at https://gvcc.duke.edu/wp-content/uploads/2013-09-30HighPointMarket-economic-impact-analysis-1.pdf.
[20] Marcy Lowe, Hua Fan and Gary Gereffi, "U.S. smart grid: Finding new ways to cut carbon and create jobs," Duke CGGC, Durham, N.C., April 19, 2011, available at https://gvcc.duke.edu/wp-content/uploads/Lowe_US_Smart_Grid_CGGC_04-19-2011.pdf.
[21] Marcy Lowe, Hua Fan and Gary Gereffi, "Smart grid: Core firms in the Research Triangle Region, NC," Duke CGGC, Durham, N.C., May 11, 2011, available at https://gvcc.duke.edu/wp-content/uploads/Lowe_Research-Triangle-Smart-Grid_CGGC_05-24-2011.pdf.
[22] Gary Gereffi, Kristen Dubay and Marcy Lowe, "Manufacturing climate solutions: Carbon-reducing technologies and U.S. jobs," Duke CGGC, Durham, N.C., November 2008, available at https://gvcc.duke.edu/wp-content/uploads/greeneconomy_Full_report.pdf.
[23] https://gvcc.duke.edu/search-our-work/?fwp_cggc_search=environmental%20defense%20fund.
[24] Lukas Brun and Gary Gereffi, "Battery storage: North Carolina's footprint in the global value chain," report commissioned by Audubon North Carolina, February 1, 2021, available at https://mercury.postlight.com/amp?url=https://nc.audubon.org/press-release/report-finds-north-carolina-well-positioned-battery-storage-growth.
[25] David Sebastien, "Apple to build new campus in North Carolina: Move would create at least 3,000 jobs in machine learning, AI, software engineering and other fields, company says," *Wall Street Journal*, April 26, 2021, available at https://www.wsj.com/articles/apple-to-build-new-campus-in-north-carolina-11619441000; Rick Smith, "Google picks Durham for engineering hub, aims to create 1,000 jobs," March 18, 2021, available at https://www.researchtriangle.org/news/google-picks-durham-for-engineering-hub-aims-to-create-1000-jobs/.
[26] The GVC Initiative agenda and members are discussed in Gary Gereffi and Raphael Kaplinsky (eds.), "The value of value chains: Spreading the gains from globalization," special issue of *IDS Bulletin* 32(3), July (2001).
[27] Gary Gereffi, "Increasing resilience of medical supply chains during the COVID-19 pandemic," *Industrial Analytics Platform*, June 24, 2021, available at https://iap.unido.org/articles/increasing-resilience-medical-supply-chains-during-covid-19-pandemic.

[28] Gary Gereffi, "What does the COVID-19 pandemic teach us about global value chains? The case of medical supplies," *Journal of International Business Policy* 3(3) (2020): 287-301, available at https://link.springer.com/article/10.1057/s42214-020-00062-w.
[29] Faiz Siddique, "The U.S. forced major manufacturers to build ventilators. Now they're piling up unused in a strategic reserve," *Washington Post*, August 18, 2020.
[30] White House (2021), op. cit., pp. 34, 42 & 59.
[31] Joonkoo Lee and Gary Gereffi, "Innovation, upgrading, and governance in cross-sectoral global value chains: The case of smartphones," *Industrial and Corporate Change*, (2021), available at https://doi.org/10.1093/icc/dtaa062.
[32] Eric Thun, Daria Taglioni, Timothy J. Sturgeon and Mark P. Dallas, "Why policy makers should pay attention to the concept of massive modularity: The example of the mobile telecom industry," *Let's Talk Development*, World Bank blog, June 18, 2021, available at https://blogs.worldbank.org/developmenttalk/why-policy-makers-should-pay-attention-concept-massive-modularity-example-mobile.
[33] Gereffi (2018), op. cit., p. 436.
[34] Gereffi, Lim and Lee (2021), op. cit.; Timothy Sturgeon, Johannes Van Biesebroeck and Gary Gereffi, "Value chains, networks and clusters: Reframing the global automotive industry," *Journal of Economic Geography* 8(3) (2008: 297-321.
[35] "Chair Cantwell statement on Senate passage of the U.S. Innovation and Competition Act and NASA authorization," June 8, 2021, https://www.commerce.senate.gov/2021/6/chair-cantwell-statement-on-senate-passage-of-the-u-s-innovation-and-competition-act-and-nasa-authorization.