Class of 2024

Industry Study: Microelectronics

Embracing the Global Chip Game: Building and Sustaining a Chip Manufacturing Industry in the U.S.

Word Count: 8,744

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Executive Summary

Given the increasing integration of artificial intelligence (AI) into both commercial and military sectors, compute power is poised to shape the future of economic and national security. At the forefront of this battle for competitive advantage in compute power are semiconductors. This paper explores the strategic significance of semiconductors in shaping the competitive landscape between the United States and the People's Republic of China (PRC). It explores how through strategic investments and redefined partnerships, the United States is seeking to rebuild its depleted semiconductor manufacturing capacity and extend its current advantages in other aspects of the semiconductor industry. It considers key challenges for advancing the U.S. position while limiting the PRC's own efforts to gain semiconductor self-sufficiency. It offers policy recommendations into ways the United States can shape and navigate geopolitical tensions while enhancing its semiconductor infrastructure and posture. The United States faces a vital imperative to strengthen the semiconductor industry as a key means for safeguarding national security and economic resilience in this era of strategic competition.

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The future of economic and national security competition will be determined by compute power. As Artificial Intelligence (AI) increasingly enables decision-making in business and military systems, the firms and nations that can best leverage compute power to conduct tasks like training AI models, rapidly processing incoming data, and deploying drone swarms will have a competitive advantage. At the heart of this advantage are semiconductors, or chips. Robust access to leading-edge chips is a baseline imperative for both developing and employing advanced technologies. Furthermore—and well outside the most advanced applications—because chips enable virtually every aspect of the modern world, reliable and cost-effective semiconductor supply is critical for national health in any realm. U.S. leadership across the semiconductor environment is thus essential to the nation's economic strength and dominance in the critical technologies that underpin the deterrence and competition aims laid out in the U.S. National Security Strategy and National Defense Strategy.[1]

At a foundational level, this means that semiconductors are poised to shape the conduct and results of ongoing strategic competition between the United States and the People's Republic of China (PRC) over the coming decades. Whether searching for the next biotechnology breakthrough, building a next-generation weapons system, or leveraging digital twins to improve modeling and performance, maximizing semiconductor industry strength and resilience will be critical. That makes chips a quintessential dual-use product as lines blur between military and non-military potential uses. Washington and Beijing are both highly attuned to this fact. Today the semiconductor industry is very publicly at the crosshairs of their competition, as each nation forges a pathway for advantage.

U.S. national security leadership has been clear that it is no longer sufficient to stay a generation or two ahead of the PRC in this area; now, the desire is for as large a lead as possible.[2] In line with this guidance, the United States is striving to constrain PRC chipmaking capabilities while attempting its own industrial resurgence, via the 2022 CHIPS and Science Act, after relinquishing leadership in several industry subsets over the preceding decades. However, the United States faces a significant challenge, one that is less difficult for the PRC to navigate within its authoritarian system. The varying priorities of those seeking to enhance economic efficiency, national security, and business-firm value creation generate competing interests. These three perspectives certainly overlap in the U.S. semiconductor space, but they do not neatly align. Failure to better synchronize these perspectives—along with those of U.S. partners and allies crucial for ensuring chip resilience—will risk further erosion of U.S. competitive advantages and lost opportunities to outpace the PRC.

The key question then is how best to overcome this challenge and improve U.S. semiconductor posture vis-à-vis the PRC. This paper seeks to address this question first by detailing and understanding the strategic environment, to include key trends, industry characteristics, and public sector efforts to date. Next, it analyzes this environment by breaking the larger problem set down into its constituent components, focusing first on assessing 'offense-oriented' issues impacting U.S. efforts to strengthen its own posture and then on 'defense-oriented' issues regarding U.S. capacity to limit the PRC's semiconductor prospects. In analyzing each of these offensive and defensive elements, this paper evaluates whether current approaches are sufficient and where gaps remain. Finally, policy recommendations highlight opportunities to close those gaps in the most sustainable and self-reinforcing manner, recognizing that the American taxpayers will not have an appetite for unending semiconductor-related subsidies.

Overall, the prospects for future U.S. semiconductor strength and resilience are favorable. Certain structural advantages—to include a robust share of the industry's core intellectual property (IP) and a strong network of partners and allies—will help offset weaknesses like price competitiveness of U.S.-based production and an inability to block every PRC pathway. These structural advantages will not be enough to maintain a persistent advantage in compute power over the PRC without mutually reinforcing investments and smart policy implementation.

The Strategic Environment for Semiconductors

Key Trends: Three primary trends set the stage for U.S. efforts to rapidly strengthen its semiconductor posture: unfolding U.S.-PRC strategic competition, massively expanding AI-driven demand for compute power, and the COVID-19-accelerated realization that the United States has off-shored too many vital capabilities, especially in chip manufacturing. The first two trends require little explanation, but it is important to understand the nature of this U.S. wakeup call during the pandemic. How did the United States get to this point?

As experienced in most U.S. manufacturing sectors, years of profit-maximizing business decisions drove elements of chip manufacturing overseas to gain proximity to supply chains, lower labor rates, and less-costly regulation. Some firms found shareholder value in ceasing manufacturing entirely. This led to the rise of 'fabless' U.S. chip companies that opted to rely on other companies to fabricate chips rather than spend tens of billions of dollars of upfront costs to build a fabrication facility, or fab. With 'industrial policy' a forbidden phrase in Washington in recent decades, this focus on shareholder value triumphed. If the negative consequences of off-shoring manufacturing were largely unseen by the American public in recent decades, COVID-19 brought the impact to light.[3] It became apparent that capacity to surge production was severely impacted by the globalization of supply chains, the reduced share of U.S.-based fabs, and the shrinking of the domestic technical and manufacturing workforce.

As it became difficult to procure chips during the pandemic, the ripple effects were widespread. The unavailability of end products like cars and appliances due to limited chip supplies provided the realization that an average person likely interacts with at least several hundred semiconductors every day. Public awareness of the importance of semiconductors surged, even as chip supplies stabilized post-pandemic. The pandemic shortages also stoked new fears for those who even before COVID-19 believed U.S. manufacturing capability had atrophied to the point where it posed a national and economic security risk. These geopolitical risks provide the other half of this wake-up call for altering U.S. semiconductor posture. The sense that supply chains should not depend on Chinese companies while the United States was engaged in competition with an increasingly assertive PRC government was becoming more pronounced. Furthermore, it became clear that with the majority of the world's semiconductors fabricated in

China and Taiwan, any disruption to manufacturing and trade in this volatile zone could have severe economic and defense implications. Assessing the severity of these concerns and determining how Washington might best respond requires a thorough understanding of the makeup of the semiconductor industry.

Industry Overview: The design, manufacturing, and distribution of semiconductors is an incredibly complex process that has been increasingly globalized. The industry has featured consistent growth over time, rising to more than $500B in global industry sales in 2023.[4] This revenue enables large investments in the research and development (R&D) that has kept Moore's Law—the doubling of transistors on an integrated circuit every two years—alive for several decades. As chip design capabilities, materials, and manufacturing processes have become more technically advanced, increasingly specialized firms have gained prominence. The overall industry is now highly segmented, creating chokepoints, strengths, and gaps for nations.

In the design phase, some firms specialize in providing the foundational building blocks for chip design—core IP and electronic design automation (EDA) tools—while others design complete chip architecture. This includes 'fabless' designers like NVIDIA and Qualcomm, as well as integrated design manufacturers (IDMs, those who design and fabricate their chips) like Intel and Samsung. Design firms typically specialize in memory, logic, or multiple other chip types comprising the discrete/analog/other (DAO) category.[5]

The manufacturing phase involves suppliers of materials and semiconductor manufacturing equipment (SME) like the Dutch firm ASML, whose multi-hundred-million-dollar photolithography machines are essential for creating

Semiconductor Five Forces Analysis

While Michael Porter's Diamond Theory of National Advantage is more relevant to strengthening the U.S. semiconductor posture, his Five Forces framework is helpful for understanding certain industry dynamics. Because the semiconductor industry is highly segmented, a Five Forces analysis of each subset would be warranted for a paper with a more tactical, line-of-business focus. However, at a macro-level, the Five Forces illuminate several key takeaways for this strategic analysis.

1) Of the forces, ***Industry Rivalry*** emerges as the most significant given the dominance of a small number of major firms in each of the industry's subsets. These firms compete fiercely on R&D, product differentiation marketing, and price, ensuring continual innovation and relative cost control for consumers. Maintaining this rivalry across subsets is thus largely in the public sector's best interests. The exception is likely the predominant AI chip designer NVIDIA; end users are hoping a viable alternative emerges to increase rivalry, reducing dependence and costs.

2) The ***Threat of Substitutes*** is complex, as there is no viable substitute for semiconductors overall, but there are potential alternatives for the technology and processes within subsets of the value chain at different stages of the manufacturing process. A key implication is that while switching costs for alternative IP, equipment, and material inputs would be high, they remain feasible. This means that the PRC likely has the potential to work around U.S. export controls to find new, homegrown substitutes that would be economically unviable for most Western firms.

3) The ***Bargaining Power of Suppliers*** is mixed depending on the subset, but given how specialized the industry has become, certain equipment suppliers like ASML can essentially name their price. However, price gouging is not widespread, as these specialized suppliers need the overall industry to remain profitable.

4) Due to the capital-intensive nature of both R&D and of setting up manufacturing facilities, along with the strong economies of scale that the established players possess, the ***Threat of New Entrants*** is relatively low. This has major implications for how public capital can be best leveraged to improve the semiconductor ecosystem.

5) The ***Bargaining Power of Customers*** is also fairly low due to the growing demand for chips. Major firms specializing in AI chip production have sold out their production runs through 2025. However, with new fabs projected to start production, this factor may change as buyers gain more options. .

cutting-edge chips. Meanwhile, foundry firms like top Taiwanese firm TSMC and U.S.-based GlobalFoundries do not design their own chips, but instead fabricate wafers of chips that other companies designed. These wafers are then sent to assembly, test, and packaging (ATP) firms prior to distribution.[6]

Many of these firms rely on intricate supply chains that in some cases depend on sustained access to a single supplier. ASML's latest generation extreme ultraviolet (EUV) photolithography machine, for instance, is made up of 100,000 parts. Most of those parts have sourcing that goes several tiers deep, making a firm's visibility into its supply chain and supporting industries a complicated and costly endeavor. Therefore, even if firms were interested in sharing a full accounting of their supply chains—which they are reluctant to do for proprietary reasons—most would be unable to do so.[7] The industry's supply chain is further complicated by the fact that there are so many different types of semiconductors at different levels of technological sophistication; although there is overlap, there is some variation.[8]

Armed with this high-level view of semiconductor firms and select economic factors, it is helpful to visualize where these different subsets are based and which subsets contribute the most value added to the entire industry's output. The chart below from the Semiconductor Industry Association provides a good overview of value by subset and by country or region.[9]

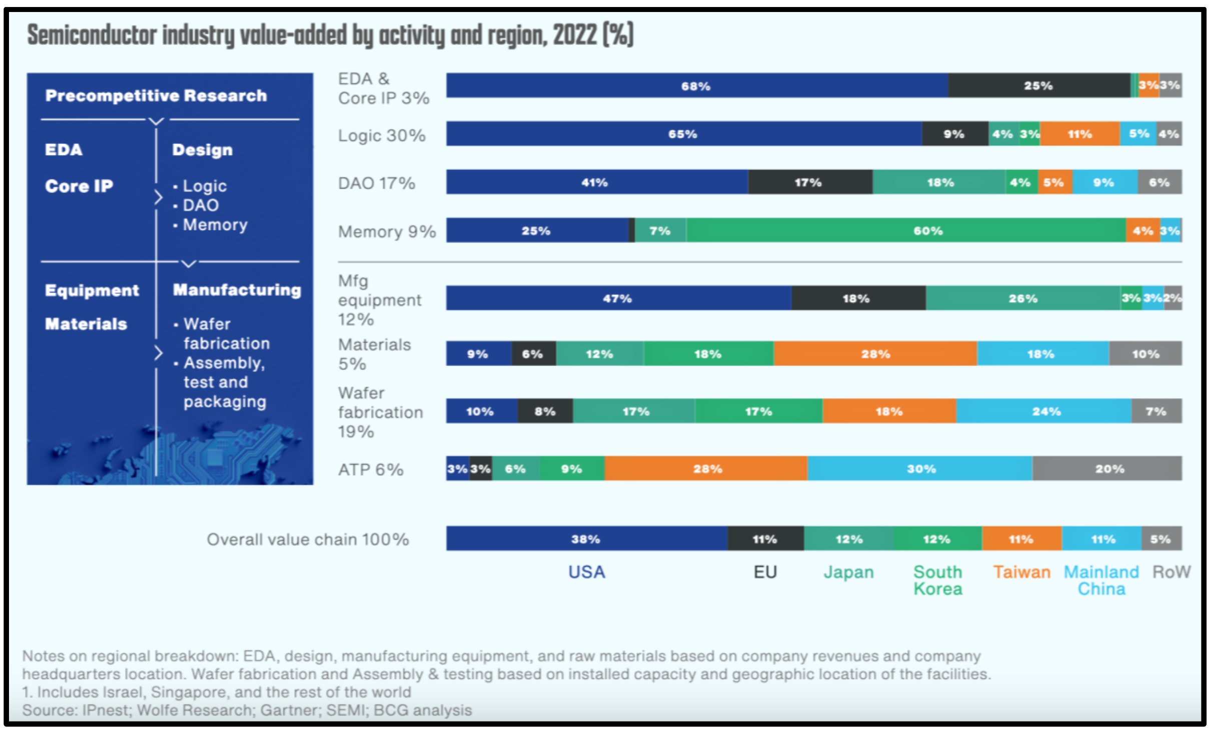
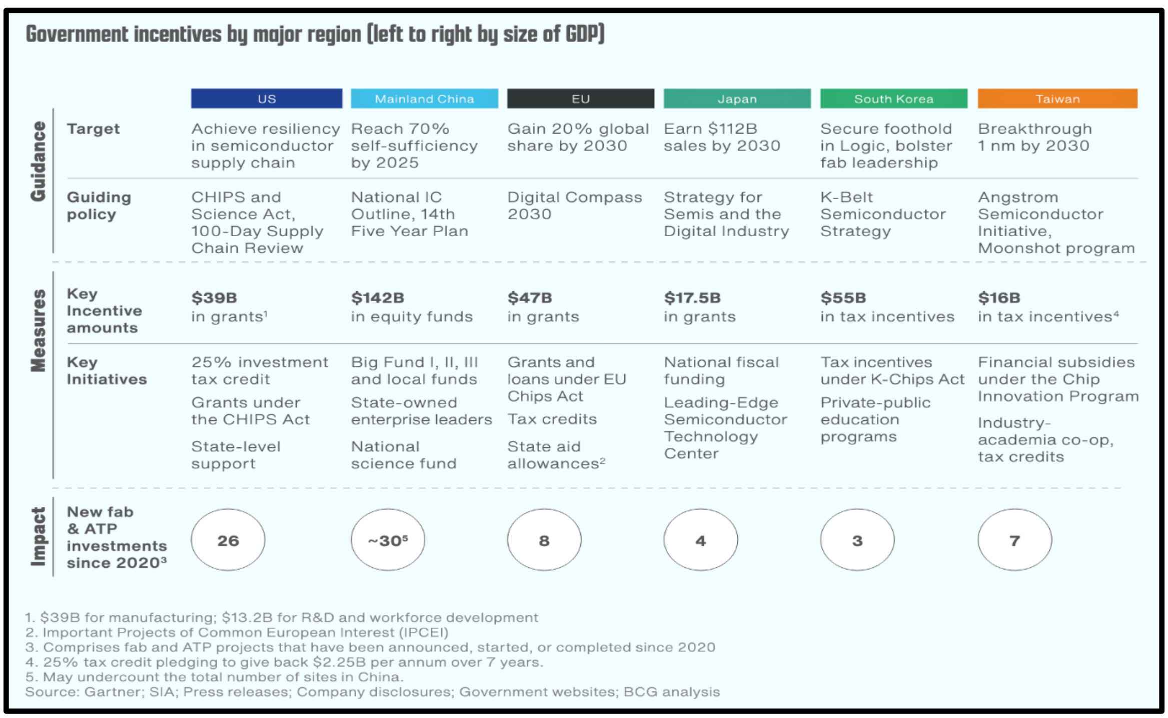


Figure 1. Semiconductor Industry Value-Added by Activity and Region, 2022

While it is not surprising that logic chip design and wafer fabrication—the essential underpinnings of processing power for things like smartphones and AI—represent the highest value-add for the industry, at 30% and 19% respectively, other aspects of the chart may come as a bit of a shock. Those who have heard only doom-and-gloom about U.S. semiconductor weaknesses may be startled to see the United States claiming the largest share of the overall value chain. However, it is not entirely surprising that as U.S.-based firms stopped putting money into manufacturing and redirected some of the savings toward R&D, they still capture a large portion of the design and highly technical manufacturing equipment industry subsets.

Although things are bleaker on the materials, fabrication, and ATP fronts—and troubling chokepoints do exist—it is important to note that this overall picture represents a U.S. structural advantage over the PRC. In 2022, the United States and its partners and allies claimed more than 85% of the total industry added value. Moreover, due to the longstanding U.S.-based involvement in advancing technology across all subsets, U.S. IP is embedded throughout many of the industry's key design and manufacturing elements. This pervasiveness of U.S. IP is a lever for Washington's export controls. It also represents a chokepoint threat for the PRC, serving as the driving force for the PRC's own efforts to develop self-sufficiency.

Public Sector Efforts to Date: In response to the pandemic-driven global chip shortage and growing geopolitical tensions, nations are implementing various strategies to address challenges in the semiconductor industry. The United States, the PRC, the European Union, Japan, South Korea, and Taiwan each have distinct approaches aimed at bolstering domestic chip production, enhancing technological leadership, and ensuring supply chain security. Each approach has strengths and weaknesses, and all regions are seeing initial results in the form of commitments to build new manufacturing facilities.



Government incentives by major region (left to right by size of GDP)

		US	Mainland China	EU	Japan	South Korea	Taiwan
Guidance	Target	Achieve resiliency in semiconductor supply chain	Reach 70% self-sufficiency by 2025	Gain 20% global share by 2030	Earn $112B sales by 2030	Secure foothold in Logic, bolster fab leadership	Breakthrough 1 nm by 2030
	Guiding policy	CHIPS and Science Act, 100-Day Supply Chain Review	National IC Outline, 14th Five Year Plan	Digital Compass 2030	Strategy for Semis and the Digital Industry	K-Belt Semiconductor Strategy	Angstrom Semiconductor Initiative, Moonshot program
Measures	Key Incentive amounts	$39B in grants[1]	$142B in equity funds	$47B in grants	$17.5B in grants	$55B in tax incentives	$16B in tax incentives[4]
	Key Initiatives	25% investment tax credit; Grants under the CHIPS Act; State-level support	Big Fund I, II, III and local funds; State-owned enterprise leaders; National science fund	Grants and loans under EU Chips Act; Tax credits; State aid allowances[2]	National fiscal funding; Leading-Edge Semiconductor Technology Center	Tax incentives under K-Chips Act; Private-public education programs	Financial subsidies under the Chip Innovation Program; Industry-academia co-op, tax credits
Impact	New fab & ATP investments since 2020[3]	26	~30[5]	8	4	3	7

1. $39B for manufacturing; $13.2B for R&D and workforce development
2. Important Projects of Common European Interest (IPCEI)
3. Comprises fab and ATP projects that have been announced, started, or completed since 2020
4. 25% tax credit pledging to give back $2.25B per annum over 7 years.
5. May undercount the total number of sites in China.
Source: Gartner; SIA; Press releases; Company disclosures; Government websites; BCG analysis

Figure 2. Government Incentives by Major Region.

The chart above, compiled by the Semiconductor Industry Association in May 2024, provides an excellent summary of the key components of each set of government incentives.[10]

Of note, there is a key divergence in how the PRC and the rest of the world are tackling this problem set. The PRC is racing to develop self-sufficiency and is willing to put an enormous amount of capital toward that goal. Unlike for Western firms that must produce extremely high wafer yields (the percentage of usable chips on a fabricated wafer) to be economically viable, Chinese firms are producing high-end memory chips with yields in the 20-30% range.[11] These yields will increase, of course, but Beijing's willingness to support production at that level is indicative of their commitment to propping up homegrown capabilities. Meanwhile, the United States and its partners are attempting to navigate a complicated global semiconductor policy landscape replete with protectionism concerns as they balance domestic resilience with international collaboration.

The centerpiece of offense-oriented U.S. public sector efforts is the CHIPS and Science Act, which designates $52B in federal funds to create a semiconductor manufacturing capability inside U.S. borders.[12] In the race to generate new advantages to support the ever-growing demand for compute power, this legislation and funding is designed for national security goals.[13] The Commerce Secretary's aim is to ensure 20% of leading-edge chips are made in the United States by 2030.[14] Several U.S. states also implement state-level semiconductor incentives to boost manufacturing, R&D, and workforce development.[15] While the implementation of the Act has drawn criticism, it is telling that the top chip firms are all constructing new fabs in the United States and that the private sector has matched the public sector's $30B in grants with $300B of their own capital.[16] Based on these initial results, some industry experts conclude that public incentives fundamentally shifted private sector investment strategies.[17]

The centerpiece of defense-oriented U.S. public sector efforts are the export controls rolled out by the Department of Commerce's Bureau of Industry and Security (BIS). A major initial push to limit the PRC's use of U.S. semiconductor technology for military purposes debuted on October 7, 2022.[18] The identified target was the PRC's military AI development, but the controls applied to China as a whole (vice specific end-users) and focused on restricting its access to advanced semiconductor technology, marking a key inflection point for U.S.-PRC geopolitics and the semiconductor industry.[19] BIS issued revised controls on October 17, 2023, seeking to address gaps by changing the performance threshold of chips that fell under restrictions and adding additional countries to the licensing list to mitigate PRC efforts to circumvent controls.[20] Since 2023, the Biden Administration escalated these controls to further restrict PRC access to high-end semiconductors and SME, to include an initiative to stop servicing critical SME already purchased by Chinese firms.[21] Outbound U.S. investment to Chinese semiconductor firms has also been curtailed, while tariffs on imported Chinese chips are set to rise from 25% to 50% in May 2024.[22] The implications of these activities and the larger defensive strategy will be explored later.

Together these offense and defense initiatives are intended to extend U.S. competitive advantage over the PRC in the semiconductor space. Success in these endeavors will depend on how well key stakeholders in government, industry, academia, and abroad work together, something senior government officials acknowledge. These stakeholder interests overlap, but are not aligned, making it difficult to carve out the slate of incentives that best maximize economic and national security while accounting for business-firms' value-creation imperatives. The policy recommendations section will explore these incentive structures in more depth and *Appendix 1* provides a closer look at these stakeholder categories and their interaction.

Analyzing Key Aspects and Challenges of the Offense and Defense

The strategic environment for semiconductor competition illuminates a slate of challenges that require deeper analysis. On the offense-oriented side, to strengthen U.S. posture, the following issues are evident: the conundrum of what and how much to home-shore, insufficient supply chain resilience, human capital shortfalls, and health of U.S. semiconductor ecosystems. On the defense-oriented side the following issues emerge determining the best strategy for limiting the PRC's semiconductor advances, PRC ability to work around controls, aligning enforcement efforts with partners, effectively enforcing controls, undermining U.S. innovation, and mitigating PRC retaliation. This section analyzes these key component pieces of the overall challenge in turn.

Offense Challenge – The X-Shoring Conundrum. One of the most pivotal U.S. semiconductor policy debates centers around the degree to which the U.S. government should pursue home-shoring (bringing a component of the industry into the United States), near-shoring (bringing it closer to home in neighboring countries), or friend-shoring (diversifying it among friends, allies, and like-minded countries) for different aspects of the industry. Each option has costs, benefits, and risks. Getting this mix right will likely require significant trial, error, learning, and dialogue about where and how to prioritize economic efficiencies and where national security is paramount. For one portion of the semiconductor value chain, home-shoring as much as possible may be the best move. For another part, it may be appropriate to home-shore enough to satisfy U.S. military and critical infrastructure chip requirements. For other capabilities, friend-shoring may be the optimal path. The answer to this question effectively serves as the philosophical underpinning of the entire U.S. offense-oriented approach to semiconductor competition.

Answering this question requires insight into how Porter's Diamond applies to U.S. competitive advantages in the international semiconductor industry market. *Appendix 2* provides a deeper dive into Porter's Diamond, but the key takeaway is that the U.S. semiconductor posture has long been enabled by strong demand conditions, related and supporting industries, and firm strategy, structure, and rivalry. Where it was weaker was in factor conditions. This is now changing due to the investments and momentum generated by the CHIPS and Science Act. The gameboard for the United States is shifting in the right direction.

Analysis of the home-shoring approach reveals incentives and benefits beyond simply providing extra security for the semiconductor supply and value chain. Industry insiders indicate customers are increasingly demanding U.S.-designed and U.S.-manufactured chips, which certainly played a role in incentivizing the top firms to start building fabs in the United States.[23] Additionally, there appears to be a strong correlation between successful innovation and closer proximity of R&D to manufacturing.[24] This collocation and collaboration will be explored in greater depth later, but in brief, manufacturing lessons learned can amplify R&D efforts and R&D can be more attuned to take advantage of manufacturing process improvements.

There are strong national security imperatives that make home-shoring worthwhile, but the potential economic and business downsides of home-shoring are significant. For instance, the sheer cost of setting up portions of the value chain domestically is staggering, even with the government incentives in place. In addition, operating costs are typically higher in the United States, with one estimate suggesting domestic semiconductor production is 30-45% more expensive than production elsewhere.[25] This potentially requires the private sector to absorb a blow to their balance sheets, causes the private sector to pass the costs along to the consumer in full, forces the public sector to extend subsidies, or all of the above.

Additionally, U.S. regulatory guidance accounts for the fact that chip manufacturing can be a major strain on the environment, depleting energy and water resources while contributing to harmful emissions and waste streams. Thus, home-shoring includes environmental sustainability hurdles that may not exist in other countries. This adds to the list of potential home-shoring disincentives for the private sector, but also provides an opportunity. The firms that make upfront investments in using fewer resources should find long-term benefits in operating costs, while upfront investments to reduce pollution should enhance firm reputation in the marketplace. In fact, the annual 10K reports of multiple top semiconductor firms highlight these potential benefits and their ongoing efforts to increase environmental sustainability. (For a deeper look at how environmental factors can be better addressed through careful planning, thoughtful application of regulations, and a collaborative approach, see *Appendix 3*.) Decisions to home-shore aspects of the supply and value chain have a dramatic impact on national security, economic efficiencies, and business-firm value creation. As such, these are some of the most important decisions U.S. public and private sector leaders will make in the coming years.

Near-shoring and friend-shoring are alternatives that could facilitate greater economic sustainability than home-shoring—albeit at potentially lower levels of assurance for secure and sustained U.S. chip supply—while still reducing reliance on Chinese firms and mitigating the consequences of any natural disasters or PRC actions that disrupt the Taiwan-based chip industry.[26] The economic benefits are similar for both, with near-shoring having an additional advantage of reducing the logistical costs of long-distance global supply chains and further mitigating the disruptive potential of conflict in the Indo-Pacific. Near-shoring and friend-shoring aspects of the industry may help facilitate strong bilateral and multilateral collaboration for U.S. government and firms. The tangential benefits here would be easing diplomatic relations in the face of potential accusations of protectionism, offering additional business opportunities, and helping to avoid a self-defeating national subsidy race that would reduce the efficiency and effects of public sector incentive programs.[27] On this front, the CHIPS and Science Act does include a $500M International Technology Security and Innovation (ITSI) Fund aimed at working with partners to expand and diversify manufacturing capacity in the Indo-Pacific and Western Hemisphere.[28] Solving this x-shoring conundrum will not be easy, but optimizing the U.S. pathway is essential for ensuring the long-term success of the CHIPS and Science Act's up-front investments.

<u>Offense Challenge – Insufficient Supply Chain Resilience</u>. Diagnosing resilience challenges can be difficult because there is little consensus on what the term actually entails.[29] The National Defense Strategy views it as, "the ability to withstand, fight through, and recover quickly from disruption."[30] The Semiconductor Industry Association broadly defines it as geographic diversification.[31] A Brookings Institution report on supply chains, meanwhile, determined that, "the essence of resilience lies in flexibility and adaptability."[32] For the semiconductor supply chain, all of the above requires analysis of key vulnerabilities like the lack of geographic diversification, overreliance on competitor nations, reliance on single-source suppliers, and lack of transparency.

The risk of conflict with the PRC translates into a risk for all aspects of the supply chain in East and Southeast Asia. With roughly three-quarters of all chips being manufactured in the Indo-Pacific—and with key industry segments located in Japan, South Korea, and Taiwan—withstanding and recovering from major regional disruptions would be immensely difficult. A sustained conflict could create unprecedented supply chain interference and bring the semiconductor industry to a halt. Although PRC efforts to undermine Western chipmaking via conflict or threat of conflict would almost certainly create significant backlash and cause a self-inflicted economic wound, Beijing may calculate the risk is worth the reward in a moment of geopolitical struggle. Even in the absence of military conflict, the PRC has some ability to threaten supply chains. Given the size and diversity of the Chinese export market, it is unsurprising that supply chain analysis reveals that the industry—including top SME firms ASML and Tokyo Electron—has exposure to China.[33] Similarly, the PRC could leverage its strong position in the strategic materials realm to hold semiconductor supply chains at risk.[34]

Outside PRC-related challenges, single-source suppliers and lack of transparency into subordinate suppliers below the initial tiers make it difficult for firms to assess and manage supply chain risk. The most visible and strategic example is the advanced EUV lithography machines that can only be sourced from ASML.[35] Within this lithography supply chain, even more vulnerabilities appear; ASML has one supplier of the precision mirrors critical to the operation of the EUV machine.[36] Given the lack of visibility deep into supply chains, it is hard to determine how many instances of single-source supplier risk exist across the industry.

Eliminating these supply chain vulnerabilities entirely would be impractical from a time and cost perspective. Increasing supply chain resilience by reducing the likelihood and impact of these vulnerabilities, however, may be more feasible.

<u>Offense Challenges – Human Capital Shortfalls</u>. The success of the CHIPS and Science Act hinges on U.S. public and private sector success in cultivating the skilled workforce necessary to do everything from running equipment in fabs to driving the R&D advances that will provide first-mover advantage in groundbreaking semiconductor technologies.[37] Determining the best option for accomplishing this feat first requires an assessment of current shortfalls and analysis of three pathways for filling these shortfalls: long-term STEM education for engineering and computer science students, shorter-term training in specialized skills required to execute chipmaking tasks, and immigration that supplements homegrown talent.

The Semiconductor Industry Association projects that to meet CHIPS and Science Act objectives, 115,000 new jobs will need to be filled by 2030.[38] Their chart below depicts the historical semiconductor workforce, as well as a projected talent gap of 67,000 workers across the computer scientist, engineer, and technician ranks.[39]

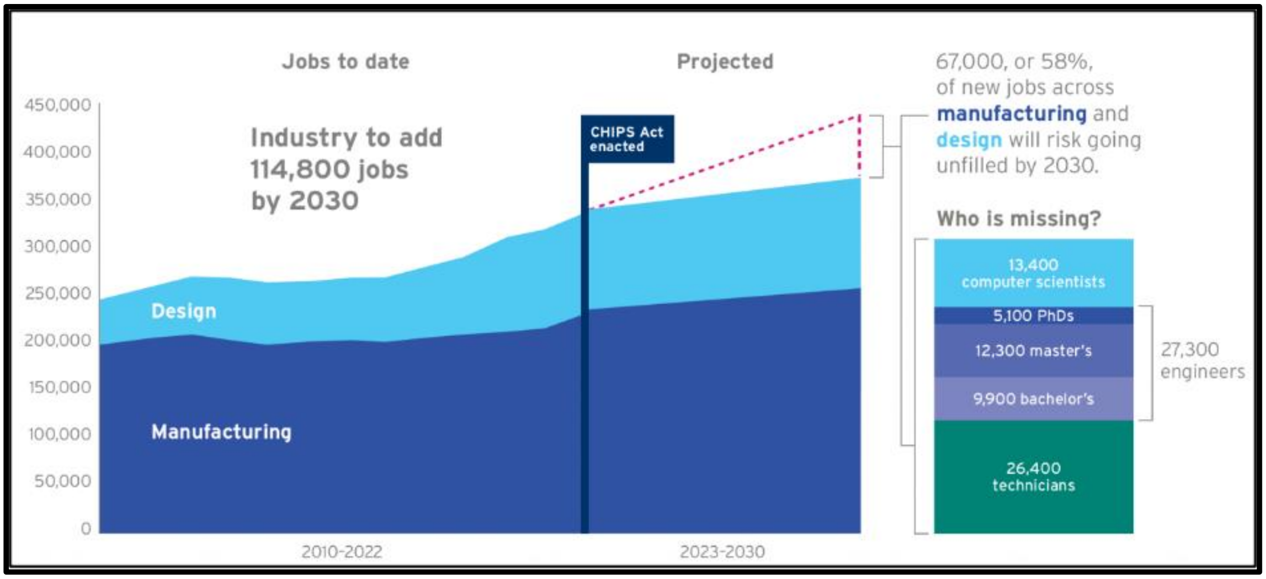


Figure 3. Historical Semiconductor Workforce and Projected 2023-2030 Gap.

Today, semiconductor firms across the United States are struggling to fill existing positions. Higher-end talent is siphoned off to more lucrative or prestigious jobs in other technology industries. Many applicants for technician positions fail to meet baseline requirements; given the industry's technical complexity, even entry-level jobs require some advanced training. Contributing to this challenge are deficiencies in the U.S. educational system in preparing students for rigorous STEM education, a historical emphasis on college over vocational and technical training, and political impasse over immigration reform that hinders the recruitment and retention of top STEM talent.

At the Kindergarten through post-graduate STEM level, any education reforms made today will not have a significant impact on industry shortfalls for a generation. Still, every improvement helps, and 20 years from now, that focus on STEM education should produce a national competitive advantage. The CHIPS and Science Act allocates some fundings for scholarships and grants, while also tasking the National Science Foundation and the Department of Energy's Office of Science with promoting collaboration among elementary and secondary school teachers, students, university faculty, and national laboratories.[40] Other company-university collaborations are crafting new semiconductor-focused programs aiming to align STEM education with future workforce demands.[41] These are promising starts, but likely insufficient without future investments and greater public awareness and interest in this arena.

At the vocational and Career & Technical Education (CTE) level, community and technical colleges emerge as vital links for semiconductor companies, addressing the growing demand for technical workers. Many community colleges offer apprenticeships, on-the-job training, and vocational programs—often in partnership with local firms and governments—providing students with affordable pathways to trade credentials.[42] For instance, a Texas public-private sector collaboration based out of Austin Community College is having success with a unique demand-side program where the school cooperates more deliberately with industry to meet targeted needs, pivoting away from the traditional supply-side educational pipeline.[43] Sharing and scaling these best practices and lessons learned is crucial.

As this industry's demand for STEM talent grows and nascent steps to increase homegrown talent are beginning to have tactical-level impacts, government action to increase the supply of external STEM talent via immigration reform is lacking. Simply, it should be easier for existing foreign talent to be eligible for jobs the industry desperately needs to be filled today. The lack of action to date, however, indicates the tenuous political nature of solving this fairly obvious problem.

American students represent only one-fifth of the total graduates awarded U.S. electrical engineering and computer science degrees.[44] Immigration restrictions prevent too many foreign graduates from staying in the United States to support U.S.-based technology leadership over the long term. 80% of master's and 25% of PhD STEM graduates leave the United States after graduating, some by choice, but many because of immigration challenges.[45] This is a significant problem because foreign-born workers are prevalent in almost every occupation in the semiconductor industry, as displayed in the below graphic from the Brookings Institution.[46]

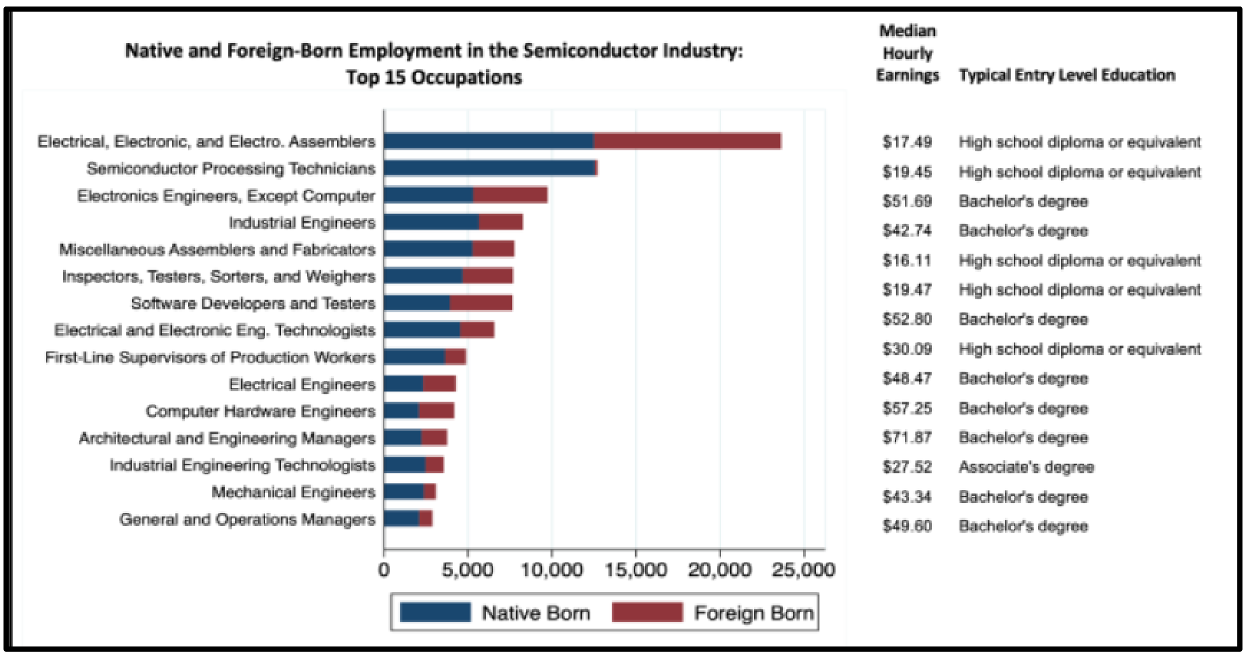


Figure 4. Native and Foreign-Born Employment in the Semiconductor Industry: Top 15 Occupations

Developing the workforce to support U.S. semiconductor leadership is inherently complex given the array of actors who must converge: legislative and executive public sector officials, employers, training and education institutions, economic development organizations, community-based groups, and labor unions, among others. The vision of the CHIPS and Science Act will not be realized unless these stakeholders collaborate and invest effectively.

Offense Challenge – Semiconductor Ecosystem Health. As the United States searches for gamechangers that will propel its home-shored chip industry forward, improving the health of domestic semiconductor ecosystems stands out as a potential catalyst for transformative growth. These industry clusters, if facilitated and fostered properly, are the key factor for ensuring the human capital, manufacturing, and R&D investments made via the CHIPS and Science Act will be self-reinforcing and sustainable. A healthy and interconnected chip ecosystem can promote economic sustainability across the industry, reducing the need for unending semiconductor subsidies that will not be palatable to American taxpayers.

The benefits of clustering and robust ecosystems are well-established in economic and business literature, as illustrated in the adjacent tonebox.[47] Within the semiconductor industry specifically, a good example of the types of dividends that hubs pay is evident in the R&D benefits from clustering, overlapping, and intertwining relationships of government, industry, and academia. Each actor has a key role to play; bringing them together in clusters facilitates more rapid and iterative touchpoints that shape and accelerate R&D roadmaps. For instance, synchronizing academia's focus on basic research—advancing fundamental semiconductor technologies and materials science—with industry and government's focus on applied research for developing and prototyping applications is made easier by collocation. This synchronization yields significant gains, like accelerating the lab-to-fab transitions that are critical to increasing the U.S. lead over the PRC in semiconductor technology.

General Ecosystem Benefits

Real-world examples ranging from Silicon Valley and Hollywood in California to Shenzhen in China illustrate how industry ecosystems continually innovate to boost productivity and scale. Within these clusters, linked institutions tend to cooperate throughout the segmented value chain, enabling each unit to achieve greater economies of scale while maintaining favorable levels of flexibility. Intense competition ensures these clusters thrive through self-reinforcing product, process, service, and pricing improvements. Importantly, these clusters also spur the creation of new businesses, strengthening the ecosystem and fostering an ever-expanding talent pool that both enables and reduces the risk of firm innovation.

The collocation of increasingly specialized industry producers, buyers, suppliers, service providers, labor pools, training institutions, and entrepreneurs enables not only knowledge spillover, but also the coordination and growth of industry standards that can have a powerful multiplier effect. Finally, the concept of trusted capital looms large as a driver of firm expansion and new business creation. Years of collaboration lower barriers to financial trust—via industry connections or simply due to investment institution familiarity with the cluster—thereby lowering the risk premium on capital.

The Economic Development Administration (EDA) Regional Technology and Innovation Hubs (Tech Hubs) and Microelectronic (ME) Commons are good examples of nascent semiconductor ecosystems, and they are poised to play pivotal roles in the coming years. (For more information on the role and impact of Tech Hubs and ME Commons to date, see *Appendix 4*.) Analyzing their experiences thus far yields several lessons learned for enhancing the health of any semiconductor ecosystem. First, multiple funding streams are essential, ideally featuring a flexible and scalable mix of federal, state, and local government resources alongside industry and venture capital funding.[48] Second, connectivity among separate semiconductor clusters enables the identification of technical overlaps and collaborative opportunities that leverage shared talent, knowledge, and infrastructure.[49] Third, state-level organizations, industry consortiums, and R&D organizations are force multipliers for streamlining coordination and helping smaller organizations with issues like navigating government incentive programs.

The United States has an opportunity to sustain its leadership in semiconductor innovation by embracing ecosystems as the way to foster those robust interconnections amongst R&D, design, manufacturing, advanced packaging, and other aspects of the value chain. The graphic below summarizes key analytic findings regarding mutual benefits public and private sectors can reap from semiconductor ecosystem investments.[50]

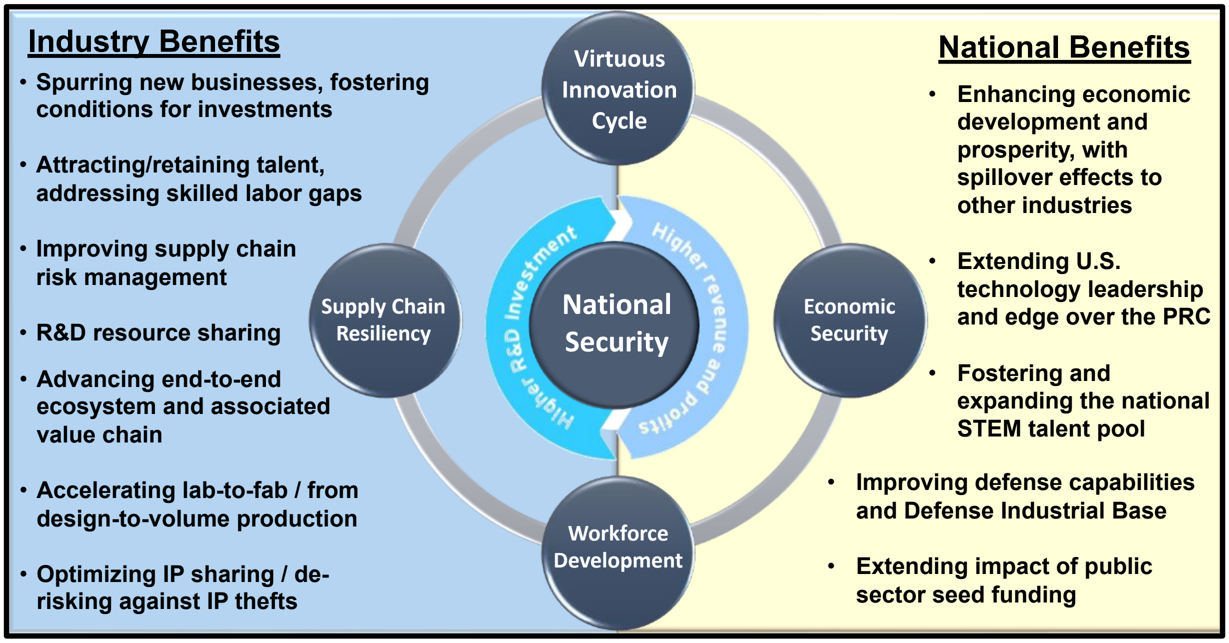


Figure 5. Benefits of Technology Clusters.

Enhancing semiconductor clusters supports every aspect of the industry, from bringing suppliers and producers closer together to expanding the talent pool to bridge human capital shortfalls.[51] Finding ways to reinforce nascent clusters is the key for ensuring the upfront CHIPS and Science Act investments are not only impactful in the short-term, but self-sustaining in the long-term.

Defense Challenge – Determining the Best Strategy to Limit PRC Chip Advances. Like the offense challenge of solving the x-shoring conundrum, determining the right mix and timing of export controls and other limitations is the overarching challenge for the defense. The answer to this question similarly serves as the philosophical underpinning for the entire U.S. campaign to limit the PRC's ability to employ compute power in strategic competition. The crux of the debate revolves around a key dilemma: U.S.-imposed limits can certainly slow the PRC down in the near-term, but doing so may hasten a more innovative PRC pathway toward semiconductor self-sufficiency while simultaneously reducing innovation resources for U.S. and partner chip companies and introducing new risks that may strain important U.S. stakeholder relationships. This puzzle will be explored throughout the following subordinate defense challenges.

Defense Challenge – PRC Ability to Advance Compute Power in Spite of U.S. Controls. To properly analyze the PRC's potential to work around U.S. restrictions, it is useful to consider the PRC version of Porter's Diamond. A more detailed laydown is available at *Appendix 5*, but the key takeaway is that China's gameboard for establishing semiconductor competitive advantages is vastly different than that of any other nation. The PRC has enormous amounts of labor, infrastructure, capital, entrepreneurship, domestic demand, and spillover advantages from other technology manufacturing efforts. These are all key ingredients for Beijing's desired self-sufficiency.[52]

While current controls are having a significant impact on the PRC's semiconductor operations, it would be naïve to assume U.S. efforts have blocked all progress.[53] Even without ASML's most advanced photolithography equipment, there are other ways to increase chip processing power such as rapidly developing industry capabilities to construct 3D advanced packaging architectures and application-tailored chiplets.[54] Importantly, while the PRC lacks the human capital of the leading chip firms and is at a disadvantage in terms of foundational IP, it does have one major advantage. The PRC has demonstrated both the willingness and capability to throw incredible sums of money at industries to establish global leadership. It has done so for solar, batteries, and electric vehicles. If Beijing now has its sights set on semiconductor dominance, this means that Chinese firms will not have to make the same types of difficult investment tradeoffs that Western companies face.

The PRC aims to mitigate its reliance on foreign technology through strategic state investments and targeted tax incentives to bolster domestic production companies.[55] Specifically, in support of the 'Made in China 2025' policy initiative, the PRC created the 'Big Fund' in the semiconductor industry to provide long-term funding to domestic producers.[56] The intent is that these domestic firms will 'design-out' U.S. and allied semiconductor IP, reducing the impact of current U.S.-imposed controls and the deterrent value of future U.S. restrictions.

Beyond these investments, the PRC has so far proven capable of circumventing U.S.-imposed controls, although Washington has worked to close identified gaps as quickly as possible. As one example, Chinese semiconductor firms increasingly began setting up companies in Malaysia and entering into joint ventures with Malaysian firms to avoid U.S. tariffs and maintain Western supply chains.[57] Another public example was Huawei's ability to produce a 5G smartphone that had an advanced 7-nanometer chip.[58]

This raises another key question: would further increases to U.S.-imposed controls incentivize the PRC's drive for self-sufficiency to a greater extent? If Beijing is bore-sighted on designing-out all U.S. IP anyway, then the proverbial cow may have already left the barn. If true, the primary reason Washington might hold back on escalating restrictions would be to avoid negative impacts on U.S. business revenue and relations with allies and partners. To return to the guidance of the U.S. National Security Advisor—to build as large a lead in chip technology as possible—if increased restrictions won't stop the PRC's semiconductor advances, but will slow them down by a couple years, that is a favorable outcome. However, any policy efforts to achieve this favorable outcome from a national security standpoint must be balanced and calibrated against the equities of key private sector and allied stakeholders.

Defense Challenge – Aligning U.S. Enforcement Efforts with Allies and Partners. A major issue that complicates U.S. efforts to keep high-end chips and advanced semiconductor technologies away from the PRC is the fact that the globally interconnected supply chain demands globally synchronized restrictions. Each nation and region has their own political systems and processes for codifying export controls and other limitations, such as those on outbound investment. It is thus unsurprising that international stakeholders are not fully aligned. Any policy recommendations must account for the fact that when the United States and its partners and allies fail to synchronize the scale, timing, and enforcement of new and existing restrictions, the PRC has an opportunity to exploit gaps in the system. Washington can deploy carrots and sticks to bring reticent partners in line with U.S. controls, but these efforts can also cause diplomatic backlash that undermines attempts to forge a united front.

Defense Challenge – Enforcing Controls. BIS is working to address loopholes and prevent evasion of export restrictions, but the organization's manpower has not kept pace with its rapidly expanding mission requirements. Additionally, years of underinvestment in BIS leave the organization with archaic tools, a far cry from the AI-enabled systems likely required to adequately monitor and enforce controls.[59] A key risk here is that if the private sector lacks confidence in the ability of BIS to prevent circumvention, the firms that do abide by these regulations will be at a competitive disadvantage.[60] If BIS struggles to monitor compliance, future levels of compliance could potentially diminish, removing the teeth of new U.S. export control initiatives. An even greater enforcement challenge rests with the governments of U.S. allies and partners. Although many American commentators may feel BIS is too small for its mission, it is gargantuan in comparison to their counterparts in other countries. This presents an enormous blind spot that similarly could derail the effectiveness of future U.S.-led restrictions.

Defense Challenge – Undermining U.S. Private Sector Innovation. On average, U.S. semiconductor companies reinvest 15% of their revenue for R&D.[61] Meanwhile, the PRC imported more than $350B worth of chips in 2020.[62] Depriving U.S. (and allied and partner) semiconductor firms of this revenue pool thus has a direct follow-on effect in reducing R&D budgets. Lam Research Corporation has historically sold roughly 30% of its high-end semiconductors to the PRC and anticipates a $2-2.5B reduction in its 2023 revenue, for example.[63] This lost revenue is currently offset in part by R&D tax credit incentives and the overall growing demand for leading edge chips, but simple math dictates that many U.S. firms will likely have reduced R&D budgets in the coming years. With U.S.-PRC strategic competition revolving around technology competition, this is a highly unfavorable trend from the national security, economic security, and business-firm perspective.

Defense Challenge – Mitigating the Impact of PRC Responses to U.S. Controls. The PRC has several options for responding to U.S.-imposed restrictions on semiconductor technology. First, the PRC has a long history of using the strength of its economy to coerce and punish nations and companies when they threaten PRC interests. CSIS reported in May 2023 that 123 private companies across 18 countries have been the target of PRC economic coercion, amounting to billions of dollars in lost revenue.[64] Partner nations are open about their concern over PRC reprisal due to export controls, and Washington has attempted to find ways to assuage those fears. This U.S. goal is made easier by the fact that many PRC economic coercion initiatives in recent years have been largely ineffective at swaying the target nation's actions and have sometimes been more costly to the PRC. For instance, PRC tariffs and bans placed on Australian wine, coal, and agriculture did very little to deter—and in fact may have solidified—Canberra's new security agreement with the United States and United Kingdom (AUKUS).[65]

Another PRC response is to target denied technology via state-sponsored hacking, theft, and other forms of economic espionage and circumvention. Separately, while the PRC may struggle to produce leading edge chips at scale, their ability to become the world's largest producer of less-advanced chips is more feasible.[66] Analysts disagree on the validity of this threat, but there is concern that Chinese firm overcapacity in these less advanced chips could enable the PRC to dump them on the world at lower price points, destroying the value of many Western chip firms.

Finally, PRC has in the past responded to U.S. export controls by announcing export controls of their own on strategic semiconductor materials like gallium and germanium.[67] A potential concern here is that in some ways it may be easier for the PRC to de-risk from the United States than the other way around. However, some analysts have concluded that the actual threat these controls pose to the global semiconductor supply chain is low.[68] Similar to the PRC's self-sufficiency efforts in the face of export controls, these PRC restrictions may accelerate U.S. and partner efforts to secure alternate sources for these materials. The uncertain degree of risk associated with these potential PRC reprisals notwithstanding, U.S. policymakers must be aware of the impact these threats will have on stakeholder decision-making.

Policy Recommendations

The challenges described above initially appear overwhelming when trying to determine the optimal path for extending and maintaining a lead in semiconductor technology and production over the PRC. Evaluating efforts to date against these challenges reveal significant gaps. It is important to remember, however, that the United States retains some key structural advantages over the PRC and that private and public sector leaders have been attuned to many of these challenges for years. In fact, to the great credit of these leaders, many of the key policy recommendations identified early in the research for this paper were found to already be underway in some fashion. Thus, this section focuses on policies and programs that have not commenced at visible scale, while more briefly noting afterward some ongoing efforts that should be sustained and strengthened.

X-Shoring and Supply Chain Recommendations

Set Clear X-Shoring Goals and Be Ready to Iterate on the Model. There is no obvious answer to the x-shoring conundrum, and tackling this challenge will certainly feature a cycle of iterative trial, error, and dialogue in the coming years. However, Washington should establish a more explicit starting framework for the level of home-shoring, near-shoring, and friend-shoring it desires for specific aspects of the industry. Crafting this starting point will allow public sector officials to implement strategies more deliberately toward those ends, for instance by giving administrators of the ITSI fund better guidance about how to prioritize friend-shoring investments. Additionally, this would send a clearer message to the private sector about where it should expand and where it might expect federal support for those efforts.

- As an extremely high-level recommendation and example, the United States should ensure sufficient and secure access to the semiconductor production that enables AI compute power. This might mean home-shoring at least 15% of the most advanced capabilities for leading-edge wafer fabrication and advanced packaging for both memory and logic chips;

it would also mean ensuring sufficient clustering of suppliers around these manufacturing facilities. Similarly, home-shoring at least enough mature node chip production to satisfy U.S. government requirements—such as for military equipment that predominately uses these older chips—would be advisable as a hedge against sustained conflict in the Indo-Pacific. Meanwhile, to diversify the supply chain and enhance resilience for lower-value-added activities that would be less economically viable domestically (like ATP), a portion of these activities should be near-shored to locations with some form of a chip ecosystem already in place, like Costa Rica. Finally, friend-shoring a greater share of manufacturing, tool production, and materials supply outside of Asia would offset the impact of disruptions in the Indo-Pacific. For a unique International Fellow view on the value of additional friend-shoring in Southeast Asia, see *Appendix 6*.

Ease the Environmental Burden and Cost of Home-Shoring. The Environmental Protection Agency and Department of Commerce should chair a task force designed to deconflict federal and state environmental regulations. The intent is to identify where federal permitting regulations for high-technology facilities are redundant with state rules and might therefore be modified, streamlined, or removed. While taking action on these findings, the EPA should create a federal-state synchronized fast-track process that is tailored to the needs of semiconductor manufacturing firms. Once regulatory approvals are in place for new builds, the local government should establish and maintain a working group consisting of, at a minimum, representatives from federal, state, and local energy and environmental organizations, as well as industry representatives, economic development organizations, suppliers, and citizens from local communities. Together, these recommendations will streamline processes while generating trust and buy-in, making home-shoring a more attractive option for the private sector.

Human Capital Recommendations

Targeted Incentives to Attract Students to the Semiconductor Industry. While the CHIPS and Science Act provides some scholarship funding, the government could offer other incentives to encourage students to get STEM degrees and enter the semiconductor industry. Both programs, if targeted specifically at the chip industry, could help prevent engineers and computer scientists from being pulled into other industries.

- A new chip-focused loan forgiveness program to encourage students to pursue advanced degrees in STEM. In practice, after a semiconductor company hires a student, they would submit a request to forgive their loan debt. However, if talent-related portions of authorized CHIPS and Science Act are never appropriated, new legislation may be required to advance this program. Public-private partnership on this initiative may be more ideal, as the government could match the amount of STEM education loan forgiveness a semiconductor company provided to one of it is employees.

- Worker tax incentives for new entrants into the semiconductor industry would be a significant recruitment tool. Under this policy, technicians and engineers would be exempt from paying federal income tax up to the first $100,000 earned per year for the first three years of their employment in the industry.

Industry Standards and Improved Micro-credential Tracking. The Semiconductor Industry Association, SEMI, National Institute for Innovation and Technology Talent Hub, and Department of Labor should collaborate to establish nation-wide standards for entry-level technicians. In additional to improving employee on-boarding, this public-private collaboration could serve as the foundation for a system for tracking qualifications and credentials. This would provide clarity to the semiconductor workforce about potential career pathways and training next steps. It would also allow firms to design their own certification programs consisting of select standard credentials and on-the-job training. Together, these initiatives would support skill-building and worker retention in the industry.

Vocational Pathway Reform. Several European countries like Germany and the Netherlands offer distinct educational pathways for secondary school students. Typically, a student's vocational path begins at age 12 and integrates apprenticeships and practical training through high school. As the United States looks to home-shore manufacturing beyond just the chip industry, this would be a broader gamechanger for filling U.S. labor shortfalls. Acknowledging that any attempts to reform K-12 schooling will be a political and controversial issue, the Department of Education should partner with industry groups to first convene a task force to chart a feasible reform model.

Create a Sense of Urgency for Immigration Reform. If K-12 vocational (and STEM) reform is expected to pay dividends in the long-term, and student incentives and industry standards should pay dividends in the medium-term, there is a significant human capital shortfall that must be addressed in the short-term. Left unfilled, it will be difficult for firms to meet the objectives and provide returns on the upfront capital supplied by the CHIPS and Science Act. Countless experts have written passionate editorials and data-backed reports detailing sensible options to increase the number of visas for the semiconductor workforce and crafting STEM-specific pathways to citizenship. This report will not re-hash these valid options, recognizing that the bigger hurdle is political gridlock. Public and private sector leaders must come together to generate a sense of urgency that overcomes political gridlock; it must become more obvious to all that the United States will lose in a technology competition with the PRC without this sensible immigration reform.

Ecosystem Recommendations

Share and Scale Ecosystem Best Practices. The CHIPS Program Office should charter a multidisciplinary expert group to review existing hubs and clusters, document lessons learned and identify best practices that are applicable to other regions. This group should then work with this network of hubs to implement select improvements. A positive byproduct of this initiative would virtually linking disparate hubs, providing an opportunity to establish long-term connectivity that helps foster future R&D breakthroughs.

Foster Inter-Cluster Collaboration. If initial efforts to link semiconductor clusters yields positive results, the CHIPS Program Office may consider identifying a centralized body to more deliberately foster cooperation among ecosystems. For instance, by establishing challenge awards that incentivize inter-hub collaboration and are targeted to forge breakthroughs in top U.S. R&D priorities.

Defense Recommendations

Establish a Commission to Inform Improved Decision-Making on Semiconductor Controls. The U.S. President should charter an expert group to study and report on the complex nature of the benefits and drawbacks of restricting PRC access to high-end chips and chipmaking equipment. This body should represent the four key perspectives (national security, economic efficiency, business-firm value creation, and allied interests) whose interests, as discussed above, overlap but do not align. This recommendation acknowledges that the highly nuanced equities and decades of expertise of these stakeholders go far beyond the remit of this research paper, and thus no new export controls will be proposed here. The expert commission should critically analyze the second- and third-order effects of potential new or rolled-back controls or limits on the PRC and leverage those findings to develop a risk management framework and assessment tool that can serve as an enduring aid to decision-makers as they wrestle with new control options.

Enhance Monitoring and Enforcement of Export Controls. BIS staffing should be increased to match the scope of its mission and should be better equipped with a modernized suite of AI-enabled analytic tools. As it is unlikely the perfect toolset for monitoring enforcement exists, a challenge award should be released to incentivize private sector collaboration with BIS in achieving this mission. This could include contracting with firms to analyze data. To close gaps in international enforcement—and as a carrot to encourage alignment with U.S. policies—BIS should share this enhanced data posture and analytic capabilities with allies and partners. Simultaneously, the Department of Commerce and Department of State should leverage increased sharing efforts to secure buy-in from key partners for a more robust, standing collaboration forum with foreign counterparts. BIS officers should then play a leadership role in this new international monitoring and enforcement task force. Finally, the U.S. Intelligence Community should further enable these efforts by increasing its focus on economic intelligence and tailoring opportunity analysis that is actionable for BIS officers.

***Ongoing or Nascent Initiatives That Should Be Sustained and Strengthened*.**

Supply Chains. To further enhance supply chain resilience, the Department of Energy and Department of Defense should continue to award funds for projects that establish domestic strategic materials supply chains, seek to extract rare earth elements from unconventional sources, and support R&D targeted at developing alternate materials solutions. Additionally, early public-private efforts to stockpile the chips essential for U.S. defense equipment and critical infrastructure are valuable risk mitigation techniques.

Human Capital. U.S. government organizations, industry, and academia should continue to experiment with innovative training models—such as the model implemented by Austin Community College—to prepare a workforce for domestic chipmaking. Separately, while some K-12 STEM reform initiatives are having localized success, these efforts should be strengthened and scaled nation-wide.

Defense. Efforts to align international controls are already underway, and although these proceedings are delicate, they are essential to the overall U.S. posture for countering the PRC. The U.S. government should ensure it remains a top priority to synchronize policies, entity control lists, exemption requests, and promote supply chain transparency. These efforts should ensure no member of the coalition disproportionately benefits or suffers from these restrictions.

One final overarching policy recommendation is to launch a sustained strategic communications and education campaign, collaboratively funded and staffed by the U.S. government and semiconductor industry players. The intent is to increase public awareness of the chip manufacturing industry in a way that captures the national urgency and significance of U.S. leadership in this realm in an era of strategic competition with the PRC. The goal would be to draw human capital into the industry, strengthen local buy-in for home-shoring initiatives, and generate a groundswell of support and pressure that helps senior U.S. officials tackle the financial and political challenges addressed in this paper. The policy recommendations described above should help mitigate the need for continued infusions of public capital, but this communications campaign would also lay the groundwork for a potential CHIPS 2.0. The policy recommendations above are not resource-neutral, and to ensure impactful return on initial public-private investments and fill any emerging gaps that CHIPS 1.0 reveals, a CHIPS 2.0 may be necessary.

Conclusion

The strategic environment for semiconductor competition reveals that the United States does have structural advantages that are the envy of the PRC. Moreover, U.S. efforts to date are on the right track for improving upon existing strengths and tackling weaknesses. This inspires a sense of optimism that public and private sector collaboration on semiconductors can address the challenges described in the offense section. Private, patriotic capital is walking through the door that public capital is opening. Defense challenges are thornier and will present more complicated tradeoffs among the four perspectives of national security, economic competitiveness, business-firm value, and international partners. While offense-oriented policy recommendations should yield self-reinforcing improvements that get easier over time, defending against the PRC's semiconductor growth will likely get more complicated. The United States, alongside its partners and allies, should still endeavor to limit the PRC's rise in this realm; these efforts will at a minimum buy time in the near-term for U.S. and partner breakthroughs in chip performance and production, extending the current lead. Over the long-term, the best defense is likely to be a good offense. Mobilizing stakeholders to propel this semiconductor offense should be this decade's moonshot goal.

Appendix 1: Semiconductor Stakeholders

The semiconductor industry features constantly evolving dynamics between and among the full array of stakeholders: federal, state, and local governments; academic institutions and research associations; industry firms of every size and across dozens of specialized subsets; public-private consortia; and foreign partners and allies. Each plays an important role in shaping the future of this critical technology sector, contributing uniquely to its growth and innovation. They also come to the table with different slates of interests, so policy initiatives must account for the fact that each will be responsive to a different slate of incentives. Crafting and aligning those incentives for maximum buy-in across this set of stakeholders can be a challenge. Although the COVID-19 pandemic and the rising ‘Chip Wars’ have put additional strain on these semiconductor stakeholders, there was one major benefit. Crisis often encourages collaboration. These semiconductor stakeholders have, of course, protected their own equities, but they have also been willing to compromise on certain issues to move forward together. The overall U.S. chip posture would struggle to improve without this cooperation.

Below are summaries of the major roles and contributions of these stakeholder groups:

Government Stakeholders. Governments act as catalytic forces by providing public capital for their prioritized semiconductor initiatives, as well as implementing policies and regulations intended to foster innovation, promote competitiveness, and ensure safety.[69] This visibly occurs at the national level, but state governments, regionally-focused public sector groups, and municipalities have been key drivers of growing levels of chip R&D, human capital development, and manufacturing throughout the United States. Key government roles include creating an environment that encourages business growth and innovation, providing essential and foundational infrastructure, and facilitating stakeholder coordination.[70] [71] Through its interaction with, and support to, other stakeholders, the government benefits from a healthier economy and stronger posture for technology competition with the PRC.

***Academia Stakeholders*:** Academia is a crucial enabler for keeping U.S.-based semiconductor technology ahead of competitor nations. Academic institutions generate and test ideas that serve as the foundation for the next breakthrough in semiconductor advances, for instance, by experimenting with new materials or design architectures. While the industry may be under greater pressure to deliver fast results to meet shareholder objectives, academia has more freedom to tackle low probability but high-impact game-changers. Its key role is to contribute basic research, but academia also conducts applied research and develops prototypes. It also plays a significant role in training the future semiconductor workforce. Finally, academia plays a significant role in expanding the base of knowledge and disseminating findings that can be used by established companies and startups in the industry.[72]

Industry Stakeholders. Firms within the semiconductor value chain contribute to R&D, designing, testing, packaging, manufacturing, supplying (materials, equipment, and tools), commercializing, and end-product retail. Major companies can be categorized into integrated device manufacturers (IDMs), fabless design companies, foundries (pure manufacturing), and semiconductor equipment and materials companies.[73] These firms deliver on the upfront investment of academia’s research and government support by bringing that technology to market. Many firms are increasingly seeing the value of partnering with academia early in the R&D process, finding these synergies can speed the transition from developing technology in a lab to building a product in a fab. Venture capitalists represent another type of industry stakeholder; with the skyrocketing demand for AI compute power, venture capital can be a key enabler to bring more start-ups into the chip ecosystem.[74]

The below graphic from the Semiconductor Research Corporation (SRC) provides an excellent summary of the key needs and contributions of these three types of stakeholders.[75]

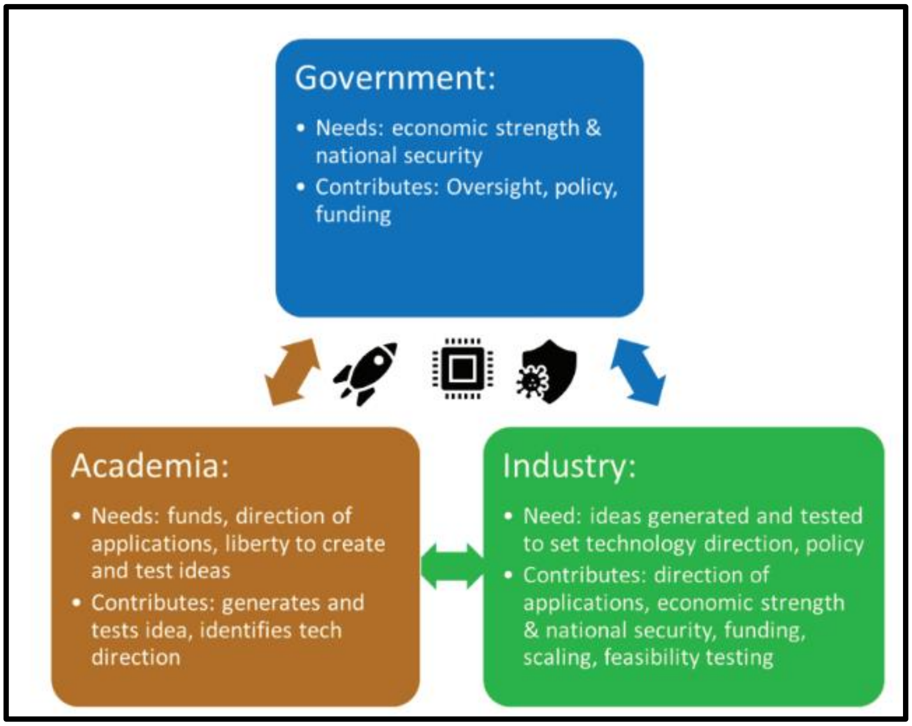


Figure 1. Semiconductor Stakeholder Interaction

Industry Consortia and Partnerships. Public-private partnerships (PPPs) consist of a range of organizations operated by private sector stakeholders that are publicly funded, such as Federally Funded Research and Development Centers (FFRDCs). These include national labs, public-private partnerships operated by academic institutions, or private companies funded by and performing research for the federal government.[76] Separately, industry consortia consist of semiconductor companies and their suppliers created for various purposes. For example, SRC is a consortium of semiconductor companies as well as government agencies that fund high-technology research at more than a hundred universities.[77] Finally, non-academic research organizations also work with the U.S. R&D ecosystem on research and development See Figure 2 for a sample list of non-academic research organizations.[78]

	US	Europe			Asia	
	SRC Semiconductor Research Corporation	imec	cea leti	Fraunhofer	工業技術研究院 Industrial Technology Research Institute	Agency for Science, Technology and Research
Headquarters[1]	United States	Belgium	France	Germany	Taiwan	Singapore
Year founded	1982	1984	1967	1949	1973	1991
Entity Type	Non-profit	Non-profit Govt. Funded	Non-profit Govt. Funded	Non-profit Govt. Funded	Non-profit Govt. Funded	Govt. owned
Number of partners	125+	600+	300+	75	143	20
Number of employees	~10[2]	4,000	1,500	30,000	6,000	NA
Revenue	$90M	$741M	$330M[3]	$3,096M	NA[4]	NA
Regions of operation	1[2]	7	3	9	5	1
Number of patents	700+	1,600+	3,100+	6,800+	17,000+	350+
Cleanroom facilities	None	12,000 sq. meters	8,000 sq. meters	5,500+ sq. meters	NA	3,000 sq. meters

Figure 2. Non-academic research organizations in Europe and Asia.

Partners and Allies. Given the globally interconnected nature of the industry, foreign partners are important stakeholders in any semiconductor initiative. The actions of foreign counterparts can bolster shared semiconductor innovation and resilience, especially when research roadmaps, joint prototyping efforts, technology ecosystems, workforce development, and supply chain diversification initiatives are aligned. Unilateral U.S. actions to restrict the PRC's pathways for advancing its semiconductor posture are unlikely to succeed, so chip policy discussions playing out in capitals across Europe, Asia, and the Americas are crucial. A combined posture on offense and defense nurtures collective competitiveness and mitigates emerging security challenges. These efforts can be bilateral or multilateral, and it would not be surprising to see new 'minilateral' groupings materialize for tailored semiconductor goals. One example of this is a proposed 'Chip 4' alliance—comprised of the United States, Japan, Taiwan, and South Korea—that would collectively work to diversify chip manufacturing away from China.

Appendix 2: Porter's Diamond Model for the United States

Introduction to Porter's Diamond

Michael Porter's Diamond Model details the factors that give one national economy a competitive advantage over another. Competitiveness can be thought of in terms of productivity and the rate of productivity growth. However, when considering a nation's competitiveness, Porter's Diamond Model argues that the domestic environment creates innovation and a forward-looking mindset, which is dynamic and challenging, ultimately contributing to competitive advantage.[79] Porter's Diamond Model uses four attributes to help frame national advantage: Factor Conditions, Demand Conditions, Related and Supporting Industries, and Firm Strategy, Structure, and Rivalry:

1. ***"Factor conditions:*** the nation's position in factors of production—labor, capital, land and resources, and entrepreneurship—necessary to compete in a given industry.
2. ***Demand conditions:*** the nature of home-market demand for the industry's product or service.
3. ***Related and supporting industries:*** the presence or absence in the nation of supplier industries and other related industries that are internationally competitive.
4. ***Firm strategy, structure, and rivalry:*** the conditions in the nation governing how companies are created, organized, and managed, as well as the nature of domestic rivalry."[80]

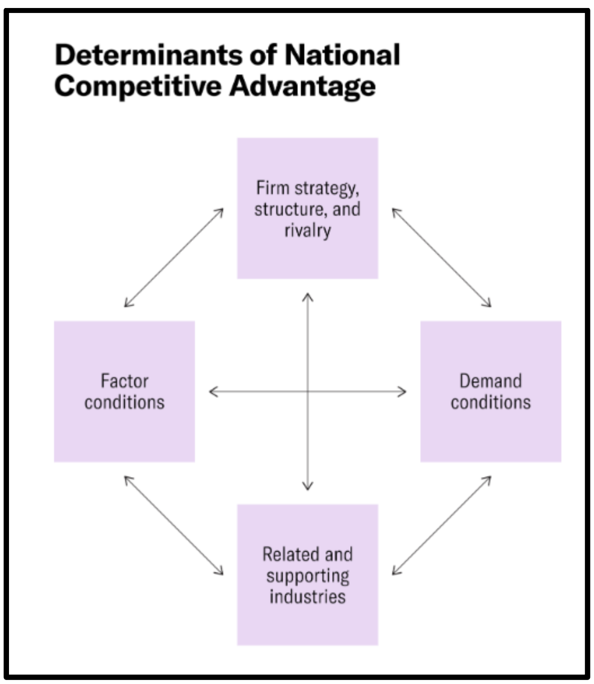


Figure 3. Porter's Diamond Model: Determinants of National Competitive Advantage.[81]

Porter's Diamond for the U.S. Semiconductor Industry

Factor Conditions:

Factor Condition – Labor. An examination of the U.S. semiconductor industry quickly highlights the shortage of skilled workers, engineers, and computer scientists.[82] The technical workforce is a key aspect that the United States is lacking in the semiconductor industry. Since 1979, American companies have moved their manufacturing and production overseas to capitalize on cheaper labor markets, depleting resident knowledge and skillsets crucial for the semiconductor industry. However, America's growing population provides potential for a robust semiconductor workforce in the future. Through the CHIPS and Science Act, Congress recognized the need to grow and develop a new workforce to meet the needs of the growing industry. The funding provided for workforce development within the Act is a promising sign. There are also growing instances of companies, governments, and schools partnering to tackle the workforce shortage together.[83]

Factor Condition – Capital. The capital investment factor in Porter's diamond refers to a country's access to capital vital for businesses to invest in R&D, infrastructure, and technology.[84] U.S. financial markets are perhaps its greatest competitive strength vis-à-vis the PRC, but also as compared to its allies and partners. This is an immediate structural advantage. However, this advantaged waned over the past few decades in the semiconductor industry as capital expenditure was focused in the Indo-Pacific region. Here, the CHIPS and Science Act provided a major boost for U.S.-based capital expenditures; the act has significantly changed the trajectory of this factor condition for U.S. semiconductor health.

Factor Condition – Land and Resources. The U.S. chip manufacturing industry is at a disadvantage in this factor condition relative to other nations. While physical land—in terms of space available to build new fabs and ecosystems—is not an issue, the ability to start using the land in a cost-effective and streamlined manner is a challenge. It simply takes longer to build a fab in the United States than is does anywhere in Asia. The primary contributor to the extended time is environmental permitting and the labyrinth of federal, state, and local environmental regulations a chip manufacturer must negotiate in order to build and operate and fab. Allied and partner countries have streamlined their processes and China's lack of concern for the environment or any of its industries' impact upon it renders this factor in that country a non-issue. Water and energy are the two primary resources consumed by the chip manufacturing industry. The demand for each at a single fab is staggering; on an annual basis a fab can consume 5 million gallons of water per day and consume the equivalent amount of energy in one year that 50,000 U.S. homes consume. Renewable sources of energy and manufacturing process requiring less water are key to the environmental sustainability of the industry and its long-term competitiveness.

Factor Condition – Entrepreneurship. The fourth production factor with a potential to affect the U.S. chip manufacturing industry's global competitiveness is entrepreneurship. Entrepreneurs combine the other three factors to conceptualize, create, and produce a particular product. They are the drivers behind any technical change to the industry. In the semiconductor industry, this is an area where the United States excels relative to its primary competitor, the PRC.

Historically, the PRC excels at non-cutting edge manufacturing but does less well in established markets where invention, sustaining innovation, and tacit knowledge are key such as the market for advanced chips.

Demand Conditions: The domestic market in the U.S. for semiconductors is significant, driving innovation and competition. High demand for advanced technology products fuels the industry's growth and creates a dynamic and competitive environment that spurs innovation, investment, and growth within the semiconductor industry. These demand conditions support the success of semiconductor companies operating in the United States and contribute to the industry's global leadership and influence.

Significant domestic market. The United States boasts one of the largest and most sophisticated markets for semiconductor products in the world. The country is home to various industries, including consumer electronics, automotive, telecommunications, healthcare, and aerospace, which rely heavily on semiconductor technology. This diverse and expansive domestic market provides a strong foundation for the semiconductor industry, driving demand for various semiconductor products and applications.[85]

Innovation and competition. The high demand for advanced technology products in the U.S. market incentivizes semiconductor companies to innovate and develop cutting-edge technologies continually. This innovation-driven environment fosters intense competition among semiconductor firms vying for market share and leadership positions. Companies must continuously invest in research and development to stay ahead of competitors and meet the evolving demands of the market.[86]

Technological advancement. The demand for advanced technology products in the U.S. market catalyzes technological advancement within the semiconductor industry. Consumers and businesses in the United States have a strong appetite for the latest gadgets, devices, and applications, driving the need for increasingly powerful, energy-efficient, and feature-rich semiconductor components. This demand for innovation pushes semiconductor companies to invest in new technologies, manufacturing processes, and product designs to meet the market's ever-changing needs.[87]

Global influence: The strength of the domestic market in the United States extends beyond its borders, influencing demand for semiconductor products worldwide. As a global leader in technology and innovation, trends and developments in the U.S. market often have ripple effects across international markets. Semiconductor companies operating in the United States are well-positioned to leverage their expertise and capabilities to serve global customers and capitalize on opportunities in emerging markets.[88]

Related and Supporting Industries: Complementary industries such as software development, telecommunications, and electronics manufacturing support the semiconductor industry's growth and innovation. Together, they help create a synergistic ecosystem that drives innovation, collaboration, and growth within the U.S. semiconductor industry. The interconnectedness and interdependencies among these industries contribute to the competitiveness and resilience of the semiconductor ecosystem, enabling it to adapt to evolving market dynamics and technological trends.

Software Development. The software industry is closely intertwined with the semiconductor industry, as semiconductors are the foundation for computing devices and systems. The United States is a global hub for software development, with Silicon Valley being particularly renowned for its concentration of software companies, startups, and tech giants. The proximity and collaboration between software developers and semiconductor manufacturers enable rapid innovation and the creation of new applications and technologies that leverage the capabilities of semiconductor chips. Moreover, advancements in software algorithms and programming techniques often drive demand for more robust and specialized semiconductor solutions, further fueling growth in the semiconductor industry.[89]

Telecommunications. The telecommunications sector relies heavily on semiconductor technology to develop networking equipment, mobile devices, and communication infrastructure. In the United States, telecommunications companies work closely with semiconductor manufacturers to integrate the latest chipsets and components into their products and services. The evolution of telecommunications technologies, such as 5G networks and Internet of Things (IoT) devices, presents new opportunities and challenges for the semiconductor industry, driving innovation in wireless communication, signal processing, and connectivity solutions.[90] The symbiotic relationship between the semiconductor and telecommunications industries fosters collaboration, knowledge exchange, and joint R&D efforts, leading to the development of cutting-edge technologies and standards that shape the future of communication.[91]

Electronics Manufacturing. The presence of a robust electronics manufacturing ecosystem in the United States complements the semiconductor industry by providing the infrastructure and capabilities for the production and assembly of semiconductor components into finished electronic products. From consumer electronics and automotive systems to industrial equipment and medical devices, semiconductor chips are integral components of various electronic devices. The availability of skilled labor, advanced manufacturing facilities, and supply chain networks within the electronics manufacturing sector supports the semiconductor industry's growth by enabling efficient production processes, quality control, and product customization. Additionally, close collaboration between semiconductor manufacturers and electronics OEMs (Original Equipment Manufacturers) facilitates rapid prototyping, product testing, and customization to meet the specific needs of customers and end-users.[92]

Firm Strategy, Structure, and Rivalry: Intense competition among existing semiconductor firms in the U.S. fosters innovation and efficiency. The industry is characterized by strategic collaborations, mergers, and acquisitions to maintain competitiveness.

Intense competition: The semiconductor industry in the United States is competitive, with many major firms vying for market share and technological leadership. This intense competition fosters a culture of innovation and drives firms to continually improve their products, processes, and operations to stay ahead of rivals. Companies invest heavily in research and development to develop cutting-edge technologies, improve performance, and reduce costs. Additionally, competition encourages firms to focus on operational efficiency, supply chain optimization, and customer satisfaction to enhance their competitive position in the market.[93]

Innovation-driven strategies. Innovation is a cornerstone of competition in the semiconductor industry, with firms constantly seeking to develop new products, technologies, and solutions to address evolving market needs and customer demands. Companies invest in research and development to drive technological advancements in semiconductor design, manufacturing processes, packaging techniques, and integration capabilities. Strategic alliances, partnerships, and collaborations with research institutions, universities, and other industry players are common strategies adopted to accelerate innovation and access complementary expertise and resources.[94]

Mergers and acquisitions. Mergers and acquisitions (M&A) play a significant role in shaping the competitive landscape of the semiconductor industry in the U.S. Firms engage in M&A activities to strengthen their market position, expand their product portfolios, acquire key technologies or intellectual property, and achieve economies of scale. Consolidation within the industry through M&A transactions can lead to the formation of larger, more diversified companies with enhanced capabilities and resources to compete effectively in the global market. However, M&A activities also present challenges related to integration, cultural alignment, and regulatory scrutiny, which firms must navigate to realize the full benefits of consolidation.[95]

Strategic alliances and collaborations. These are common strategies semiconductor firms employ to leverage complementary strengths, share risks and costs, and access new markets or technologies. Joint ventures, technology partnerships, and consortiums enable firms to pool resources, expertise, and intellectual property to pursue shared objectives such as developing industry standards, addressing technical challenges, or entering new market segments. Strategic alliances can enhance firms' competitiveness by expanding their reach, accelerating innovation, and reducing time-to-market for new products and solutions.[96]

In summary, intense competition among existing semiconductor firms in the U.S. drives innovation and efficiency. At the same time, strategic collaborations, mergers, and acquisitions are tools used to maintain competitiveness and adapt to evolving market dynamics. The dynamic interplay of firm strategy, structure, and rivalry within the semiconductor industry shapes its competitiveness and influences the pace of technological advancement and industry consolidation.

Appendix 3: Environmental Sustainability

Note: This section is heavily excerpted from the individual paper of a member of this seminar.[97]

The Problem

As the United States embarks on its quest to create and sustain a viable and competitive chip manufacturing industry at home, the country's focus has largely been on the near-term requirements to make such an industry successful complete with a productive work force, a robust infrastructure, and healthy market demand. Little emphasis is placed, from the public domain, on the environmental aspects of this manufacturing industry and how it can be responsibly sustained in this country for the foreseeable future. The resource-intensive nature of chip manufacturing and the waste streams it generates present enduring challenges to its environmental sustainability in the United States. Energy demands, regulatory constraints, and public sentiment towards the industry have the potential to affect its long-term viability. How does the United States ensure sufficient resources remain available to support a robust chip-manufacturing industry while adhering to regulations, standards, and policies enacted by federal, state, and local governments to safeguard the environment?

In Europe, regional governments and the European Union have successfully combined to create a regulatory environment aimed at lessening effects on the industry while ensuring its ability to operate with little-to-no environmental impact. In the United States, civic and environmentally-minded chip manufacturers have established their own goals for sustainability and instituted plans to reduce their environmental impact independent of local or federal environmental regulations.[98] Therefore, there is hope for the U.S. chip manufacturing industry, as resource-intensive as it is, to operate sustainably and with minimal impact on this country's, and the globe's, limited natural resources.

Under the careful application of environmental regulations and with deliberate planning, strategic communication, and earnest due diligence, the U.S. chip manufacturing industry can balance its operations within the environmental regulatory confines imposed upon it by federal, state, and local governments. Going forward, chip fabrication sites will need to generate, recycle, or reuse as many resources as they consume to sustain their operations in an environmentally responsible manner. A balanced, whole-of-government approach, developing regionally-focused, tailor-made solutions for a sustainable chip manufacturing industry, is not only possible but necessary to meet the current U.S. intent to establish a home-based chip manufacturing capability.

The Burden

Chip manufacturing requires a steady supply of water. Data suggests a modern fabrication facility (fab) consumes approximately five million gallons of water per day (MGD)[99,100], although this can vary regionally, depending on the size of the fab and the climate zone in which it is located. TSMC's chip manufacturing facilities in Taiwan, for example, are in arid regions of the island and collectively consumed 193,000 tons of water in 2020.[101] The complications, therefore, of establishing a chip manufacturing capability in arid locations such as Arizona and Texas are obvious. In a water-scarce environment, how is a water-intensive manufacturing process sustainable?

Staggering amounts of energy are required to power the chip manufacturing industry. A recent report suggests that the global chip industry consumed 149 billion kilowatt-hours (kWh) in 2021, which is enough to power a metropolis of 25 million people for a year.[102] An individual fab's energy consumption can reach 100 megawatt-hours (MWh) per hour equivalent to the energy consumed by 80,000 typical North American homes,[103] or more simply, one fab consumes the same amount of electricity in one year as 50,000 households in the United States.[104] However it is measured, the energy consumption rate for a fab is significant and has obvious negative implications for local or regional power grids such as those supporting proposed fabs in Arizona.

The chip manufacturing industry employs a series of gases and chemicals in its processes. These gases are applied primarily during the etching and deposition stages and are generally considered by the Environmental Protection Agency (EPA) to have high global warming potential (GWP).[105] Additionally, perfluoroalkyl and polyfluoroalkyl substances (PFAS), also known as "forever chemicals," are used in the chip manufacturing process.[106] While the use of these gases and chemicals is not constrained by availability in the same way as water and electricity resources are constrained, their use does generate off-gases and waste products, which must be addressed to create a sustainable environmental footprint.

Waste streams generated by the chip manufacturing process form a significant challenge to making the industry environmentally sustainable. A fab can generate up to 15,000 tons of solid waste in three months of operations, 60 percent of it hazardous.[107] The millions of gallons of water purified and used in the manufacturing process must be treated before being re-used or released. Off-gases and air contaminants generated during manufacturing must be treated prior to release into the air. Together, these things must be addressed to reduce their environmental impacts and ensure a sustainable manufacturing process.

<u>The Solution</u>

There are plenty of environmental, health, and safety (EHS) laws on the books to regulate the day-to-day operations of fabs and their environmental impacts. The National Environmental Policy Act (NEPA), the Clean Air Act (CAA), the Clean Water Act (CWA), the Toxic Substances Control Act (TSCA), and the Resource Conservation and Recovery Act (RCRA) are but a few of the federal statutes with which the chip manufacturing industry must comply. States have their own sets of EHS regulations, which may complement federal laws or, in some cases, be more stringent. Absent from this legal landscape is sufficient local, state, and federal regulatory support in the United States compared to that provided by governments of peer semiconductor-producing companies.[108]

<u>The Imperative</u>

There is no getting around the fact that the chip manufacturing industry has the potential to be a strain on available natural resources in any region, as well as a significant contributor to the region's waste streams and harmful emissions. These challenges, however, can be overcome through careful planning, thoughtful application of regulations, and most importantly, a collaborative approach to arriving at the solutions which best fit the affected region. The key to a successful program for sustainability is to think in terms of long-term viability beyond partisan politics, beyond the next presidential administration, and beyond the short-sighted policy-making that stymies the best of intentions. The national security imperative behind the creation of a sustainable and long-lasting chip manufacturing capability in the United States demands that all efforts at the federal, state, and local levels of government be expended to ensure the development of an environmentally responsible and sustainable semiconductor manufacturing industry.

Appendix 4: Overview of EDA Tech Hubs and the Microelectronics Commons

EDA Tech Hubs

The Tech Hubs Program was enacted as part of the CHIPS and Science Act of 2022 (as the Regional Technology and Innovation Hubs program). The statute authorized $10B for the program over five years. As part of the FY 2023 Consolidated Appropriations Act, Congress appropriated $500 million for the EDA to launch the program.[109] The Tech Hubs Program aims to strengthen U.S. economic and national security with investments in regions across the country that have assets and resources with the potential to become globally competitive in the technologies and industries of the future.[110] The goal is to create ecosystems that will produce increasingly powerful and specialized chips by leveraging strengths in areas like new transistor materials, flexible and modular manufacturing and packaging, and microfluidics.[111]

Below are brief summaries of the four semiconductor-focused EDA Tech Hubs:[112]

New York Semiconductor Manufacturing and Research Technology Innovation Corridor (NY) – Led by CenterState Corporation for Economic Opportunity (CEO), aims to enhance regional semiconductor manufacturing capabilities while ensuring economic opportunity for underserved communities.[113] Website: N/A

- Lead Organization Profile - CenterState CEO: Central New York's premier business leadership and economic development organization, committed to creating a region where business thrives, and all people prosper. Website: CEO | Center for Employment Opportunities (ceoworks.org)
- Membership – 90 members in the consortium.[114]
- Proposals totaling ~$54M for Tech Hub Phase 2 implementation funding.[115]

Corvallis Microfluidics Tech Hub (OR) – Led by Oregon State University (OSU), aims to establish global leadership in developing, scaling, and commercializing microfluidics technology for use in semiconductor and electronics cooling.[116] Website: Cormic Tech Hub

- Lead Organization Profile - OSU comprises two campuses, with the main campus at Corvallis, Oregon. The university has 11 colleges, 12 experiment stations, extension programs in all 36 counties, and nearly 200 degree programs.
- Membership – 65 members in the consortium.[117]
- Proposals totaling ~$70M for Tech Hub Phase 2 implementation funding.[118]

Texoma Semiconductor Tech Hub (TX & OK) – Led by Southern Methodist University, seeks to unify existing and planned semiconductor supply chain infrastructure by enhancing regional collaboration and uplifting underserved communities through workforce expansion. This tech hub offers a semiconductor manufacturing model that geographically consolidates the semiconductor manufacturing supply chain from bare wafers to products. By deploying a geographically distributed "Fablet" model, building targeted, accessible labs for electronic design, semiconductor manufacturing, packaging, and testing.[119] Website: Texoma Tech Hub: Unifying the Semiconductor Supply Chain

- Lead Organization Profile – A nationally ranked global research university in Dallas. SMU's alumni, faculty, and over 12,000 students in eight degree-granting schools demonstrate an entrepreneurial spirit as they lead change in their professions, communities, and the world. The Office of Research and Innovation is the lead office for this tech hub.[120]

- Membership – 41 members in the consortium.[121]
- Proposals totaling $73.4M for Tech Hub Phase 2 implementation funding.[122]

Vermont Gallium Nitride Tech Hub (VT) – Led by the University of Vermont (UVM), seeks to innovate gallium nitride (GaN) manufacturing, a critical material technology for semiconductor production. It aims to leverage previous investments in GaN technology, regional physical assets, and technical workforce development programs to boost GaN manufacturing through technology innovation and prototype demonstrations. The Vermont GaN Tech Hub will further develop semiconductor technological applications.[123] Website: Welcome to the Vermont GaN Tech Hub (vgan.tech)

- Lead Organization Profile – UVM is a top research university and a member of the National Science Foundation. Over 13,000 students enrolled in over 100 bachelor's degree programs, 58 master's degree programs, and 26 doctoral programs.[124]
- Membership – 22 members in the consortium.[125]
- Proposals totaling ~$41M for Tech Hub Phase 2 implementation funding. [126]

***Way Ahead*.** The 31 designated EDA tech hubs are eligible to compete for Phase 2 which will award Implementation Grants to help propel the designees' chosen geography into self-sustaining global competitiveness in a key technology area. For each tech hub selected for Implementation Grants, EDA expects to fund approximately 3-8 tightly aligned projects – totaling between $40 million and $70 million each – that aim to address the region's key inhibitors of global competitiveness collectively. All four semiconductor-focused tech hubs have submitted their proposals for Phase 2 funding since the end of February 2024, and results are expected to be announced in the summer of FY24.[127]

Major Risk – Sustainability. Despite having submitted proposals for Phase 2 implementation funding, only 5-10 of 31 hubs are expected to be selected, contingent upon available funds from Congress. Funding disbursement may also face delays. Even if EDA funding materializes, the amount may not adequately meet the capability and capacity needs as intended due to unforeseen expenditures.[128] Given this risk, existing tech hubs should develop strong relationships with adjacent hubs, including ones predating the CHIPS Act and ME Commons to optimize resource-sharing.

Microelectronics Commons

This effort seeks to enable direct pathways to commercialization via eight regional innovation hubs focusing on six technology areas: electronic warfare, secure edge and internet of things computing, AI at the edge, quantum technology, 5G/6G technology, and commercial leap ahead technologies.

The Commons will be successful if it can help technologies overcome the 'Valley of Death' by creating partnerships between emerging technology research, domestic manufacturing facilities, and interagency partners. The goal is to create viable products not only for government use, but also commercial advances. It aims to propel startups and small companies forward and leverage their entrepreneurial activity where they would otherwise be halted without strong venture capital (VC) funding.[129]

***What's Happening*.** In FY 2023, awards totaled $238M to the eight regional innovation hubs (Fig. 4). This standup meant the transition of resources and focus to jumpstart a self-sustaining ME Commons. The call for FY 2024 ME Commons projects, is in line with the U.S. Secretary of Defense's priorities, announced in December 2023 and awards are expected in the third quarter, with the National Security Technology Accelerator (NSTXL) acting as the end-to-end government acquisition entity to accelerate contract awards.

Figure 4. Microelectronic Commons' Hub Model [130]

Appendix 5: Porter's Diamond Model for the PRC & Russia

The PRC's Porter's Diamond

Porter's Diamond reveals a mixed bag of national strengths and weaknesses for the PRC's desired strength in semiconductor technology leadership. While their attempts to develop semiconductor self-sufficiency in the face of U.S.-led export controls will be an uphill battle, they will have some key domestic enablers, like large amounts of public capital, population, infrastructure, and manufacturing know-how.

Factor Conditions:

Infrastructure. Although the PRC has been cut off from the most advanced semiconductor manufacturing equipment, it does have well-established semiconductor infrastructure, including many component parts of the supply chain. The PRC has established technology regions that facilitate short distance to move people, products, and support necessary for a resilient semiconductor ecosystem.

Technology and Innovation Capabilities. The PRC lags its primary competitors in its innovation base. Its technical advances have come largely through IP theft, reverse engineering, or espionage, although it has demonstrated strong abilities to advance in other fields like batteries, solar, and electric vehicles.

Skilled Labor. The PRC has an enormous population that represents immense potential in terms of a future semiconductor workforce. They are strongest at the technician level, those who operate and maintain the manufacturing facilities. They are less strong on higher-end engineering talent, as many of the PRC's scientists, engineers, and researchers are U.S.-educated.

Research Institutions and Universities. The PRC is making headway in this area, but it does not represent a competitive advantage. Leading PRC scientists, engineers, and researchers are educated outside the PRC. The PRC also put controls and incentives in place that stifle certain innovation and ground-breaking R&D efforts.

Capital Investment. Public capital is the PRC's primary competitive advantage over other nations, as it has proven it willing to invest incredible sums in the industrial projects they prioritize.

Firm Strategy, Structure, and Rivalry:

Intense competition. The PRC features one firm (SMIC) that is the leading producer of chips. Due to the state-controlled and -influenced nature of this critical industry, SMIC has received significant government funding. There is some domestic competition, but it is not a driver of innovation like competition is in the West.

Strategic Partners and Collaborations. While the PRC sells its products across the global market, its window of opportunity to collaborate on semiconductors with the top nations in this realm is closing quickly. Due to U.S.-led export controls and growing distrust of the PRC across the world, firms see less benefit and more risk in PRC-based ventures. This will leave the PRC with collaboration opportunities with unstable autocracies such as Russia, Iran or North Korea. As far as a competitive disadvantage in this area, where the United States has partners, the PRC merely has customers.

<u>Demand Conditions</u>: While the PRC's economic miracle was achieved in part by exporting their products, the demand for chips within China is skyrocketing due both to AI demand and the need to put semiconductors in all of the electronic products the PRC manufactures. The Chinese chip market demand is high, second only to the US. China is the second largest final consumption market for electronic devices that have chips in them[131] This is particularly true in markets like electric vehicles, in which the PRC government is demanding Chinese firms buy a certain percentage of their chips from Chinese semiconductor companies. The market is more outside of China so as it loses market share or is denied access to markets, the PRC will continue to subsidize its chip maker(s) to remain viable. The risk is, how much market isolation is the PRC willing to accept without reacting violently?

<u>Related and Supporting Industries</u>: Electronics manufacturing and telecommunications are strong suits for the PRC. They have a long history of successful process innovation and spillover effects in these areas. These will be strong enablers of the PRC's attempts to build semiconductor self-sufficiency.

<u>Russia's Porter's Diamond</u>

Russia does not contribute to the overall production of semiconductors in a meaningful way. Its most significant impact on the semiconductor industry has been thanks to its invasion of Ukraine. Russia's invasion of Ukraine threatened the semiconductor industry's noble gas supply chains. In addition to other noble gases used for photolithography, Ukraine supplies 90 percent of the world's semiconductor-grade neon for chips.[132] Porter's Diamond analysis confirms Russia has little promise in becoming a relevant semiconductor player.

1. Factor Conditions: Russia's small chipmaking capacity largely serves government customers.[133]
2. Demand Conditions: Russia imported $836 million in semiconductor devices in 2022, down from $1.7 billion in 2021.[134] For reference, the US imported $16.6 billion worth of semiconductor devices in 2022, while China imported $23 billion.[135][136]
3. Related and supporting industries: Russia's domestic ability to produce chips is limited. Before the invasion of Ukraine, Russia was designing its own chips and using foundries to make them; however, sanctions have cut Russia off from using most non-Chinese foundries.[137]
4. Firm strategy, structure, and rivalry: Given Russia's lack of manufacturing capability, this section of Porter's Diamond Model is not applicable.

<u>Appendix 6: Friend-shoring Vignette</u>

ASEAN Potential Demonstrates Not Everything Needs to Be Home-Shored: The Perspective of an International Fellow from Southeast Asia

The Biden Administration, while deploying resources to return chipmaking capabilities to America, has also acknowledged that the United States cannot manufacture everything itself.[138] This recognition underscores the need for collaboration with partners and allies, a crucial ingredient for fostering and promoting shared supply chain resilience. As the semiconductor industry grapples with challenges such as talent shortages, intellectual property concerns, and geopolitical tensions, the Association of Southeast Asian Nations (ASEAN) region presents an opportunity for like-minded nations to strengthen their economic and technological partnerships through friend-shoring initiatives. ASEAN constitutes the world's fifth-largest economy and plays a significant role as it offers several advantages such as growing manufacturing capabilities, skilled workers, and supportive government policies.[139]

ASEAN's Advantages

The ASEAN region is ideally situated at the crossroads of major global trade routes, offering significant logistical advantages that reduce costs and transit times, making it a key hub for international trade. ASEAN presents a diverse array of investment opportunities, ranging from areas primed for advanced manufacturing to emerging markets ideal for labor-intensive industries. This diversity is underpinned by a robust semiconductor ecosystem that has flourished since the 1970s, a testament to the region's stability and allure for investors like Intel, Infineon, Arm, Global Foundries, Texan Instrument, and others.[140]

The workforce in ASEAN is a valuable asset, being young, well-educated, and vocationally trained. This demographic advantage fuels industry growth and innovation, making ASEAN as an attractive location for future semiconductor business. Most ASEAN countries are part of several free trade agreements, including the Regional Comprehensive Economic Partnership (RCEP), which connects them with major Asian economies and enhances economic integration and market access throughout the region. Culturally, ASEAN aligns well with the West, with the widespread use of English in business. This eases communication and simplifies operations, making ASEAN an appealing choice for Western companies looking to expand globally.

The Dilemma

Geopolitical Alignment vs Economic Interest. ASEAN's neutral foreign policies have long allowed its member countries to navigate the global stage with diplomatic finesse. However, the increasing economic ties between ASEAN nations and the PRC pose a challenge for any U.S. friend-shoring initiative with ASEAN. For ASEAN member states, balancing economic interests with geopolitical alignment requires careful diplomacy; they risk straining essential relationships with Beijing if they tilt excessively toward Washington. [141]

Capacity and Technologies Capabilities. While ASEAN has been advancing its semiconductor industry posture, it lags behind competitors like Taiwan, South Korea, and the United States in semiconductor manufacturing. To enhance high-tech semiconductor production and attract U.S. friend-shoring interest, ASEAN needs to invest in technology transfer, infrastructure enhancement, and skilled labor.[142]

Economic Dependencies and Incentives. ASEAN countries may require significant economic incentives to develop semiconductor industries that primarily serve U.S. interests. However, this could strain local resources and skew national economic priorities. Balancing local economic development with the demands of friend-shoring agreements necessitates robust economic planning. Substantial support from U.S. investments and incentives will be crucial for ASEAN to ensure sustainable growth and avoid compromising its national economic priorities.[143]

Divergence Between the U.S. and PRC Approaches to ASEAN. The PRC employs a non-coercive approach in its diplomatic engagement with ASEAN member states, prioritizing economic collaboration and refraining from forces nations to choose between Beijing and Washington. This has allowed the PRC to subtly increase its influence in the region through initiatives like the Belt and Road and the RCEP. On the other hand, the United States often takes a more confrontational stance, pressuring ASEAN nations to take sides in the U.S.-PRC competition. This has made ASEAN hesitant to fully embrace U.S. initiatives as they navigate relationships with both powers. By adopting a more diplomatic and economically-focused strategy that emphasizes cooperation over confrontation, the Washington could strengthen its relations with ASEAN and its member states, promoting regional stability and prosperity.

Conclusion

ASEAN currently contributes 22.5% to the global semiconductor chain, with most of its involvement in backend manufacturing. Intel recently announced that its new fabs in Malaysia will focus on 3D advanced packaging.[144] The semiconductor ecosystem in ASEAN has been established since 1970. However, recent studies show that ASEAN is concerned about the increasing influence of both the United States and the PRC, but is more concerned about the PRC.[145] It is apparent that the people in the region show a greater inclination towards embracing investment in the U.S. investment system. However, U.S. military presence in the area is a cause for concern for ASEAN, and its member states would favor U.S. efforts to prioritize its economic presence in the region over its military posture. Recognizing that complete self-sufficiency in the semiconductor sector is unattainable, the Indo-Pacific Economic Framework represents a potential platform for establishing frameworks related to chip-related imports, exports, and overall supply chain resilience and security.

REFERENCES

[1] The White House, *National Security Strategy of the United States of America* (Washington, DC: White House, 2022), https://www.whitehouse.gov/wp-content/uploads/2022/10/Biden-Harris-Administrations-National-Security-Strategy-10.2022.pdf; U.S. Department of Defense, *2022 National Defense Strategy of the United States of America*, October 2022, https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

[2] The White House, "Remarks by National Security Advisor Jake Sullivan at the Special Competitive Studies Project Global Emerging Technologies Summit," The White House, September 16, 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/09/16/remarks-by-national-security-advisor-jake-sullivan-at-the-special-competitive-studies-project-global-emerging-technologies-summit/.
[3] Sujai Shivakumar, Charles Wessner, and Thomas Howell, "The Strategic Importance of Legacy Chips," *Center for Strategic & International Studies*, March 2023, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023-03/230303_Shivakumar_Legacy_Chips.pdf?VersionId=3CnqsaOufV9_n0l35miYXEqfM8hpcZ6z.
[4] Semiconductor Industry Association, "Global Semiconductor Sales Decrease 8.2% in 2023; Market Rebounds Late in Year," SIA, February 5, 2024, https://www.semiconductors.org/global-semiconductor-sales-decrease-8-2-in-2023-market-rebounds-late-in-year/.
[5] Corey Richard, *Understanding Semiconductors - A Technical Guide for Non-Technical People*, Maker Innovation Series (Apress, 2023), 42–79.
[6] Ibid.
[7] "Marisa Brown, "Extend Visibility Beyond Tier 1 Suppliers," *Supply & Demand Chain Executive*, May 18, 2022, https://www.sdcexec.com/software-technology/supply-chain-visibility/article/22236371/apqc-extend-visibility-beyond-tier-1-suppliers.; U. S. Government Accountability Office, "Supply Chain Resilience: Agencies Are Taking Steps to Expand Diplomatic Engagement and Coordinate with International Partners," February 2, 2023, https://www.gao.gov/products/gao-23-105534; Aime Williams, "US Presses Chipmakers for More Transparency on Supply Chains," Financial Times, September 23, 2021, https://www-ft-com.nduezproxy.idm.oclc.org/content/7bd59b60-c53d-4796-93f4-d0f51c2b5066.
[8] Raj Varadarajan et al., "Emerging Resilience in The Semiconductor Supply Chain" (SIA and BCG, May 2024), 6-7, 10-11, https://www.semiconductors.org/wp-content/uploads/2024/05/Report_Emerging-Resilience-in-the-Semiconductor-Supply-Chain.pdf.
[9] Raj Varadarajan et al., "Emerging Resilience in The Semiconductor Supply Chain."
[10] Ibid, 9.
[11] Sujai Shivakumar, Charles Wessner, and Thomas Howell, "Balancing the Ledger: Export Controls on U.S. Chip Technology to China," Center for Strategic and International Studies, February 21, 2024, https://www.csis.org/analysis/balancing-ledger-export-controls-us-chip-technology-china.
[12] Justin Badlam, et al., "The CHIPS and Science Act: What Is It and What Is in It?" McKinsey, October 4, 2022. https://www.mckinsey.com/industries/public-sector/our-insights/the-chips-and-science-act-heres-whats-in-it; The White House, "FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China," The White House, August 9, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/
[13] Kai Ryssdal and Leeson Sarah, "Commerce Chief Raimondo Lays out Blueprint for U.S. Chipmaking," Marketplace (blog), May 10, 2024, https://www.marketplace.org/2024/05/10/commerce-chief-lays-out-blueprint-for-chip-manufacturing-in-america/.
[14] Ken Moriyasu, "U.S. Aims to Make 20% of World's Leading-Edge Chips by 2030: Raimondo," *Nikkei Asia*, February 27, 2024, https://asia.nikkei.com/Business/Tech/Semiconductors/U.S.-aims-to-make-20-of-world-s-leading-edge-chips-by-2030-Raimondo.
[15] Raj Varadarajan et al., "Emerging Resilience in The Semiconductor Supply Chain;" Kai Ryssdal and Leeson Sarah, "Commerce Chief Raimondo Lays out Blueprint for U.S. Chipmaking."
[16] Kai Ryssdal and Leeson Sarah, "Commerce Chief Raimondo Lays out Blueprint for U.S. Chipmaking."
[17] Madeleine Ngo, "Billions in Chips Grants Are Expected to Fuel Industry Growth, Report Finds," *NY Times*, May 8, 2024, https://www.nytimes.com/2024/05/08/us/politics/chips-grants-fuel-industry-growth.html.
[18] Gregory C. Allen et al., "The Post-October 7 World," September 28, 2023, https://www.csis.org/analysis/post-october-7-world.
[19] Ibid.
[20] Thibault Denamiel et al., "Beyond Economics: How U.S. Policies Can Undermine National Security Goals," May 3, 2024, https://www.csis.org/analysis/beyond-economics-how-us-policies-can-undermine-national-security-goals.
[21] Diederik Baazil et al., "US Urges Allies to Further Squeeze China on Chip Technology," Bloomberg, March 6, 2024, https://www.bloomberg.com/news/articles/2024-03-06/us-urges-allies-to-further-squeeze-china-on-chip-technology.
[22] Thibault Denamiel et al., "Beyond Economics: How U.S. Policies Can Undermine National Security Goals;" The White House, "FACT SHEET: President Biden Takes Action to Protect American Workers and Businesses from China's Unfair Trade Practices," The White House, May 14, 2024, https://www.whitehouse.gov/briefing-

room/statements-releases/2024/05/14/fact-sheet-president-biden-takes-action-to-protect-american-workers-and-businesses-from-chinas-unfair-trade-practices/.

[23] Lucas Mearian, "The CHIPS Act Money: A Timeline of Grants to Chipmakers," Computerworld, May 8, 2024, https://www.computerworld.com/article/2099381/the-chips-act-money-a-timeline-of-grants-to-chipmakers.html; Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.

[24] Gary P. Pisano and Willy C. Shih, "Why America Needs a Manufacturing Renaissance." Harvard Business School, October 17, 2012. https://www.un-industria.it/Public/Doc/manufacturing%20renaissance.pdf; Pisano, Gary P, and Willy C Shih, Excerpt from: *Producing Prosperity: Why America Needs a Manufacturing Renaissance.* (Boston, Mass.: Harvard Business Press, 2012).

[25] Department of Commerce, "Assessment of the Status of the Microelectronics Industrial Base in the United States" (Washington D.C.: Department of Commerce, December 2023), https://www.bis.doc.gov/index.php/documents/technology-evaluation/3402-section-9904-report-final-20231221/file.

[26] John McIlroy. 2024. "Our Guide to 'Friend-Shoring' – the OCO Insight on Getting the Right Global Supply Chains for You." OCOGLOBAL, March 12, 2024. https://www.ocoglobal.com/general/our-guide-to-friend-shoring-the-oco-insight-on-getting-the-right-global-supply-chains-for-you/; Ellerbeck, Stefan, "What's the Difference between 'Friendshoring' and Other Global Trade Buzzwords?" World Economic Forum. February 17, 2023, https://www.weforum.org/agenda/2023/02/friendshoring-global-trade-buzzwords/.

[27] Paul Timmers, "How Europe Aims to Achieve Strategic Autonomy for Semiconductors," Brookings Institute, August 9, 2022, https://www.brookings.edu/articles/how-europe-aims-to-achieve-strategic-autonomy-for-semiconductors/; Emily Benson and Ethan B. Kapstein, "The Limits of 'Friend-Shoring,'" CSIS, June 14, 2023, https://www.csis.org/analysis/limits-friend-shoring.

[28] "The U.S. Department of State International Technology Security and Innovation Fund," *United States Department of State* (blog), accessed May 15, 2024, https://www.state.gov/the-u-s-department-of-state-international-technology-security-and-innovation-fund/.

[29] Katarína Svitková, "Resilience in the National Security Discourse," *Obrana a Strategie (Defence and Strategy)* Vol 17, no. 1 (October 6, 2017): 012–040, https://doi.org/10.3849/1802-7199.17.2017.01.021-042.

[30] U.S. Department of Defense, *2022 National Defense Strategy of the United States of America.*

[31] Raj Varadarajan et al., "Emerging Resilience in The Semiconductor Supply Chain."

[32] Richard Baldwin, et al., "Hidden Exposure: Measuring US Supply Chain Reliance," Brookings, September 27, 2023, https://www.brookings.edu/articles/hidden-exposure-measuring-us-supply-chain-reliance/.

[33] Bloomberg Terminal, "Supply Chain Analysis for ASML," Bloomberg L.P., 1981, accessed 4/20/2024; Bloomberg Terminal, "Supply Chain Analysis for Tokyo Electron," Bloomberg L.P., 1981, accessed 4/20/2024.

[34] Annabelle Liang & Nick Marsh, "Gallium and Germanium: What China's New Move in Microchip War Means for World," BBC News, August 1, 2023, https://www.bbc.com/news/business-66118831.

[35] Katie Schoolov. 2022. "ASML Is the Only Company Making the $200 Million Machines Needed to Print Every Advanced Microchip. Here's an inside Look." CNBC. March 23, 2022. https://www.cnbc.com/2022/03/23/inside-asml-the-company-advanced-chipmakers-use-for-euv-lithography.html.

[36] ASML, "ZEISS and ASML Strengthen Partnership for next Generation of EUV Lithography," ASML, November 3, 2016, https://www.asml.com/en/news/press-releases/2016/zeiss-and-asml-strengthen-partnership-for-next-generation-of-euv-lithography.

[37] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.

[38] Dan Martin and Dan Rosso, "Chipping Away - Assessing and Addressing the Labor Market Gap Facing The U.S. Semiconductor Industry," The Semiconductor Industry Association, July 2023, https://www.semiconductors.org/wp-content/uploads/2023/07/SIA_July2023_ChippingAway_website.pdf.

[39] Ibid.

[40] Mariana Ambrose, John Jacobs, and Natalie Tham, "CHIPS and Science Act Summary: Energy, Climate, and Science Provisions | Bipartisan Policy Center," November 14, 2022, 12, https://bipartisanpolicy.org/blog/chips-science-act-summary/.

[41] Christy Pambianchi, Keyven Esfarjani, and Anna B. Kelleher, "Intel's Relentless Pursuit of Next-Gen Workforce Pipeline. - Document - Gale Business: Insights," *Gale Business Insight*, September 9, 2022, https://www.intel.com/content/www/us/en/newsroom/opinion/relentless-pursuit-next-gen-workforce-pipeline.html; Purdue University News, "Purdue University Partners with Leading Global Chipmaker on Semiconductor Design Center," Purdue University, June 28, 2022, https://www.purdue.edu/newsroom/releases/2022/Q2/purdue-university-partners-with-leading-global-chipmaker-on-midwests-first-semiconductor-design-center.html.

[42] Dan Martin and Dan Rosso, "Chipping Away - Assessing and Addressing the Labor Market Gap Facing The U.S. Semiconductor Industry;" Luke Sophinos, "To Close The Skills Gap, We All Need To Empower Vocational

Educators," *Forbes*, March 2, 2022, https://www.forbes.com/sites/forbestechcouncil/2022/03/02/to-close-the-skills-gap-we-all-need-to-empower-vocational-educators/?sh=273cf97d9977.
[43] University of Texas at Austin Public Affairs, "UT, Acc, Texas Institute for Electronics to Launch Semiconductor Training Center to Meet Industry Workforce Needs," *US Fed News Service, Including US State News*, March 28, 2024, https://www.proquest.com/docview/3015074197/citation/23BD2CF3891C4C34PQ/1.
[44] U.S. National Science Foundation, "Dear Colleague Letter: Request for Information on Future Topics for Workforce Development in Emerging Technology Career Pathways (NSF23-100)" National Science Foundation, May 8, 2023, https://www.nsf.gov/pubs/2023/nsf23100/nsf23100.jsp.
[45] Raj Varadarajan et al., "Emerging Resilience in The Semiconductor Supply Chain."
[46] Greg Wright, Dany Bahar, and Ian Seyal, "Smarter immigration policies could help alleviate the semiconductor shortage," Brookings Institution, June 17, 2022, https://www.brookings.edu/articles/smarter-immigration-policies-could-help-alleviate-the-semiconductor-shortage/

[47] Michael E. Porter, "Clusters and the New Economics of Competition," *Harvard Business Review*, November 1, 1998, https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition;
Cameron Davis et al., "A Playbook for Innovation Hubs and Ecosystems," McKinsey and Company, February 28, 2023, https://www.mckinsey.com/industries/public-sector/our-insights/building-innovation-ecosystems-accelerating-tech-hub-growth; Sujai Shivakumar, Charles Wessner, and Thomas Howell, "The Role of Industrial Clusters in Reshoring Semiconductor Manufacturing," CSIS, October 10, 2023, https://www.csis.org/analysis/role-industrial-clusters-reshoring-semiconductor-manufacturing.
[48] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.
[49] Ibid.
[50] Ibid.
[51] Sujai Shivakumar, Charles Wessner, and Thomas Howell, "The Role of Industrial Clusters in Reshoring Semiconductor Manufacturing."
[52] Laha, Michael. "PRC Pursues Chip Design Software Dominance." *China Brief* 24, no. 6 (MARCH 15, 2024): 22-27, https://jamestown.org/program/prc-pursues-eda-software-dominance/.
[53] Shivakumar, Wessner, and Howell, "Balancing the Ledger: Export Controls on U.S. Chip Technology to China."
[54] Paul Triolo, "A New Era for the Chinese Semiconductor Industry: Beijing Responds to Export Controls," *American Affairs Journal* (blog), February 20, 2024, https://americanaffairsjournal.org/2024/02/a-new-era-for-the-chinese-semiconductor-industry-beijing-responds-to-export-controls/.
[55] Bhattacharjee, Yudhijit, "The Daring Ruse that Exposed China's Campaign to Steal American Secrets," New York Times, March 7, 2023, https://www.proquest.com/blogs-podcasts-websites/daring-ruse-that-exposed-china-s-campaign-steal/docview/2783574396/se-2?accountid=12686
[56]Liu, Qianer and Cheng Leng. "China's Economic Malaise Hits Efforts to Raise $41bn Chip Fund," Financial Times, September 26, 2023, https://www.ft.com/content/521c8ac3-1933-4077-88b9-e9086a0196ca.
[57] Mercedes Ruehl, "Malaysia: The Surprise Winner from US-China Chip Wars," Financial Times, March 11, 2024, https://www.ft.com/content/4e0017e8-fb48-4d48-8410-968e3de687bf.
[58] Miles Evers, "Why the United States is Losing the Tech War With China," The Lawfare Institute and Brookings Institution, January 14, 2024, https://www.lawfaremedia.org/article/why-the-united-states-is-losing-the-tech-war-with-china.
[59] Gregory Allen, Emily Benson, and William Alan Reinsch, "Improved Export Controls Enforcement Technology Needed for U.S. National Security," CSIS, November 30, 2022, https://www.csis.org/analysis/improved-export-controls-enforcement-technology-needed-us-national-security#:~:text=For%20BIS%2C%20the%20scale%20and,new%20legislative%20and%20executive%20requirements.
[60] Thibault Denamiel et al., "Beyond Economics: How U.S. Policies Can Undermine National Security Goals."
[61] Semiconductor Industry Association, 2023 Factbook, May 2023, https://www.semiconductors.org/wp-content/uploads/2023/05/SIA-2023-Factbook_1.pdf
[62] Helen You, "Semiconductors and the U.S.-China Innovation Race," Foreign Policy, February 16, 2021, https://foreignpolicy.com/2021/02/16/semiconductors-us-china-taiwan-technology-innovation-competition/.
[63] Reuters, "Lam Research Wars of Up to $2.5 Billion Revenue Hit from US Curbs on China Exports," October 19, 2022, https://www.reuters.com/technology/lam-research-warns-up-25-bln-revenue-hit-us-curbs-china-exports-2022-10-19/.
[64] Victor Cha, "Examining China's Coercive Economic Tactics," CSIS, May 10, 2023, https://www.csis.org/analysis/examining-chinas-coercive-economic-tactics.

[65] Matthew Reynolds (Congressional Testimony), “Standing United Against the People’s Republic of China’s Economic Aggression and Predatory Practices,” (Washington D.C.: CSIS, May 18, 2023), https://www.csis.org/analysis/standing-united-against-peoples-republic-chinas-economic-aggression-and-predatory.
[66] Gregory Allen, “China's New Strategy for Waging the Microchip Tech War,” CSIS, May 3, 2023, *https://www.csis.org/analysis/chinas-new-strategy-waging-microchip-tech-war#:~:text=China%20has%20become%20an%20important,the%20Covid%2D19%20lockdown%20years*
[67] Zeyi Yang, “China just fount back in the semiconductor exports war. Here’s what you need to know,” MIT Technology Review, July 10, 2023, https://www.technologyreview.com/2023/07/10/1076025/china-export-control-semiconductor-material/.

[68] Carter Atlamazoglou, et al., “China’s Export Controls on Critical Minerals – Gallium, Germanium and Graphite,” FTI Consulting, December 19, 2023, https://www.fticonsulting.com/-/media/files/insights/articles/2023/dec/chinas-export-controls-critical-minerals-gallium-germanium-graphite.pdf

[69] FasterCapital, “Government: The Catalytic Force in the Porter Diamond Model,” *FasterCapital*, April 11, 2024, https://fastercapital.com/content/Government--The-Catalytic-Force-in-the-Porter-Diamond-Model.html.
[70] Ibid.
[71] Department of Commerce, “US Department of Commerce Strategic Plan 2022-2026," Department of Commerce, March 28, 2023, https://www.commerce.gov/sites/default/files/2022-03/DOC-Strategic-Plan-2022%E2%80%932026.pdf.
[72] Semiconductor Industry Association, “American Semiconductor Research: Leadership Thorugh Innovation” (SIA, 2022), 8, https://www.semiconductors.org/wp-content/uploads/2022/11/American-Semiconductor-Research-Report-FINAL1.pdf.
[73] Corey Richard, *Understanding Semiconductors - A Technical Guide for Non-Technical People*, Maker Innovation Series (Apress, 2023), 175–85.
[74] Akhilesh Ganti, “Investopedia - Venture Capitalists Definition: Who Are They and What Do They Do?,” accessed May 6, 2024, https://www.investopedia.com/terms/v/venturecapitalist.asp.
[75] SRC REPORT WITH GRAPHIC IN IT
[76] Semiconductor Industry Association, “American Semiconductor Research: Leadership Through Innovation,” 8.
[77] Semiconductor Industry Association, 8.
[78] Semiconductor Industry Association, 25.
[79] Michael E. Porter, “The Competitive Advantage of Nations, International Business,” Harvard Business Review, March-April 1990, https://hbr.org/1990/03/the-competitive-advantage-of-nations, accessed April 30, 2024
[80] Ibid.
[81] Ibid.
[82] Martin and Rosso, “Chipping Away - Assessing and Addressing the Labor Market Gap Facing The U.S. Semiconductor Industry,” 13.
[83] UT Austin Public Affairs, “UT, ACC, Texas Institute for Electronics to Launch Semiconductor Training Center to Meet Industry Workforce Needs,” University of Texas at Austin, March 28, 2024, https://news.utexas.edu/2024/03/28/ut-acc-texas-institute-for-electronics-to-launch-semiconductor-training-center-to-meet-industry-workforce-needs/.
[84] Faster Capital, "Factor Conditions: Unveiling the Key Elements of the Porter Diamond Model," Faster Capital, Updated April 3, 2024, https://fastercapital.com/content/Factor-Conditions--Unveiling-the-Key-Elements-of-the-Porter-Diamond-Model.html.
[85] Semiconductor Industry Association, “State of the U.S. Semiconductor Industry 2023,” SIA, July, 27, 2023, https://www.semiconductors.org/wp-content/uploads/2023/07/SIA_State-of-Industry-Report_2023_Final_072723.pdf.
[86] Non-attributable source, “Investing in the Future.” March 15, 2024.
[87] Semiconductor Industry Association, “State of the U.S. Semiconductor Industry 2023”,
[88] Helen You, “Semiconductors and the U.S.-China Innovation Race,” Foreign Policy, February 16, 2021, https://foreignpolicy.com/2021/02/16/semiconductors-us-china-taiwan-technology-innovation-competition/.
[89] Brett Bonthron, “Softwarisation for Semiconductors,” Capgemini, 2021, accessed May 3, 2024: . https://www.capgemini.com/wp-content/uploads/2024/03/Softwarization-for-Semiconductors_Capgemini-POV_new.pdf.
[90] Ginger Woolridge, ”Unpacking the Semiconductor Shortage and Its Impact on Telecom,” Lightyear, December 2, 2021, https://lightyear.ai/blogs/unpacking-the-semiconductor-shortage-and-its-impact-on-telecom.

91 Alejandro Pinero and Joel Brand, "Semiconductor Innovation: The Impact on Telecommunication," Fierce Network, February 12, 2024, https://www.fierce-network.com/sponsored/semiconductor-innovation-impact-telecommunication.
92 Muirae Kenney, "What's Changing in U.S. Electronics Manufacturing (And Why it Matters)," MacroFab Blog, April 13, 2023, https://www.macrofab.com/blog/changes-us-electronics-manufacturing/.
93 Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.
94 Ibid.
95 Ibid.
96 Ibid.
97 David Hudock, "It Ain't Easy Being Green; But the U.S. Chip Manufacturing Industry Would be Well Served to Figure Out How to Get That way," Eisenhower College, NDU, April 24, 2024.
98 Katy Barlett, et al, "Semiconductor fabs: Construction challenges in the United States," McKinsey & Company, January 27, 2023, https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/semiconductor-fabs-construction-challenges-in-the-united-states#/; NXP, "Corporate Sustainability Report," NXP, 2023, https://www.nxp.com/docs/en/supporting-information/Corporate-Sustainability-Report-2023.pdf; Intel Corp, "Intel is Leading the Industry in Sustainable Semiconductor Manufacturing," Intel, July 2023, https://www.intel.com/content/dam/www/central-libraries/us/en/documents/2023-07/sustainable-semiconductor-manufacturing.pdf; Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.
99 Owais Ali, "Resource Consumption in the Semiconductor Industry," Azo Nano, December 15, 2023, https://www.azonano.com/article.aspx?ArticleID=6658.
100 John VerWay, "No Permits, No Fabs: The Importance of Regulatory Reform for Semiconductor Manufacturing," Center for Security and Emerging Technology (CSET), October 2021, https://cset.georgetown.edu/publication/no-permits-no-fabs/.
101 Ali, "Resource Consumption in the Semiconductor Industry."
102 Ibid.
103 Ducan Stewart, et al., "Semiconductor Sustainability: Chips Take a Smaller Byte out of Resources," Deloitte Insights, November 29, 2023 https://www2.deloitte.com/uk/en/insights/industry/technology/technology-media-and-telecom-predictions/2024/semiconductor-sustainability-forecast.html.
104 VerWay, "No Permits, No Fabs: The Importance of Regulatory Reform for Semiconductor Manufacturing."
105 Ducan Stewart, et al., "Semiconductor Sustainability: Chips Take a Smaller Byte out of Resources."
106 Ibid.
107 Pádraig Belton, "The Computer Chip Industry Has a Dirty Climate Secret," The Guardian, September 18, 2021, sec. Environment, https://www.theguardian.com/environment/2021/sep/18/semiconductor-silicon-chips-carbon-footprint-climate.
108 VerWay, "No Permits, No Fabs: The Importance of Regulatory Reform for Semiconductor Manufacturing."
109 Economic Development Administration, "Regional Technology and Innovation Hubs (Tech Hubs)," 2024, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs#:~:text=The%20Tech%20Hubs%20Program%20aims,good%20jobs%20they%20create%2C%20to.
110 Ibid.
111 Economic Development Administration, "Fact Sheet Phase 1 Portfolio" (Washington D.C.: Department of Commerce, October 25, 2023), 2, https://www.eda.gov/sites/default/files/2023-10/EDA_TECH_HUBS_Phase_1_Fact_Sheet.pdf.
112 Jay Bao, "Securing America's Semiconductor Future – The Vital Role of EDA Tech Hubs," 16, Eisenhower College, NDU, April 24, 2024.
113 Department of Commerce, "NY SMART I-Corridor Tech Hub," October 2023, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Corvallis-Microfluidics-Tech-Hub.
114 Department of Commerce, "Tech Hubs Consortia Members List" (Washington D.C.: US Economic Development Administration), 33–35, accessed April 20, 2024, https://www.eda.gov/sites/default/files/2023-12/Tech_Hubs_Consortia_Members.pdf.
115 Chuck Schumer, "AFTER SECURING BUFFALO-ROCHESTER-SYRACUSE TECH HUB DESIGNATION, SCHUMER LAUNCHES MAJOR PUSH FOR UPSTATE NY TO BE ONE OF NATION'S FIRST TECH HUB IMPLEMENTATION AWARDEES, DELIVERING $50+ MILLION FROM HIS CHIPS & SCIENCE LAW TO SUPERCHARGE TECH WORKFORCE TRAINING, GROW NEW COMPANIES, AND STRENGTHEN THE SEMICONDUCTOR SUPPLY CHAIN," March 4, 2024, https://www.schumer.senate.gov/newsroom/press-

releases/after-securing-buffalo-rochester-syracuse-tech-hub-designation-schumer-launches-major-push-for-upstate-ny-to-be-one-of-nations-first-tech-hub-implementation-awardees-delivering-50-million-from-his-chips-and-science-law-to-supercharge-tech-workforce-training-grow-new-companies-and-strengthen-the-semiconductor-supply-chain.

[116] Department of Commerce, "Corvallis Microfluidics Tech Hub," October 2023, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Corvallis-Microfluidics-Tech-Hub.

[117] Department of Commerce, "Tech Hubs Consortia Members List," 9–10.

[118] OSU - College of Engineering, "Advancing American Competitiveness: CorMic's Pursuit of Tech Hub Funding," *Oregon State University*, February 29, 2024, https://engineering.oregonstate.edu/all-stories/advancing-american-competitiveness-cormics-pursuit-tech-hub-funding.

[119] Department of Commerce, "Texoma Semiconductor Tech Hub," October 2023, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Texoma-Semiconductor-Tech-Hub.

[120] SMU, "SMU to Lead Texoma Tech Hub to Unify Semiconductor Supply Chain, Spur Innovation through Regional Collaborations and Workforce Development," SMU News, October 23, 2023, https://www.smu.edu/news/research/smu-to-lead-texoma-tech-hub-to-unify-semiconductor-supply-chain.

[121] Department of Commerce, "Tech Hubs Consortia Members List," 45–46.

[122] SMU Office of the Provost, "Weekly Update (March 8, 2024)," March 8, 2024, https://www.smu.edu/-/media/Site/Provost/provost-office/Communications/weekly-newsletters/2024/weekly-update-march8-2024.pdf.

[123] Department of Commerce, "Vermont Gallium Nitride Tech Hub," October 2023, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Vermont-Gallium-Nitride-Tech-Hub.

[124] University of Vermont, "The University of Vermont - Facts," 2024, https://www.uvm.edu/uvm_facts.

[125] Department of Commerce, "Tech Hubs Consortia Members List," 3.

[126] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.

[127] Department of Commerce, "Tech Hubs Program Phase 2," February 29, 2024, https://www.eda.gov/funding/funding-opportunities/tech-hubs-program-phase-2.

[128] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.

[129] Dev Shenoy, "DoD Microelectronics Commons," Department of Defense, February 8, 2023. https://www.nationalacademies.org/documents/embed/link/LF2255DA3DD1C41C0A42D3BEF0989ACAECE3053A6A9B/file/D828FFB06B35C789F1D20EB929FC8B6B710E365908C2?noSaveAs=1Sums.

[130] NSTXL - Various Presenters, "Microelectronics Commons Annual Meeting 2023" (Microelectronics Commons Annual Meeting 2023, Washington D.C., October 17, 2023), https://nstxlgcc.sharepoint.com/sites/Solicitation/Shared%20Documents/Forms/AllItems.aspx?id=%2Fsites%2FSolicitation%2FShared%20Documents%2FS%C2%B2MARTS%2FMicroelectronics%20Commons%20Annual%20Meeting%202023&p=true&ga=1

[131] Semiconductor Industry Association, SIA Whitepaper: Taking Stock of China's Semiconductor Industry, July 2021, https://www.semiconductors.org/wp-content/uploads/2021/07/Taking-Stock-of-China%E2%80%99s-Semiconductor-Industry_final.pdf

[132] Gabrielle Athanasia and Gregory Arcuri, Russia's Invasion of Ukraine Impacts Gas Markets Critical to Chip Production, CSIS, March 14, 2022, accessed April 30, 2024, Russia's Invasion of Ukraine Impacts Gas Markets Critical to Chip Production | Perspectives on Innovation | CSIS

[133] Chris Miller, The Impact of Semiconductor Sanctions on Russia, American Enterprise Institute, 1, April 2024, accessed April 30, 2024, The-Impact-of-Semiconductor-Sanctions-on-Russia.pdf (aei.org)

[134] Chris Miller, The Impact of Semiconductor Sanctions on Russia, American Enterprise Institute, 8, April 2024, accessed April 30, 2024, The-Impact-of-Semiconductor-Sanctions-on-Russia.pdf (aei.org)

[135] OEC, Semiconductor Devices in the United States, accessed May 2, 2024, Semiconductor Devices in United States | The Observatory of Economic Complexity (oec.world)

[136] OEC, Semiconductor Devices in the United States, accessed May 2, 2024, Semiconductor Devices in China | The Observatory of Economic Complexity (oec.world)

[137] Chris Miller, The Impact of Semiconductor Sanctions on Russia, American Enterprise Institute, 4, April 2024, accessed April 30, 2024, The-Impact-of-Semiconductor-Sanctions-on-Russia.pdf (aei.org)

[138] The White House, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth," The White House, June 2021, https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

[139] Association of Southeast Asian Nations, "Investing in ASEAN 2023," ASEAN, November 22, 2022, https://asean.org/wp-content/uploads/2022/12/investment-report-2023.pdf.
[140] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.
[141] Association of Southeast Asian Nations, "ASEAN-China Joint Statement on Strengthening Common and Sustainable Development," ASEAN, November 11, 2022, https://asean.org/wp-content/uploads/2022/11/FINAL-ASEAN-China-Joint-Statement-on-Strengthening-Common-and-Sustainable-Development.pdf
[142] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.
[143] Industry Leaders, Eisenhower School Microelectronics Seminar Field Study Meetings, April 2024.
[144] Dashveenjit Kaur, "Intel is building its largest 3D chip packaging facility in Malaysia," Techwire Asia, August, 24, 2023, https://techwireasia.com/08/2023/why-is-intel-building-largest-3d-chip-packaging-facility-in-malaysia/
[145] Visual Capitalist, "What Southeast Asians Think About Rising Chinese and U.S. Influence," Visual Capitalist, May 1, 2024, https://posts.voronoiapp.com/geopolitics/What-Southeast-Asians-Think-About-Rising-Chinese-and-US-Influence-1158.