BUILDING RESILIENT SUPPLY CHAINS: THE CASE OF SEMICONDUCTORS

August 2024

Background Paper No. 26

BY JEFFREY D. BEAN AND ANDREAS KUEHN

I. INTRODUCTION

After decades of globalization and relative stability, the world is at a turning point. Amidst rising geopolitical tensions, shifting supply chains and states' embrace of national industrial strategies, policy and corporate decision makers are facing a host of new, challenging questions concerning technologies, markets, and supply chains crucial to economic and national security. These critical and emerging technologies are increasingly and intimately intertwined with geopolitical frictions, if not at their core. Thus, it is important to recognize today's unique challenges that require innovative thinking and approaches in technology governance to strengthen and build resilient supply chains that are prepared to withstand and can adapt to new geopolitical dynamics.

Interconnected global supply chains based around comparative advantage and lower labor costs linked through complex logistics have proven to be a key component of globalization.[1] However, the interdependence between economies, and the reliance on even geopolitical rivals, has revealed downsides that go beyond pure economic and efficiency considerations. Disruptions, especially during and after the COVID-19 pandemic, have reinforced the need for states to assess risks across a variety of national industries and global market sectors. These domains range from critical food and medical supplies, to automotive, raw materials and other commodity markets, and especially high-tech supply chains, like in the semiconductor ecosystem. To address the issue of supply chain resilience, this assessment evaluates semiconductors as a case study and discusses the risks of disruptions to the supply chain and the measures governments across the globe have taken individually and collectively to strengthen this crucial industry.

Semiconductors, which underpin nearly all current and near-future technology applications in the commercial and military realms, are a key concern for nations' economic, security, and foreign policies.[2] Governments have chosen to manage dual-use technologies and their supply chains, including semiconductors, comprehensively through new export controls, tariffs, investment screening, and de-risking through investments, subsidies and international cooperation to mitigate risk from growing geopolitical friction. These efforts are primarily driven unilaterally, but collective action and cooperation will be pivotal to ensuring supply chain resilience moving forward for the United States and its allies and partners.

---

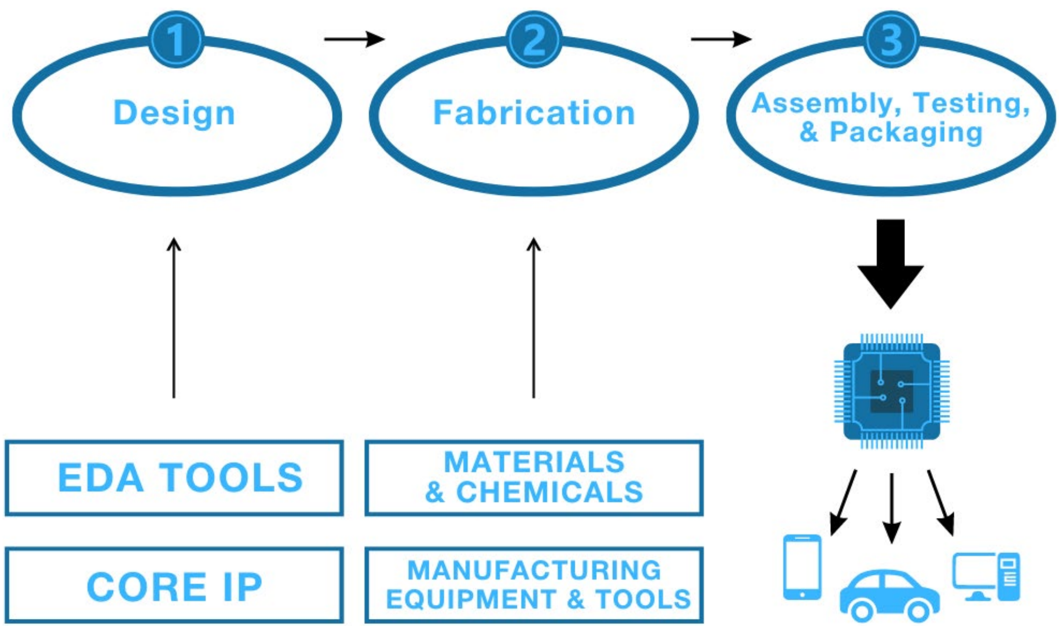
[1] OECD, "Globalisation, Comparative Advantage, and the Changing Dynamics of Trade," OECD Publishing, October 2011, 5, https://doi.org/10.1787/9789264113084-en.

[2] The White House, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-based Growth," June 2021, https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf; Raj Varadarajan, et al., "Emerging Resilience in the Semiconductor Supply Chain," Boston Consulting Group and Semiconductor Industry Association, May 2024, https://www.semiconductors.org/wp-content/uploads/2024/05/Report_Emerging-Resilience-in-the-Semiconductor-Supply-Chain.pdf; Jeffrey Bean and Stephen Ezell, "When the Chips are Down: Policy Priorities for Sustaining U.S. Semiconductor Leadership," War On the Rocks, May 14, 2021, https://warontherocks.com/2021/05/when-the-chips-are-down-policy-priorities-for-sustaining-u-s-semiconductor-leadership/. It is hard to overstate how important chips are to modern economic growth. A study estimated that in 2012 semiconductors were integral to over $7 trillion in economic activity, or 10 percent of global GDP. See Oxford Economics, "Enabling the Hyperconnected Age," Oxford Economics, 2013, 20, https://semismatter.com/enabling-the-hyperconnected-age-the-role-of-semiconductors/.

II. SEMICONDUCTOR ECOSYSTEM PRIMER

Designed for efficient operations rather than resiliency, semiconductor supply chains can be prone to disruption. To take advantage of massive economies of scale, clustering effects, and regional talent, components of chips can travel more than 25,000 miles and can cross more than 70 borders before reaching their final destination.[3] At its heart, the semiconductor ecosystem consists of three primary phases – (1) design, (2) front-end fabrication, and (3) back-end assembly, testing and packaging. This is followed by systems integration of chips into products such as televisions, video game consoles, personal computers, and cell phones by adjacent industries for consumer goods, industrial goods, as well as defense and space industries. These phases are supported by core intellectual property (IP), electronic design automation (EDA) tools, and raw and processed material inputs, built with a series of sophisticated tools, and incorporate crucial subcomponents.

Figure 1: Semiconductor Value Chain Phases



Source: Author creation.

The semiconductor industry is diverse. It includes some firms that control every aspect of chip production, i.e., integrated device manufacturers (IDMs) such as Intel, Samsung, SK Hynix, or Micron, versus some that leverage the fabless-foundry model. Fabless companies such as AMD, NVIDIA, MediaTek, Huawei/HiSilicon, or Qualcomm design chips, and then partner with foundries such as TSMC in Taiwan, Samsung in South Korea, Global Foundries in the United States, or SMIC in China to fabricate chips to spec on a contract basis. And then for assembly, packaging, and testing the fabless companies leverage those same foundries or outsource to other parties such as Amkor or ASE to complete production. The industry is highly capital intensive and new fabs cost billions of dollars to build and require extensive supporting infrastructure.

[3] Global Semiconductor Alliance, "Globality and Complexity of the Semiconductor Ecosystem," Global Semiconductor Alliance, 2020, https://www.gsaglobal.org/globality-and-complexity-of-the-semiconductor-ecosystem.

The type of chips produced vary based on the role they play in computational processes, with heavy specialization in the industry. Notable variants are logic chips, including CPUs and GPUs, memory chips, including DRAM and storage drives, and power and analog chips, such as capacitors and voltage regulators. In addition, there are supporting components such as printed circuit boards that connect chips.

The primary players for design and fabrication in the industry are concentrated in the Pacific Ocean region.[4] Firms based in the United States, Japan, South Korea, and Taiwan play essential roles in the semiconductor industry. U.S. firms lead in advanced logic chip design (namely Intel, NVIDIA, and AMD) and equipment manufacturing (KLA, LAM, and Applied Materials), Taiwan leads in advanced foundry services and advanced packaging (principally TSMC), Japanese firms (such as Tokyo Electron) lead in materials and equipment manufacturing, while South Korea leads in memory design and fabrication (Samsung and SK Hynix). China leads in legacy ATP and systems integration.[5] The Dutch firm ASML produces the most advanced extreme ultraviolet (EUV) lithography machines used in fabrication, which are essential for advanced chips. Japanese and the aforementioned U.S. firms produce deep ultraviolet (DUV) lithography tools (Nikon and Canon) or other essential leading chip manufacturing materials, tools, and equipment (such as Tokyo Electron, KLA, LAM, and Applied Materials) or EDA tools (Synopsys and Cadence), respectively. These firms are, in turn supported by facilities, equipment manufacturers, and assembly in countries ranging from Singapore, Malaysia, and Vietnam in Southeast Asia, to mainland China in Northeast Asia, to Ireland, Germany, and the Netherlands in Europe, to Israel in the Middle East.

A trade analysis prepared by the Pacific Northwest National Laboratory demonstrates the high level of concentration in Northeast Asia for the semiconductor industry for U.S. imports for 97 key commodities. This is limited to a relatively small group of suppliers for key inputs like photographic plates and goods — used in lithography — and components for tools in semiconductor manufacturing such as dicing machines and polish grinders to the United States and suggests that greater diversification throughout the semiconductor supply chain will be a challenge in some areas.[6] Fortunately, many come from companies in allied countries like Japan, South Korea, and Taiwan. However, a few specific chokepoints controlled by China exist for critical minerals that will require effort to establish viable alternatives. This conundrum of concentration and dispersed inputs provides insight into the fragility of many modern advanced technology supply chains.

III. RISKS ABOUND: DISRUPTING GLOBAL SUPPLY CHAINS

Along the chain, threats of disruption abound. In recent years, the Russian invasion of Ukraine, the resumption of the Israel-Palestine conflict, the ongoing risk of armed

[4] Akhil Thadani and Gregory C. Allen, "Mapping the Semiconductor Supply Chain: Critical Role of the Indo-Pacific Region," Center for Strategic and International Studies, May 2023, https://www.csis.org/analysis/mapping-semiconductor-supply-chain-critical-role-indo-pacific-region.

[5] Stephen Ezell, "How Innovative Is China in Semiconductors?," Information Technology and Innovation Foundation, August 2024, 20-21, https://www2.itif.org/2024-china-semiconductors.pdf.

[6] Taylor Roth, et al., "Critical Technology Supply Chains in the Asia-Pacific: Options for the United States to De-risk and Diversify," National Bureau of Asian Research, November 2023, https://www.nbr.org/wp-content/uploads/pdfs/publications/sr106_deriskingcriticaltech_nov2023.pdf.

conflict in Northeast Asia, terrorist attacks on vessels in key shipping arteries, maritime accidents, the continuation of U.S.-China trade friction, and the recognition of the exposure of tech linchpins to natural disasters, coupled with potential future pandemics — have all highlighted the necessity to strengthen and diversify chip supply chains.[7] Typologies of supply chain disruptions vary, with some experts focusing on nature of the event while others concentrate on the impact to suppliers and distributor, the frequency of the event, or the scope.[8] States are mostly concerned about the following types of supply chain disruptions: trade remedies, weaponization of supply chains, armed conflict, natural disasters, pandemics, transportation and logistical accidents, and financial crises.

Certain states' anticompetitive practices and illicit coercion to help domestic firms and undermine foreign competitors present important challenges to the industry.[9] The People's Republic of China, for example, holds significant control over the mining and processing of critical semiconductor minerals and has retaliated against U.S. export controls by imposing restrictions on the export of antimony, gallium, germanium, and graphite — the latter three are important components in a range of industries, including electronic commodities such as batteries for electric vehicles, but also utilized as semiconductor materials for optics and photonics (gallium nitride semiconductors are superior to silicon chips in some applications) or in semiconductor manufacturing.[10] When coupled with years of IP theft and China's civil-military fusion policies, considerable risks to supply chains and global trade have accumulated.[11]

Furthermore, U.S.-China trade frictions continue, including over U.S. government export control efforts announced in October 2022 and October 2023 to restrict China's access to specific advanced semiconductors, including graphics processing units (GPUs) utilized for artificial intelligence (AI) computation, supercomputer components, and semiconductor manufacturing equipment, to prevent the development of chips for use by the People's Liberation Army.[12] The same measures may also hold back Chinese tech-

---

7 Zongyuan Zoe Liu, "Baltimore Bridge Collapse Tests U.S. Supply Chains," Council on Foreign Relations, April 18, 2024, https://www.cfr.org/expert-brief/baltimore-bridge-collapse-tests-us-supply-chains.

8 K. Katsaliaki, P. Galetsi, and Sameer Kumar, "Supply Chain Disruptions and Resilience: A Major Review & Future Research Agenda," Annals of Operation Research, January 2021, https://doi.org/10.1007/s10479-020-03912-1.

9 Jon Bateman, "Countering Unfair Chinese Economic Practices and Intellectual Property Theft," *U.S.-China Technological "Decoupling": A Strategy and Policy Framework*, Carnegie Endowment for International Peace, 2022, https://carnegieendowment.org/2022/04/25/countering-unfair-chinese-economic-practices-and-intellectual-property-theft-pub-86925.

10 Christopher Cytera, "Gallium, Germanium, and China — The Minerals Inflaming the Global Chip War," CEPA, August 8, 2023, https://cepa.org/article/china-gallium-and-germanium-the-minerals-inflaming-the-global-chip-war/; SGL Carbon, "Graphite in the Production of Semiconductors," accessed August 20, 2024, https://www.sglcarbon.com/en/markets-solutions/markets/semiconductor/#.

11 Christopher Wray, "The Threat Posed by the Chinese Government and the Chinese Communist Party to the Economic and National Security of the United States," U.S. Federal Bureau of Investigation, Washington, D.C., July 7, 2020, https://www.fbi.gov/news/speeches/the-threat-posed-by-the-chinese-government-and-the-chinese-communist-party-to-the-economic-and-national-security-of-the-united-states.

12 Bureau of Industry and Security, "Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC)," U.S. Department of Commerce, October 7, 2022, https://www.bis.doc.gov/index.php/documents/about-bis/newsroom/press-releases/3158-2022-10-07-bis-press-release-advanced-computing-and-semiconductor-manufacturing-controls-final/file; Bureau of Industry and Security, "Commerce Strengthens Restrictions on Advanced Computing Semiconductors, Semiconductor Manufacturing Equipment, and Supercomputing Items to Countries of Concern," U.S. Department of Commerce, October 17, 2023, https://www.bis.doc.gov/index.php/documents/about-bis/newsroom/press-releases/3355-2023-10-17-bis-press-release-acs-and-sme-rules-final-js/file; Hanna Dohmen and Jacob Feldgoise, "A Bigger Yard, A Higher Fence: Understanding BIS's Expanded Controls on Advanced Computing Exports," Center for Security and Emerging Technology, December 4, 2023, https://cset.georgetown.edu/article/bis-2023-update-explainer/.

nology firms in competing and innovating and have further fractured the global market. China has redoubled long-standing efforts to develop semiconductor self-sufficiency with a focus on indigenous tools.[13] Export controls can also harm U.S. companies' ability to retain their technological edge.[14] This has short- and long-term implications. In the short-term, their inability to sell their most advanced chips or manufacturing tools to China cuts into revenue that is reinvested in research and development to maintain American leadership.[15] And this loss of revenue is not limited to chips or chip manufacturing equipment. A recent study estimated the total cost of export controls targeting China across all suppliers/industries at $130 billion.[16] In addition, the long-term consequences of foreign firms "designing out" U.S. licensed architectures, components, manufacturing equipment or personnel will further increase fragmentation and undermine U.S. firms position in the market.

Supply chains themselves are also a tool of geopolitical competition, which have been weaponized by China and even the United States. The risks of weaponization are essential drivers for de-risking efforts and efforts to reduce or mitigate dependencies.[17] For example, China's control over critical minerals and rare earth elements contributes to U.S. concerns that Beijing may weaponize inputs, as they have signaled with antimony, gallium, graphite, and germanium. In addition, technology bans, such as the Chinese government's restrictions on Micron memory products, limitations on the use of Apple iPhones for Chinese government and party officials, and blocking operations of Tesla cars near sensitive facilities, add to the risks for firms. Even U.S. bans on Huawei base stations and rip and replace policies are justified largely through national security concerns. The Japanese government's 2019 export control policy shift to remove leading South Korean semiconductor firms from whitelists for export licenses of high purity chemicals used in semiconductor manufacturing, including hydrogen fluoride, fluoride polyimide, and photoresists disrupted South Korean firms' operations and compelled them to develop greater levels of indigenous sourcing. The controls were later lifted and whitelisting restored in 2023.[18] Renewed emphasis on economic security has accompanied this shift in the landscape in technology competition and national economic security.

---

[13] Paul Triolo, "A New Era for the Chinese Semiconductor Industry: Beijing Responds to Export Controls," American Affairs, Spring 2024, https://americanaffairsjournal.org/2024/02/a-new-era-for-the-chinese-semiconductor-industry-beijing-responds-to-export-controls/; Will Hunt, Saif M. Khan, and Dahlia Peterson, "China's Progress in Semiconductor Manufacturing Equipment: Accelerants and Policy Implications," Center for Security and Emerging Technology, March 2021, https://cset.georgetown.edu/publication/chinas-progress-in-semiconductor-manufacturing-equipment/; Mackenzie Hawkins et al., "Global Chips Battle Intensifies With $81 Billion Subsidy Surge," *Bloomberg*, May 12, 2024, https://www.bloomberg.com/news/features/2024-05-12/chip-technology-spending-gets-81-billion-boost-in-china-rivalry.

[14] Hanna Dohmen, Jacob Feldgoise, and Charles Kupchan, "The Limits of the China Chip Ban," Foreign Affairs, July 24, 2024, https://www.foreignaffairs.com/china/limits-china-chip-ban.

[15] Antonio Varas and Raj Varadarajan, "How Restrictions to Trade with China Could End US Leadership in Semiconductors," Boston Consulting Group, March 2020, https://web-assets.bcg.com/img-src/BCG-How-Restricting-Trade-with-China-Could-End-US-Semiconductor-Mar-2020_tcm9-240526.pdf.

[16] Matteo Crosignani, Lina Han, Marco Macchiavelli, and André F. Silva, "Geopolitical Risk and Decoupling: Evidence from U.S. Export Controls," Federal Reserve Bank of New York, April 2024, https://doi.org/10.59576/sr.1096.

[17] Henry Farrell and Abraham L. Newman, "Weaponized Interdependence: How Global Economic Networks Shape State Coercion," in Daniel Drezner, Henry Farrell, and Abraham L. Newman, *The Uses and Abuses of Weaponized Interdependence*, Brookings Institution Press, 2021, 31.

[18] Presidential Office, "Japan to lift restrictions on export of 3 chip components to Korea," Ministry of Foreign Affairs, https://www.mofa.go.kr/eng/brd/m_5674/view.do?seq=320788. Roughly $33 million worth of Japanese chemicals per month was a key input into over $8 billion worth of Korean chips.

Yet other more traditional risks are still present. The risks of armed conflict and natural disasters are other significant drivers behind supply chain resilience efforts. The Russian invasion of Ukraine in 2022, for example, disrupted the global supply of neon gas used for semiconductor manufacturing. Prior to war with Russia, two Ukrainian companies produced over fifty percent of purified neon gas used for semiconductor manufacturing, forcing firms such as SK Hynix and TSMC to seek alternative suppliers.[19] Armed conflict also remains a risk on both the Korean peninsula and in Taiwan.[20] The lack of access to chips produced at TSMC in Taiwan due to a contingency in the Taiwan Strait, could cost the United States as much as five to ten percent of current gross domestic product, exceeding the cost of the COVID-19 pandemic or the 2008 global financial crisis.[21]

In addition, natural disasters, including earthquakes, tsunamis, volcanic eruptions, and violent storms, have also impacted the semiconductor ecosystem in the past and are part of future considerations. The 1999 Taiwan earthquake, the 2004 Indian Ocean tsunami, and the March 2011 triple disaster in Japan all had significant impacts on electronics and semiconductor supply chains. The recent April 2024 earthquake in Taiwan resulted in a few fatalities but was notable for the minimal damage and speed at which TSMC's operations were fully restored.[22]

Finally, global logistics networks on land, sea, and air make global supply chains seamless. Ships blocking maritime arteries or colliding with bridges, rebels attacking vessels on international trade routes, crumbling rail and highway infrastructure, or inefficient customs clearance can undermine and disrupt supply chains, leading to significant delays and costs.[23]

In this context, firms anticipate supply chain risks growing. According to one study, companies should expect supply chain disruptions to occur, even with mitigation strategies in place – with disruptions of one-two weeks occurring every two years, and with disruptions of two months or more every five years.[24] Ongoing practice and resilience

---

[19] Alexandra Alper, "Exclusive: Russia's Attack on Ukraine Halts Half of World's Neon Output for Chips," *Reuters*, March 11, 2022, https://www.reuters.com/technology/exclusive-ukraine-halts-half-worlds-neon-output-chips-clouding-outlook-2022-03-11/.

[20] Bradley Martin, et al, "Supply Chain Interdependence and Geopolitical Vulnerability: The Case of Taiwan and High-End Semiconductors," RAND, 2023, https://www.rand.org/content/dam/rand/pubs/research_reports/RRA2300/RRA2354-1/RAND_RRA2354-1.pdf.

[21] U.S.-Taiwan Business Council, "United States, Taiwan, and Semiconductors: A Critical Supply Chain Partnership," The Project 2049 Institute and the US-Taiwan Business Council, 2023, https://www.us-taiwan.org/wp-content/uploads/2023/06/2023.06.21-Final-Semiconductor-Report.pdf.

[22] Sasha Rogelberg, "TSMC shrugs off Taiwan's biggest earthquake in 25 years, showing its massive chip foundry mega-complexes are nearly quake-proof," *Fortune*, April 3, 2024, https://fortune.com/2024/04/03/tsmc-taiwan-earthquake-nvidia-apple-chip-semiconductor-manufacturing/.

[23] Robert Hart, "Ship Refloated After Getting Stuck In Suez Canal—The Latest Incident Hitting World's Trade Artery." *Forbes*, January 9, 2023, https://www.forbes.com/sites/roberthart/2023/01/09/ship-refloated-after-getting-stuck-in-suez-canal-the-latest-incident-hitting-worlds-trade-artery; Noah Berman, "How Houthi Attacks in the Red Sea Threaten Global Shipping," Council on Foreign Relations, January 12, 2024, https://www.cfr.org/in-brief/how-houthi-attacks-red-sea-threaten-global-shipping; Sean Hackbarth, "How the Baltimore Bridge Collapse Affects Business and the Economy," U.S. Chamber of Commerce, April 2, 2024, https://www.uschamber.com/infrastructure/how-the-baltimore-bridge-collapse-affects-business-and-the-economy#:~:text=The%20collapse%20of%20the%20Francis,mobility%20for%20millions%20of%20people.

[24] Susan Lind et al, "Risk, Resilience, and Rebalancing Global Supply Chains," McKinsey Global Institute, August 2020, https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/risk%20resilience%20and%20rebalancing%20in%20global%20value%20chains/risk-resilience-and-rebalancing-in-global-value-chains-full-report-vh.pdf?shouldIndex=false.

investments will allow companies to stay more agile and better positioned to withstand supply chain disruptions but will not totally insulate firms from risks. Geographic position is another factor and firms' intentions across many sectors are shifting operations out of China as part of diversification strategies. This is reflected in the battery of data assembled about firms' intentions in China and reshoring generally. The American Chamber of Commerce in Shanghai released a member survey which indicated that, "40 percent of respondents are redirecting or planning to redirect investment originally planned for China, with most looking towards Southeast Asia." Another recent assessment found that over 70 percent of U.S. companies with manufacturing in China are now either in the process of or planning to shift operations to other countries – which has increased from 60 percent in April 2023 and 57 percent in 2022.[25] Certain firms are not just following a China+1 strategy, but recognizing the risk of concentration in Taiwan, and henceforth are pursuing Taiwan+1 strategies to ensure advanced semiconductor manufacturing is more geographically distributed to mitigate against local and regional shocks.

IV. STATE RESPONSES: RIGHT-SHORING AND RESILIENCE

States have responded to the risk of disruption by incorporating advanced technology manufacturing into their national economic security strategies, by providing incentives and grants to attract investments, and by seeking to foster talent development in key industries.

Like-minded states, including the United States, European Union (EU) members, Japan, South Korea, Australia, and India, have individually and collectively recognized the challenges and chosen to tackle them in several different ways. First, many have undertaken efforts to assess their dependencies, vulnerabilities, and relevant chokepoints in specific areas, such as semiconductors or critical minerals, in response to specific risks.[26] Second, leaders have pushed for policies of "right-shoring" to reduce reliance on any single region or country for manufacturing and also begun to grapple with establishing national economic security frameworks suited to their national contexts.[27,28] Third, some governments have established incentivization policies including subsidies, tax credits, and talent

---

[25] UBS Investment Bank, "China Economic Perspectives: CFO's take on COVID-19 impact," October 2020, https://www.ubs.com/global/en/investment-bank/in-focus/covid-19/2020/cfostake.html.

[26] The White House, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth: 100-Day Reviews under Executive Order 14017," The White House, 2021, https://purl.fdlp.gov/GPO/gpo156599; Taylor Roth, et al., "Critical Technology Supply Chains in the Asia-Pacific: Options for the United States to De-risk and Diversify,"; U.S. Department of Energy, "Semiconductor Supply Chain Deep Dive Assessment," U.S. Department of Energy Response to Executive Order 14017, America's Supply Chains," February 24, 2022, https://www.energy.gov/sites/default/files/2022-02/Semiconductor%20Supply%20Chain%20Report%20-%20Final.pdf.

[27] Kazuto Suzuki, "Understanding Japan's Approach to Economic Security," Stimson Center, February 10, 2023, https://www.stimson.org/2023/understanding-japans-approach-to-economic-security; Jeffrey D. Bean, "The United States and Japan's Semiconductor Supply Chain Diversification Efforts Should Include Southeast Asia," East West Center Asia Pacific Bulletin, May 6, 2020, https://www.eastwestcenter.org/publications/the-united-states-and-japan%E2%80%99s-semiconductor-supply-chain-diversification-efforts-should.

[28] Right-shoring refers to a set of de-risking practices and measures, including onshoring and nearshoring of suppliers, to reshape supply chains with the objectives to mitigate supply chain risks and decrease dependencies on suppliers. This may include among others diversification of suppliers and reduction of foreign suppliers based in countries deemed to pose a heightened geopolitical risk. Right-shoring contributes to resilience but often increases cost in supply chains.

development to better attract or diversify private investment in advanced tech manufacturing to ensure constant access to essential links in the supply chain.[29]

Table 1: Nations' Chips Acts by Value in USD

COUNTRY	PLANNED GRANTS/SUBSIDIES	TAX INCENTIVES/LOANS
United States	$39 billion	$75 billion
European Union	$46.3 billion	
China	$142 billion	
Japan	$25.3 billion	
Taiwan		$16 billion
South Korea		$55 billion
India	$10 billion	

Source: Bloomberg and Semiconductor Industry Association.[30]

Most notable is the last point on incentivization. The impetus is for governments to attract advanced fabrication facilities or fabs, assembly, packaging and testing facilities, mature-node chip fabrication for defense applications, and systems integration to strengthen semiconductor resilience, especially focused on domestic efforts and investments. The United States, the EU, Germany, the United Kingdom, Japan, South Korea, India, Singapore, and other governments have appropriated funding for subsidies and/or tax incentives to compete for investments from leading technology firms through various "Chips Acts." State or provincial governments are complementing these efforts with local incentives to build or expand clusters and innovative hubs in their respective region. On the corporate side, leading players such as Taiwan's TSMC, South Korea's Samsung, and U.S. firms Intel, Global Foundries, and Micron have announced new investments to diversify their operations in Japan, Germany, the United States, Southeast Asia, and India.[31]

In the United States, Congress has appropriated $52.7 billion for the CHIPS & Science Act, including $39 billion for grants. By December 2023, the first tentative funding

[29] Tetsushi Kajimoto and Sam Nussey, "Japan to Spend $13 Bln for Chip Industry Support in Extra Budget," *Reuters*, November 10, 2023, https://www.reuters.com/markets/asia/japan-allocate-13-bln-chip-industry-support-extra-budget-2023-11-10; Jo He-rim, "Korean Chips Act Aims to Extend Tax Cuts for Local Chipmakers," *The Korea Herald*, March 30, 2023. https://www.koreaherald.com/view.php?ud=20230330000782; Nishant Annu, "U.S. Pushes Chip-Sector Talent Development to Tackle Labor Shortage," *Nikkei Asia*, November 17, 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/U.S.-pushes-chip-sector-talent-development-to-tackle-labor-shortage.

[30] Mackenzie Hawkins, "Texas Instruments wins $4.6 billion in Chips Act grants, loans," *Bloomberg*, August 16, 2024, https://www.bloomberg.com/news/articles/2024-08-16/texas-instruments-wins-4-6-billion-in-chips-act-grants-loans

[31] Riho Nago, "TSMC Plans to Produce 6-Nm Chips in 2nd Japan Plant," *Nikkei Asia*, October 12, 2023, https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-plans-to-produce-6-nm-chips-in-2nd-Japan-plant; GlobalFoundries, "GlobalFoundries Completes Purchase of 800 Acres Adjacent to New York Manufacturing Facility," GlobalFoundries, April 27, 2023, https://gf.com/gf-press-release/globalfoundries-completes-purchase-of-800-acres-adjacent-to-new-york-manufacturing-facility; Intel, "Intel, German Government Agree on Increased Scope for Wafer Fabrication Site in Magdeburg." Intel Corp, June 19, 2023, https://www.intel.com/content/www/us/en/newsroom/news/intel-german-government-agree-magdeburg.html; Surabhi Prasad, "Micron's First Phase at Sanand to Be Operational by Early 2025, CEO Sanjay Mehrotra Confirms," *Business Today*, January 11, 2024, https://www.businesstoday.in/latest/corporate/story/microns-first-phase-at-sanand-to-be-operational-by-early-2025-ceo-sanjay-mehrotra-confirms-412796-2024-01-11.

notice for a mature-node chip manufacture for defense applications was announced.[32] Subsequent preliminary awards and agreements have included focus on advanced and mature node fabrication for logic, memory fabrication, and packaging, including a mix of foreign and domestic firms (See Table 2). These new synergistic policies are not only well-furnished with significant financial incentives but also backed by political will. Nevertheless, administering these programs and getting the funds to the industry is a complex and time-consuming endeavor. Uncertainties may derail promising projects along the way.[33]

Ultimately, these investment decisions are taken by private sector companies and must make economic sense to them. For example, Micron's announcement of an investment in a back-end facility for memory chips in India and TSMC's investments and construction of new chip fabrication facilities in the United States and Japan were both in response to new policies and their anticipated financial returns.

Given growing investments in semiconductors and China's extensive market subsidization, some voices have expressed concern about overcapacity of mature or legacy node chips, which in the past had negative effects on some players as lower prices led to large losses and inhibited R&D investment due to boom and bust cycles in the semiconductor industry.[34] These concerns are not limited to China (although those are the most concerning) — as chips act investments get stood up around the world, the question remains whether sufficient demand will emerge to drive contracts for all the new fabrication capacity, even with projections showing that due to AI and IoT, demand and markets for chips will continue to rise. Nevertheless, industry analysts expect semiconductors to become a trillion-dollar industry by 2030 or shortly after.[35]

V. BUILDING A COLLECTIVE SUPPLY CHAIN RAFT

Complementing domestic efforts, many like-minded states have chosen to collaborate through bilateral, minilateral, and multilateral technology partnerships to monitor crucial supply chains and to communicate on ways to collectively ensure supply chain resilience in the future, including to coordinate to avoid a subsidy race. States clearly recognize, while extensive domestic efforts are necessary, that globally interconnected supply chains mean they cannot go it alone. While much of the effort to protect against shocks is national and local, collaboration and coordination with international partners stands as a crucial line to ensure resilience of supply chains. In the case of the United States and

---

[32] U.S. Department of Commerce, "Biden-Harris Administration and BAE Systems, Inc., Announce CHIPS Preliminary Terms to Support Critical U.S. National Security Project in Nashua, New Hampshire," U.S. Department of Commerce, December 11, 2023, https://www.commerce.gov/news/press-releases/2023/12/biden-harris-administration-and-bae-systems-inc-announce-chips.

[33] For example, in December 2023 there was a delay in Germany's government finalizing subsidies due to a court proceeding over the national budget which was later resolved. See "Germany Resolves Budget Standoff, Maintains Subsidies for TSMC and Intel," *TrendForce*, December 14, 2023, https://www.trendforce.com/news/2023/12/14/news-germany-resolves-budget-standoff-maintains-subsidies-for-tsmc-and-intel/; Anton Shilov, "Intel and TSMC Could Lose Billions in Chip Factory Funding Thanks to Stalled German Budget, Intel Construction Is Already Underway," *Tom's Hardware*, November 22, 2023, https://www.tomshardware.com/news/intel-and-tsmc-could-lose-billions-in-funding-thanks-to-stalled-german-budget.

[34] Sujai Shivakumar, Charles Wessner, and Thomas Howell, "The Strategic Importance of Legacy Chips," Center for Strategic and International Studies, March 2023, https://www.csis.org/analysis/strategic-importance-legacy-chips.

[35] Ajit Manocha, "Global Semiconductor Industry – Driving to $1 Trillion and Beyond Together," SEMI, February 13, 2024, https://www.semi.org/en/blogs/semi-news/global-semiconductor-industry-driving-%241-trillion-and-beyond-together.

Table 2: Pre-Agreed Awards for CHIPS Act as of August 2024 (in USD)

COMPANY / LOCATION	TECHNOLOGY TYPE	INCENTIVES AMOUNT	PROJECT SIZE	ANNOUNCED
BAE Systems, Nashua, NH	Mature-node	$35 million	N/A	12/11/2023
Microchip Technology, CO	Mature-node	$90 million	N/A	1/4/2024
Microchip Technology, Gresham, OR	Mature-node	$72 million	N/A	1/4/2024
GlobalFoundries, Malta, NY	Current-generation, Mature-node	$1.375 billion; $1.6 billion in loans	$11.6 billion	2/19/2024
GlobalFoundries, Essex Junction, VT	Mature-node	$125 million	$900 million	2/19/2024
Intel, Hillsboro, OR	Leading-edge	$8.5 billion in grants; $11 billion in loans across all projects	$36 billion	3/20/2024
Intel, Chandler, AZ	Leading-edge		$32 billion	3/20/2024
Intel, Rio Rancho, NM	Advanced Packaging		$4 billion	3/20/2024
Intel, New Albany, OH	Leading-edge		$28 billion	3/20/2024
TSMC, Phoenix, AZ	Leading-edge	$6.6 billion in grants; $5 billion in loans	$65 billion	4/8/2024
Samsung, Taylor, TX	Leading-edge	$6.4 billion across all projects	$45 billion	4/15/2024
Samsung, Taylor, TX	Advanced Packaging			4/15/2024
Samsung, Austin, TX	Mature-node			4/15/2024
Micron, Clay, NY	Leading-edge	$6.14 billion in grants; $7.5 billion in loans across all projects	$100 billion	4/25/2024
Micron, Boise, ID	Leading-edge		$25 billion	4/25/2024
Polar, Bloomington, MN	Mature-node	$120 million	$525 million	5/13/2024
Absolics, Covington, GA	Materials for Advanced Packaging	$75 million	$600 million	5/23/2024
SolAero (Rocket Lab), Albuquerque, NM	Mature-node	$23.9 million	N/A	6/11/2024
Entegris, Colorado Springs, CO	Materials & Equipment	$75 million	$600 million	6/26/2024
Rogue Valley Microdevices, Palm Bay, FL	Mature-node	$6.7 million	$25 million	7/1/2024
Global Wafers, Sherman, TX	Wafers	$400 million in grants across all projects	$4 billion	7/17/2024
Global Wafers, St. Peters, MO	Wafers			7/17/2024
Amkor, Peoria, AZ	Advanced Packaging and Test	$400 million in grants; $200 million in loans	$2 billion	7/26/2024
SK hynix, West Lafayette, IN	Advanced Packaging & R&D	$450 million in grants; $500 million in loans	$3.87 billion	8/6/2024
Texas Instruments, Sherman, TX	Analog and embedded processors	$1.6 billion in grants; $3 billion in loans across all projects	$18 billion	8/16/2024
Texas Instruments, Lehi, UT	Analog and embedded processors			8/16/2024

Source: Semiconductor Industry Association and Chips Program Office.[36]

[36] Semiconductor Industry Association, "CHIPS Incentive Awards," Semiconductor Industry Association, accessed August 26, 2024, https://www.semiconductors.org/chips-incentives-awards/.

its partners, supply chain specific initiatives have been established in response to disruptions.[37] For example, members of the Quad have established early warning systems, and the U.S.-EU Trade and Technology Council has institutionalized information sharing — both of which are aimed at monitoring semiconductor shortages.[38] The U.S.-India initiative on Critical and Emerging Technology (iCET) commissioned an independent assessment of feasibility for India's readiness to play a supporting role in the semiconductor supply chain.[39] On critical materials, the U.S.-led Mineral Security Partnership with 14 countries and the European Union intends to target strategic projects in the value chain for crucial minerals and elements used in advanced technology manufacturing.[40] Enabling Southeast Asian states like Vietnam, Malaysia, Thailand, and Indonesia to scale up exports of key commodities, particularly raw materials essential for chip manufacturing is also a priority.[41] The United States, Japan, and South Korea are also cooperating trilaterally on semiconductor supply chain resilience and critical minerals, and quantum computing.[42]

Moreover, a number of chip related efforts through the Indo-Pacific Economic Framework (IPEF) were included in a recent supply chain agreement to build a crisis response network, including simulations, a council to coordinate response actions, and pilot programs to enhance resilience in semiconductors and critical minerals.[43] The IPEF provides a larger aperture for collaboration on salient areas connected to chip supply chains in a key region, but the lack of a market access pillar in the framework remains a drawback for participants.[44] In the Americas, the National Leaders Summit, the United States-Mexico-Canada Agreement, and the Americas Partnership have all included announcements for collaborative initiatives to bolster and monitor trade flows and supply chains for semiconductors, critical minerals, and medical supplies in emergency situations. India,

---

[37] Ben Blanchard, "Taiwan Says 'Fab 4' Chip Group Held First Senior Officials Meeting," *Reuters*, February 25, 2023, https://www.reuters.com/technology/taiwan-says-fab-4-chip-group-held-first-senior-officials-meeting-2023-02-25; The White House, "The Spirit of Camp David: Joint Statement of Japan, the Republic of Korea, and the United States," The White House, August 18, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/08/18/the-spirit-of-camp-david-joint-statement-of-japan-the-republic-of-korea-and-the-united-states/.

[38] The White House, "Joint Statement from Quad Leaders," The White House, September 25, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/24/joint-statement-from-quad-leaders; The White House, "U.S.-EU Joint Statement of the Trade and Technology Council," The White House, May 31, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/05/31/u-s-eu-joint-statement-of-the-trade-and-technology-council-2/.

[39] The White House, "FACT SHEET: United States and India Elevate Strategic Partnership with the initiative on Critical and Emerging Technology (iCET)," The White House, January 31, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/01/31/fact-sheet-united-states-and-india-elevate-strategic-partnership-with-the-initiative-on-critical-and-emerging-technology-icet; Stephen Ezell, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains," Information Technology and Innovation Foundation, February 2024, https://itif.org/publications/2024/02/14/india-semiconductor-readiness/.

[40] U.S. Department of State, "Minerals Security Partnership," accessed on May 24, 2024, https://www.state.gov/minerals-security-partnership/.

[41] Taylor Roth, et al., "Critical Technology Supply Chains in the Asia-Pacific: Options for the United States to De-risk and Diversify."

[42] The White House, "The Spirit of Camp David: Joint Statement of Japan, the Republic of Korea, and the United States," The White House, August 18, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/08/18/the-spirit-of-camp-david-joint-statement-of-japan-the-republic-of-korea-and-the-united-states/.

[43] U.S. Department of Commerce, "Substantial Conclusion of Negotiations on Landmark IPEF Supply Chain Agreement," U.S. Department of Commerce, May 27, 2023, https://www.commerce.gov/news/press-releases/2023/05/substantial-conclusion-negotiations-landmark-ipef-supply-chain.

[44] Emily Benson, Japhet Quitzon, and William Alan Reinsch, "Securing Semiconductor Supply Chains in the Indo-Pacific Economic Framework for Prosperity Squaring the Circle on Deeper Cooperation," Center for Strategic and International Studies, May 2023, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023-05/230530_Benson_SemiconductorSupplyChains.pdf?VersionId=SIbU7F4LQk82X5EHIx1Ffjr7j.3nbfiu.

Australia, and Japan have established the Supply Chain Resilience Initiative to share best practices and promote investment matching to mitigate political and economic risk.[45]

With a history of U.S. semiconductor investment in Central America, the role of Mexico and Costa Rica could be crucial moving forward for back-end investments in particular.[46] The U.S. government and industry players also have other options to consider for right shoring close to home for key inputs in the chain including printed circuit boards – such as the Dominican Republic.[47] Both the Trump and Biden administrations have aimed to locate some functions in the supply chain closer to home, which is why there has been renewed interest in building capacity for chips in North America and Latin America. Critically, this is supported by the International Technology Security Innovation (ITSI) fund through the Chips Act, which has $500 million over five years administered by the State Department.[48] Expanding the ITSI fund and widening its scope of projects should be a bipartisan priority for the U.S. government.

At the traditional multilateral level, members of the G7, the G20, and the Organisation for Economic Co-operation and Development, have also reached agreements to intensify monitoring of critical minerals or semiconductors, share risk assessments, or facilitate financial support for supply chain resilience.[49] The United States during the Biden administration has been relatively successful in building up what it calls a "latticework" of partners with a vision for a more integrated approach to manage technology, economics, and security cooperating with allies and like-minded partners when it comes to semiconductors and beyond.

VI. CONCLUSION

The ability of states to coordinate and secure supply chains domestically and internationally has taken on new importance. This is especially the case for critical and emerging technologies, yet in times of growing geopolitical tensions all types of goods and commodities with limited suppliers and high concentration can be weaponized for foreign policy objectives. There are considerable challenges governments are facing in building resilient supply chains for semiconductors, including frequent misalignment between partners due to conflicting economic and national security objectives. While many of these new initiatives are nascent, and some may fail, they will contribute at a fundamental level to each nation's security and economic independence and strengthen the collective.

---

45 Australian Department of Foreign Affairs and Trade, "Joint Statement on the Supply Chain Resilience Initiative by Australian, Indian and Japanese Trade Ministers," Australian Government Department of Foreign Affairs and Trade, March 15, 2022, https://www.dfat.gov.au/news/media-release/joint-statement-supply-chain-resilience-initiative-australian-indian-and-japanese-trade-ministers-0.

46 U.S. Embassy San Jose, "U.S. Chips Act Funds to Support Semiconductor, Workforce in Development in Costa Rica," U.S. Embassy in Costa Rica, February 20, 2024, https://www.rand.org/content/dam/rand/pubs/research_reports/RRA2300/RRA2354-1/RAND_RRA2354-1.pdf.

47 Stephen Ezell, "Assessing the Dominican Republic's Readiness to Play a Greater Role in Global Semiconductor and PCB Value Chains," Information Technology & Innovation Foundation, January 2024, https://www2.itif.org/2024-dr-semiconductor-readiness.pdf.

48 U.S. Department of State, "The U.S. Department of State International Technology Security and Innovation Fund," U.S. Department of State, accessed on May 15, 2024, https://www.state.gov/the-u-s-department-of-state-international-technology-security-and-innovation-fund/.

49 U.S. Department of State, "Third Meeting of the Semiconductor Informal Exchange Network," U.S. Department of State, December 15, 2023, https://www.state.gov/third-meeting-of-the0semiconductor-informal-exchange-network.

ACKNOWLEDGEMENTS

The authors would like to thank Hanna Dohmen and Hideki Tomoshige for their review, comments, and suggestions on an earlier draft of this paper. The paper is part of ORF America's Technology Policy Program work. This background paper reflects the personal research, analysis, and views of the authors, and does not represent the position of the institution, its affiliates, or partners.

Cover image courtesy freepik.

ABOUT ORF AMERICA

The Observer Research Foundation America (ORF America) is an independent, non-partisan, and nonprofit organization in Washington DC dedicated to addressing policy challenges facing the United States, India, and their partners in a rapidly changing world.

ORF America produces research, curates diverse and inclusive platforms, and develops networks for cooperation between the developed and developing worlds based on common values and shared interests. Its areas of focus are international affairs, technology, climate and energy, and economics. Established in 2020, ORF America is an overseas affiliate of the Observer Research Foundation (ORF), India's premier non-government think tank.

Observer Research Foundation America
1100 17th St. NW, Suite 501, Washington DC 20036

www.orfamerica.org

ORF AMERICA