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De-risking semiconductor supply chains

BY ROB YORK AND AKHIL RAMESH

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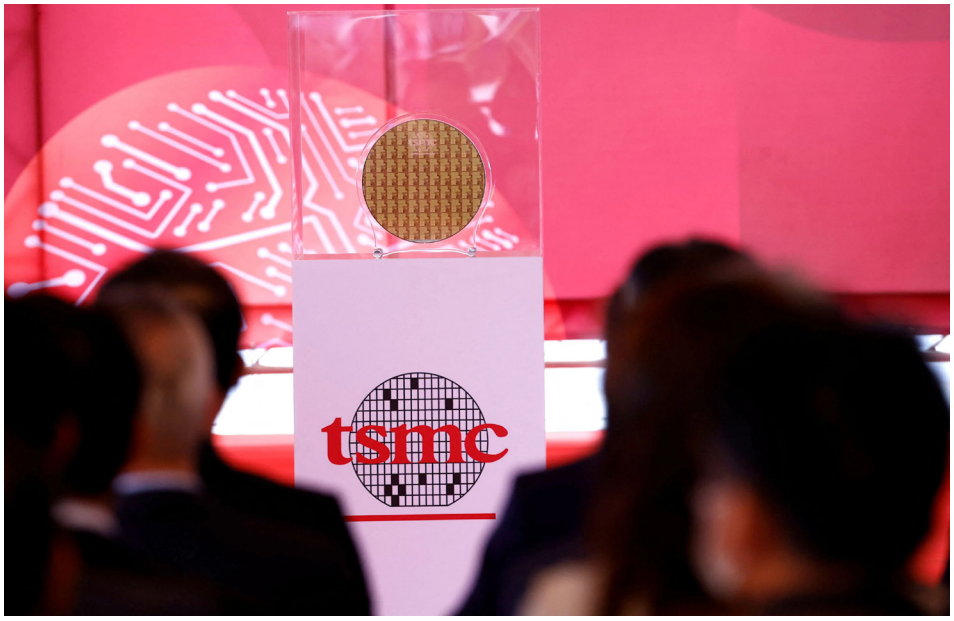
Executive summary

In semiconductors, unlike in other critical supply chains, the US and its partners currently have the edge in innovation and, increasingly, production, over China. The global semiconductor supply chain, however, has unique vulnerabilities given that the world's largest pure-play foundry is in Taiwan, a key flashpoint in global geopolitics. Beijing has successfully used industrial policy to shore up its global dominance in critical minerals, electric vehicle batteries, and other critical technologies. To achieve greater supply chain security, certain countries such as Japan, Malaysia, and Korea, can prevent potential chokepoints, but semiconductor supremacy will largely be determined based on whether the US achieves self-sufficiency in fabrication and can friend-shore both raw materials and assembly, test and packaging, or whether China achieves breakthroughs in design technology.



The global semiconductor supply chain has unique vulnerabilities given that the world's largest pure-play foundry is in Taiwan, a key flashpoint in global geopolitics.

Introduction

Unlike in other critical supply chains, the US and its partners currently have the edge in innovation and, increasingly, production of semiconductors.

Semiconductors, also known as "integrated circuits" or "microchips", are usually made from wafers of silicon. They conduct electricity less well than purer conductors such as copper or aluminum, and their conductivity and other properties can be modified to meet the specific needs of technological applications. Semiconductors have become ubiquitous. Those circuits are at the heart of 21st century geopolitical and geo-economic contest – and increasingly a standoff that policymakers and industry cannot avoid. Nations at the forefront of critical innovation in spheres such as artificial intelligence, the internet of things and advanced computing in general are taking measures to secure the supply chain.

No other sector matters to the interconnected globalized world of the 21st century as semiconductors. The US, Japan, Korea, China and select European nations all play vital roles in the widely dispersed value chain of semiconductor manufacturing. Nonetheless, emerging markets such as Vietnam, Malaysia, India, and Mexico are increasingly entering the value chain, though at its lower end.

Interestingly, unlike pharmaceuticals, critical minerals, or batteries – supply chains covered earlier in this series – semiconductors are a sector where the US and allies enjoy a significant edge in innovation and production over China.[1] Nonetheless, the US and its allies have engaged in techno-nationalism through targeted industrial policies and trade protectionist measures. In the case of semiconductors, the US is not catching up but working to maintain its edge over China and limiting China's advances in its control of critical technologies. Unlike the other three industries, there aren't one or two nations to friend-shore the entire supply chain. The value chain is widely dispersed across the Indo-Pacific and parts of Europe. Nonetheless, different partner nations can step in to play the role of a friendly shore.

There are three broad myths to be debunked before we analyze the friend-shoring prospects for semiconductor supply chains.

One, the semiconductor supply chain is concentrated in one part of the world. While East Asia plays a vital role in the overall value chain, its role is limited to one or two segments of the value chain. The overall semiconductor value chain is widely spread across the Indo-Pacific and parts of Europe.

Two, the recent calls for diversification of supply chains are a result of global shortages arising from Covid disruptions, man-made and natural disasters, plus lockdowns in China. While the black swan event of Covid and the resulting global disruptions and lockdowns in China have impacted the value chain, these are not the only forces behind the urgency to diversify supply chains. Chip shortages are not a new phenomenon in the industry but are cyclical in nature. The semiconductor industry has faced shortages caused by natural disasters, variations in supply of raw materials, and other geographic and political events. However, these shortages have been short-lived; usually less than six months in length. The scale of such disruptions during the pandemic was a deviation from the norm. Most fabs operate at 80% utilization and modify this number based

on fluctuations in demand.[2] As a Standard & Poor's recent report on disruptions in semiconductor supply chains noted, events across the world such as a fire in a fabrication plant in one location, staffing shortages at a shipping facility elsewhere, an ice storm, and a ship getting stuck in Suez Canal, all impacted the chip supply chains.[3]

Auto manufacturers drastically cut their chip orders in early 2020 in anticipation of a major downturn in sales. However, as a result of Covid lockdowns and work-from-home settings, demand for equipment such as laptops and routers that enable video conferencing, e-learning, and recreational products (such as PlayStations and VR headsets) shot up. The increase in demand for consumer electronics led semiconductor production lines to pivot from producing lower-end chips for automobiles to producing more higher-end chips for consumer electronics. A year later, with the easing of lockdowns in major auto markets, demand rose, and automakers found that foundries were already filled with orders from other sectors and much of the inventory had been sold into consumer electronics. While fabs increased utilization levels to up to 95%, the shortage persisted for the auto industry.

Three, across liberal democracies, there has been a broad discussion about the need to diversify the supply chain due to geopolitical concerns rather than protectionism. Many security experts, politicians, and officials in the Indo-Pacific are wary of a so-called "Taiwan contingency" in the next five years,[4] in which China mounts an invasion to retake the "renegade province" of Taiwan.[5] Other voices disagree with this assessment, of course, and this paper takes no stance on that possibility.[6] However, the possibility of severe damage to semiconductor manufacturing facilities cannot be discounted as a scenario in extremis.[7]

As our previous papers on friend-shoring pharmaceuticals, critical minerals, and batteries highlighted, China's deployment of industrial policies has borne fruit in creating indigenous industries leading in all three sectors. If Beijing were to emulate such success in semiconductors, it would not be just another strategic sector where Chinese companies lead, but one with consequences beyond profits or shareholder value for Western companies. The sector has far-reaching implications for national security.

If China were to gain dominance in the sector as it has with other advanced technologies, some security experts fear that it will have the world's most advanced military capabilities, strengthening conventional warfare capabilities and, as a direct result, setting the rules of the road in the industry.

Mapping semiconductor supply chains

Semiconductor supply chains have three major segments.

As figure 1 illustrates, the supply chain is widely dispersed, with companies across the Indo-Pacific and Europe dominating various segments and sub-segments of the supply chain.

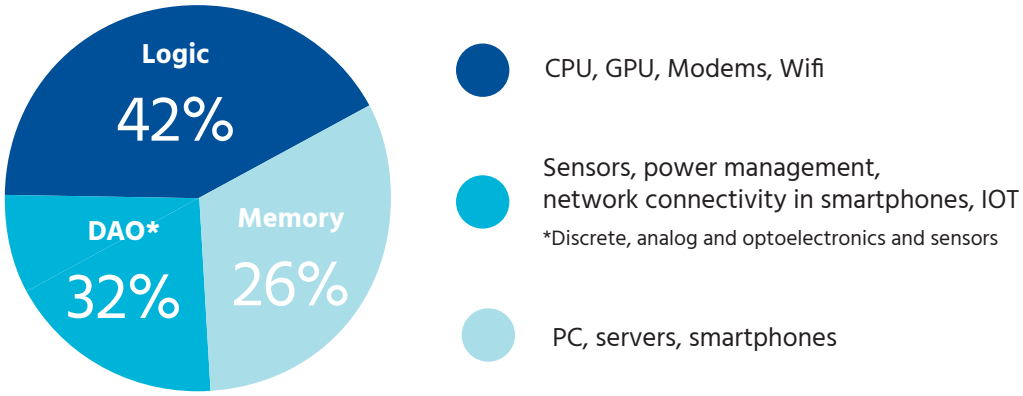
Demand for chips varies by sector and the types of semiconductors going into these different appliances are not identical. However, all major segments of the chip value chain find themselves caught in the trade tussle between the US and China.

Figure 1 – Semiconductor supply chain

Source: Author's compilation

* Assembly, testing, and packaging

Figure 1.1 – Types of chips

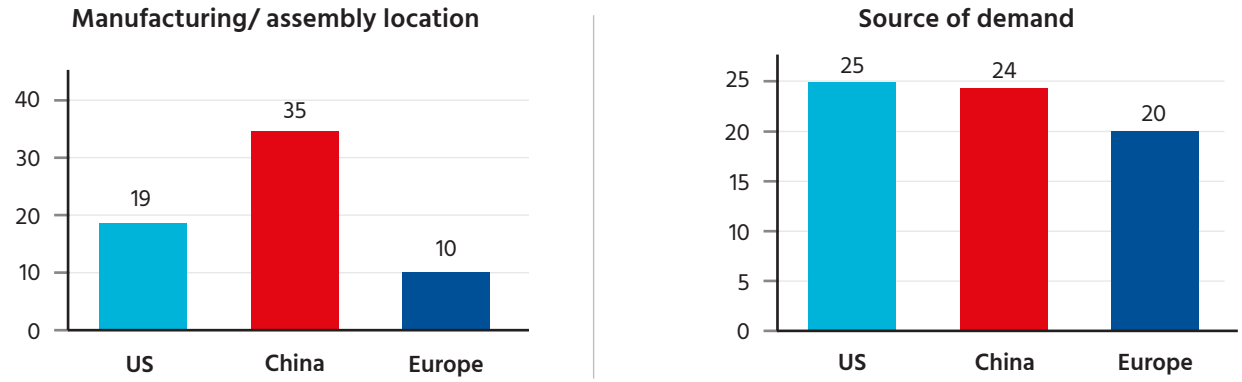


Source: Semiconductor Industry Association and Boston Consulting Group

Demand

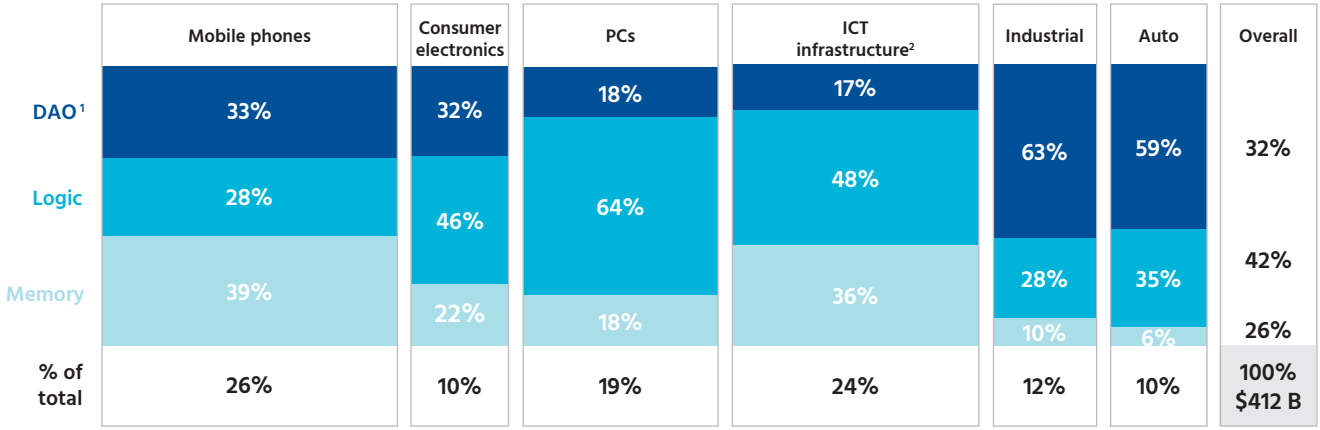
The US and China are neck-and-neck as the largest sources of demand at both current and projected levels (see figure 2). Washington's slew of export control measures and Beijing's indigenization efforts affect companies with large market shares in both geographies. As of 2021, mobile phones and information

Figure 2 – Global semiconductor sales by geographic area, 2019 (%)



Source: Semiconductor Industry Association and Boston Consulting Group

Figure 3 – End use demand of semiconductors (sectors)



1. Discrete, analog and optoelectronics and sensors
2. Informations and communications technology infrastructure, including data centers and communicarion networks

Source: Boston Consulting Group and Semiconductor Industry Association

The US and China are tied as the largest sources of semiconductor demand at both current and projected levels.

and communication technology (ICT) sectors have the largest demand for semiconductors (see figure 3). Furthermore, as end-users in China such as automobile makers, digital infrastructure, and other advanced technologies grow exponentially, the US' targeted containment of these companies is aimed at choking off their supply of chips. A case in point is China's Huawei Technologies.

Shenzhen-headquartered Huawei is among the conglomerates most impacted by the US-China trade war. As a leading conglomerate in the ICT sector, it is one of the largest consumers of semiconductors. The company is among the world's largest spenders on research and development including on artificial intelligence (AI) and advanced computing. This puts American and Western semiconductor companies who want to engage the Chinese market in a precarious position. It also pushes Huawei and other Chinese companies toward accelerating indigenization initiatives.

China has engaged in countermeasures to US chip curbs by implementing export restriction policies on raw materials (the segment of the value chain where it holds a comparative advantage over its competition – see figure 4) required for chip production.

Huawei is among the world's largest spenders on R&D including on AI and advanced computing. This puts foreign chip companies who want to engage the Chinese market in a precarious position.

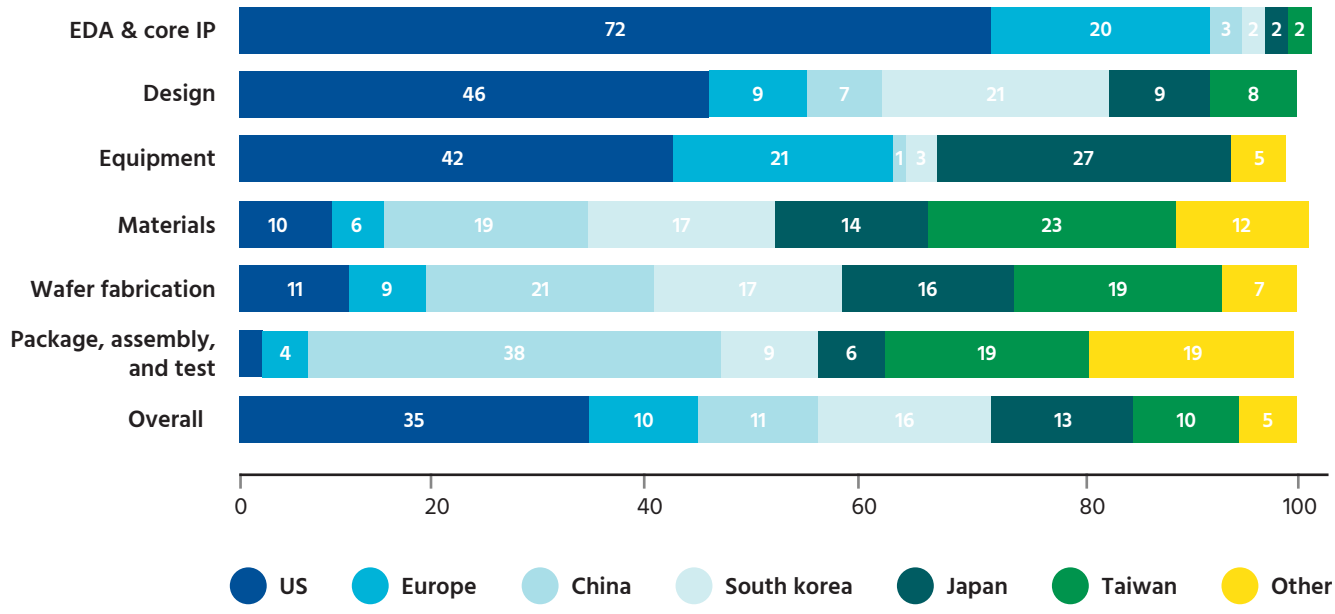
Supply

Design and fabrication

The design segment adds the most value to the entire supply chain. The top 10 companies in this sector are American. Of note, three US-based firms make up over 70% of the electronic design automation (EDA) market.[8] This segment is highly geographically concentrated in the US and to solidify its position, the US government has targeted export controls on design software. In 2021, the US Department of Commerce included EDA software in a set of export controls to restrict China from accessing this software.[9] China's EDA tools account for just over 2% of the global market.[10]

US export control measures appear to have so far limited the progress made by Chinese EDA firms. Companies such as China's especially competitive Empyrean have leveraged their subsidies to offer below-market prices and lure talent from companies in producers such as South Korea.[11] US export control measures may have a counterproductive effect with Chinese companies working toward indigenization with an unprecedented urgency. While Chinese companies such as Primarius, X-Epic, Semitronix, and others remain in nascent stages of developing indigenous capacity, Huawei says it has built over 78 design tools to catch up with American software.

Figure 4 – Comparative advantages of the US and partners in semiconductor supply chains vs. China



Source: National Semiconductor Economic Roadmap by Arizona Commerce Authority and Boston Consulting Group

The design segment adds the most value to the entire supply chain and the top 10 companies in this sector are American.

On the other end of the value chain, some fabrication facilities have been re-shored to American states such as Arizona and Texas and friend-shored to Japan and Germany. Intel is setting up fabrication units in Japan and Germany to increase geographical diversification. In the fabrication segment, Taiwan and China together account for more than 40% of market share.[12]

Semiconductor manufacturing equipment (SME) is another chokepoint in the supply chain for China. The US, Netherlands and Japan lead the way in SMEs and the US under Biden has imposed export licensing requirements for SME exports to China, curtailing China's advances in semiconductor manufacturing. Furthermore, the administration has convinced the Netherlands and Japan to follow suit. While the Netherlands Standing Committee on Foreign Trade and Development Cooperation issued restrictions on companies such as ASML to export photolithography scanners to China,[13] Tokyo has gone a step further and imposed the most stringent export restrictions on SMEs to China, restricting 23 types of semiconductor technologies, including advanced microchip manufacturing equipment.

Core intellectual property

Companies in the US and UK control about 90% of the market. Intel, Cadence, and ARM are leaders in core intellectual property (IP). These companies are vital nodes in the value chain.

For example, ARM, originally a UK-based company, was bought by Masayoshi Son's Softbank Group in 2016. Notably, this joint venture provides 27% of global licensing revenues for the parent company. ARM's software is omnipresent in the technological world with 95% of smartphones, 63% of Internet of Things (IoT) devices and 24% of cars using it.[14]

In a similar turn of events, in 2017, a Chinese state-owned fund acquired UK-based Imagination Technologies, which develops core IP for mobile phone GPUs.[15] While China could increase government subsidies to boost fabrication units and assembly, testing, and packing (ATP) sites as well as tighten its hold over raw materials, design, and core IP will remain a major chokepoint for China.

Raw materials and ATP

China has the largest share of most raw materials required for semiconductor manufacturing. The US produces no arsenic, carbon, fluorine, gallium, tellurium, or tungsten. Of note, China has around 95% of the world's primary low-grade gallium, 83% of the global production share for tungsten, and 82% for magnesium.[16] As China's recent export controls such as licensing requirements for the export of gallium and germanium demonstrate, the US and its partners face formidable counter-chokepoints and need supply chain diversification. In the case of germanium and gallium, it was largely Japan's and the Netherlands' SME makers that were directly impacted.[17]

Fabrication and ATP

China and Taiwan dominance

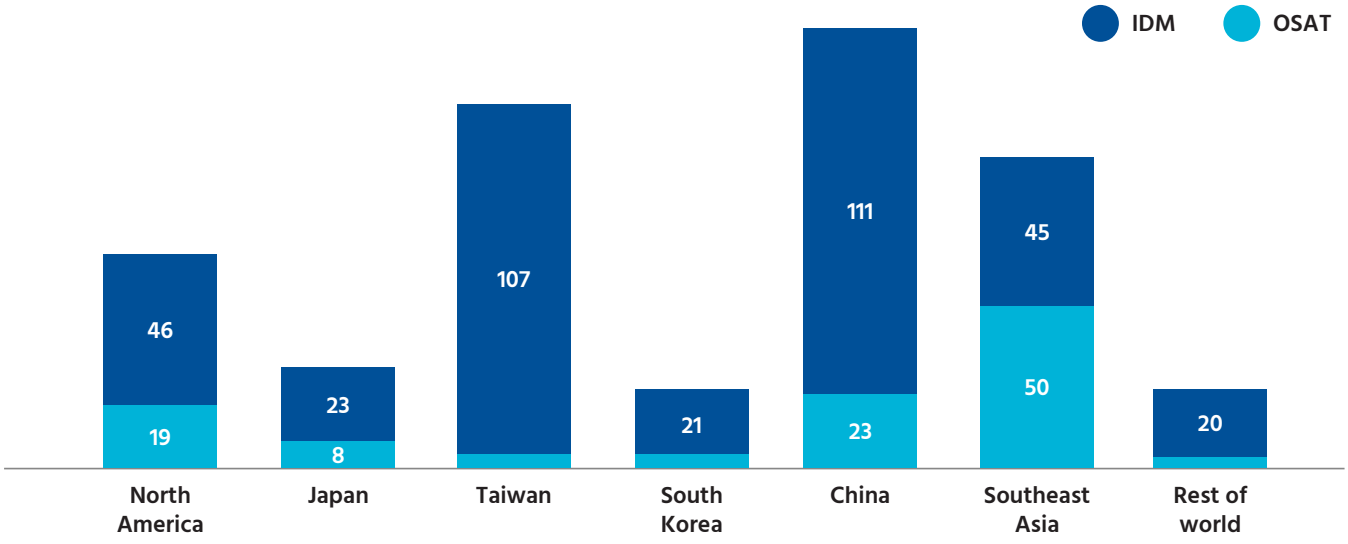
China and Taiwan together account for more than half of the world's fabrication facilities (see figure 6) by location. While these segments are relatively lower in value-add compared to design, they are concentrated in China and Taiwan, making the segment the West's most vulnerable chokepoint.

Figure 5 – Wafer fabs by country

Wafer size (in)	United States	Japan	Taiwan	South Korea	China	Total
2	10	5	19	2	49	85
3	20	4	3	0	9	36
4	63	36	19	8	57	183
5	5	15	3	2	14	39
6	84	74	30	9	64	261
8 (200mm)	61	53	26	12	36	188
12 (300mm)	33	29	44	32	41	179
Total	276	216	144	65	270	971

Source: Center for Strategic and International Studies

Figure 6 – Number of ATP facilities



Source: Center for Strategic and International Studies

Diversification measures have focused on reviving American capacity in fabrication and increasing partnerships with emerging markets such as Malaysia, Vietnam, and India in ATP activities while strengthening South Korea's existing position in the segment.

Developing domestic semicondcutor capacity

CHIPS and Science Act

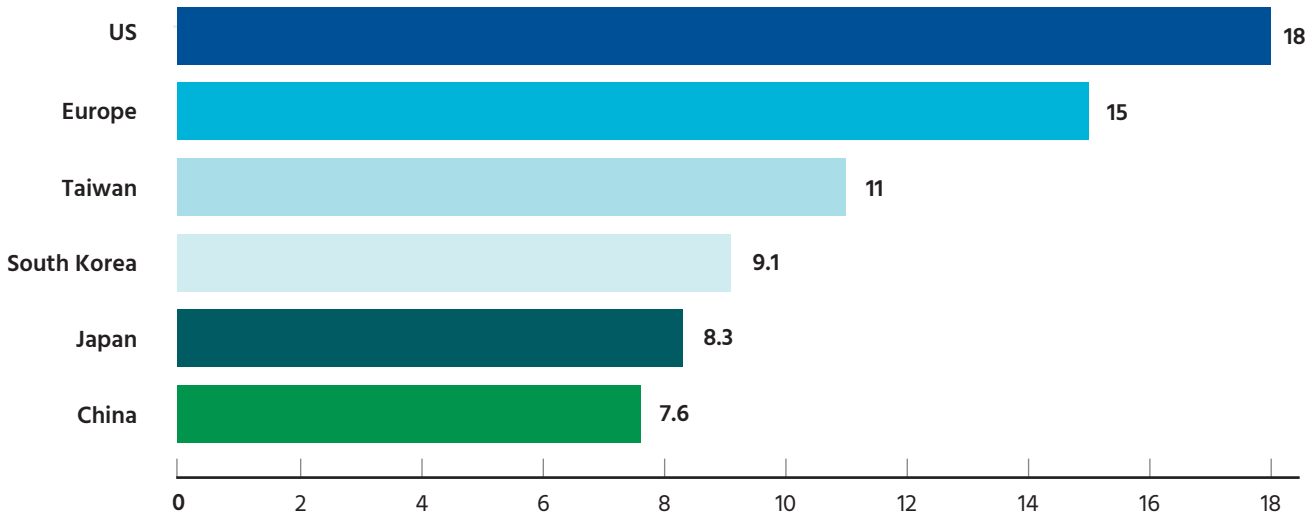
In 2022, the CHIPS and Science Act was enacted to spur investments in semiconductor manufacturing, increase investments in research and development (R&D), science and technology, and workforce development for industries designated as national security interest such as IoT, AI, and quantum computing.[18]

China's ecosystem

For China, advances in technology are about national pride as much as the success of its self-reliance. In 2020, China imported more than US$350 billion worth of semiconductors (more than crude oil). In 2021, China became the largest importer of semiconductors in the world. Unlike with crude oil, for which it has established partnerships with Middle Eastern nations and has not had challenges accessing crude, the US and its partners have repeatedly either worked toward limiting its advances in the field itself or restricted the exports of advanced semiconductors and machines required for production.

Chinese President Xi Jinping's 2025 target to reduce China's dependence on foreign technology and promote Chinese technological manufacturers in the global marketplace is directly tied to its success in the indigenization of high value-add segments of the semiconductor manufacturing process. Government handholding of semiconductor companies has proven a success in cases of Korea and Taiwan.

Figure 7 – R&D expenditure by country as a % of sales, 2021



Source: Semiconductor Industry Association

Tiger technology

Since the 1970s, the South Korean government has adopted an export-led indigenization model, which has elevated companies such as Samsung to become global leaders.

Semiconductors is one industry that has throughout its history thrived on the generous support of industrial policies. Nations with large market shares in the semiconductor value chain – both at the higher end of the value chain and the lower – have supported their private sector with subsidies. Starting in 2020, industrial policies in the US and its partner nations have been emphasized not only to revive manufacturing or catch up to their competition but also to prevent nations perceived as national security threats from gaining access to advanced chips. This is at odds with the export-led model of industrial policy in Taiwan and nations such as South Korea and Japan. For example, since the 1970s, the South Korean government has consistently adopted an export-led indigenization initiative. This has elevated companies such as Samsung and SK Hynix to become industry leaders in advanced chips.

In 2023, Washington's export controls and arm-twisting of tech corporations to fall in line with its strategic goals reflect fears that industrial policy in China could bear fruit as they had in Taiwan and Korea. Adding credence to this concern, all East Asian economies made their entry into the sector (eventually becoming leaders) via lower value-add segments in the value chain. China has a strong packaging ecosystem that presents a chokepoint for American supply chains.

In the US, states such as Arizona, Texas, Ohio, and New York seek to revive semiconductor fabrication and advanced testing and packaging on US shores.[19] GlobalFoundries, Intel, Samsung Foundry, TSMC, and Texas Instruments are all building new facilities in the US.[20] Arizona has been at the forefront of this manufacturing renaissance. Similar to the advantages many East Asian economies enjoy with vertical integration, based on Pacific Forum's conversations with local economic development and investment promotion agencies, it is evident that sectors such as solar panels, semiconductors (fabrication and ATP), batteries, and even autonomous vehicles manufacturing are riding a resurgence in the US thanks to federal subsidies such as the CHIPS Act and a business-friendly environment in the state.[21] Coupled with near-shoring opportunities in Mexico, policymakers hope that states such as Arizona and Texas would strengthen US national security. However, analysts remain skeptical of reshoring entire value chains that are not cost-competitive in the US.

In early 2023, South Korea's parliament approved the K-Chips Act, increasing tax benefits to 15% from the previous 8% for large companies and to 25% from the previous 16% for smaller and medium-sized enterprises to spur manufacturing and investments in the sector.

Ecosystem: Penang to Arizona

Intel and its founder Gordon Moore are touted as pioneers in the semiconductor industry. Moore's Law, named after the late founder, is used by analysts to study the innovation trajectory of the industry. Not only has Intel consistently introduced commercially viable semiconductors over the last five decades, but it has also set itself apart from its competition by developing ecosystems both in the US and in foreign countries such as Malaysia. Intel's customers include the US Department of Defense.[22]

However, Intel's industry lead slipped when Taiwan Semiconductor Manufacturing Company Limited (TSMC) championed the foundry model, which Intel initially eschewed.

Intel was the first company to create ecosystems surrounding semiconductor manufacturing, both domestically in the US and abroad in places such as Penang, Malaysia. Three years after its founding, Intel set up its first offshore facility in Malaysia. It supported ancillary industries, even setting up a special training facility within the Penang plant called Intel University to train professionals in design and technologies. Fast forward to 2023, it is replicating the project by expanding its footprint in the country. It is opening a new plant in Penang for its advanced 3D chip packaging unit and one in Kulim for testing and assembly in the Southeast Asian nation with plans of quadrupling its packaging services capacity, as part of Intel's planned US$7 billion expansion worldwide.[23]

As an extension, part of Intel CEO Pat Gelsinger's goals of reducing the share of semiconductors produced in Asia to 50 percent from the current 80 – while having the US produce 30 percent and Europe 20 – Intel is expanding in Arizona and Ohio while simultaneously expanding its footprint in Southeast Asia.[24]

Diversification, however, brings new challenges.

Challenges

A large chip fab needs close to 38 million liters of water a day, equivalent to the water consumption of roughly 300,000 households per day.

Diversifying and friend-shoring semiconductor supply chains has caused unease among partners and allies. These diversification measures have made commercial business decisions and national security extricable. As friend-shoring measures rise, nations with higher environmental standards have initiated discussions on the environmental impact of such moves. There are three major barriers to accelerating supply chain diversification measures.

Environment, societal, and governance Standards (ESG)

The semiconductor industry contributes to more than 30% of global greenhouse gas emissions annually. It is highly energy- and water-intensive. A reliable energy supply is vital for the manufacturing of semiconductors, which comes at the cost of the environment since most sources of energy used by facilities are not renewable. A large chip fab can use up to 10 million gallons (nearly 38 million liters) of water a day, equivalent to the water consumption of roughly 300,000 households a day.[25] High environmental standards and preexisting water scarcity in proposed locations exacerbate policy challenges. Big chip manufacturers such as Intel have therefore instituted strong water recycling programs.

The issue of per and polyfluoroalkyl (PFAS) chemicals, also known as the "forever chemicals", used as an additive in photoresists of semiconductors can develop into a larger industry challenge. The EU is considering regulations for the use of such substances. Japanese ink producer DIC has used fluorine as a substitute, but only in a prototype.

While most US companies have pulled out of China, partners and allies are not on the same page. The CHIP4 Alliance, while strong on paper, its results have not materialized yet.

In Arizona, TSMC has faced increased scrutiny over its water usage and its import of foreign labor. A big selling point for advocates of industrial policy was the increased use of local labor as a product of subsidies tied to union jobs. The Taiwanese behemoth has faced flak for bringing in talent from Taiwan for the fab under construction. While not all workers or unions are united on these concerns, select unions that represent construction workers have expressed concerns over foreign labor taking their role and the alleged lack of safety standards.

Sunk-cost trap

While Washington and chip companies advocating for subsidies have used national security as a rationale for reshoring and friend-shoring, neither have advocated for abandoning the Chinese market altogether. The world's largest importer of semiconductors is too important for the bottom line of semiconductor manufacturers to trade it for subsidies in developed markets such as the US.[26] While most US companies have pulled out of China, partners and allies are not on the same page. Both Taiwan and South Korea maintain their positions on the mainland and Korean companies such as SK Hynix have in fact acquired the assets of departing US firms, such as Intel's facilities in Northeast China.

Washington has made exceptions (see below) to its export controls for Taipei and Seoul to prevent a backlash against American industrial policies from escalating. South Korean companies such as Samsung and SK Hynix rely on US and Japanese companies for semiconductor manufacturing equipment (SME) and on the Chinese market for more than 40% of their sales.[27] This dependence on two adversarial nations for both the front end and back end, coupled with political pressures, make it extremely challenging for semiconductor companies to navigate the turbulent conditions in their largest and second-largest markets. If history is any benchmark, Chinese companies leverage the support of foreign companies before eventually pushing them out of the Chinese market through preferential subsidies.

For its part, Washington must crack down on its own industry, or else it will come off as not practicing what it preaches. In the case of SME, over the last few years, and particularly, months before export restrictions come into force, China has imported a substantial amount of SME. In recent years, SME sales to China have come to around 30 percent of all US sales, 29 percent of all Japanese sales and 20 percent of South Korea's sales.[28] It is currently the largest market for SME in the Indo-Pacific region. It purchased over US$28 billion worth of equipment in 2021. The "small yard, high fence" approach – wherein strategic assets are protected while the economic partnership remains, often cited by the US National Security Advisor Jake Sullivan as the administration's guiding principle, may come at a cost.[29] Moreover, as an extension of this practice, the Biden administration has played blow-hot, blow-cold bypassing export control measures on one day and watering it down by providing exceptions to partners on another. In early June 2023, the Biden administration announced that it will allow South Korean and Taiwanese companies to continue and expand their operations in China without any reprisals, such as being denied the opportunity to benefit under the CHIPS Act.[30] If Washington is going to set rules on investing in China and expect other countries to follow them, it must remain consistent.

South Korean companies rely on US and Japanese companies for semiconductor manufacturing equipment (SME) and on the Chinese market for more than 40% of their sales. This dependence on two adversarial nations is tricky challenging in geopolitically turbulent times.

Unhappy partners

Washington's unilateral export curbs did not sit well with Korea and Japan. While Washington has found success with political measures such as peacebuilding and reconciliation between historical rivals Japan and Korea on trade and economic linkages, the two have expressed concerns over Washington's mercantilist turn.[31] In the case of semiconductors, Seoul has been wary of Washington's protectionism given that China is Korea's largest market for exports. The CHIP4 Alliance is strong on paper with the US, Japan, Korea, and Taiwan contributing unique value-add across the different segments of the value chain, but its results have not materialized yet. At the same time, there are reports by organizations representing US semiconductor manufacturers that Huawei is leading a secret network of fabs across China to evade US sanctions.[32]

Friend-shoring counts on the success of industrial policies

Supply chain diversification heavily relies on industrial policies. While this paper has elucidated the success of select East Asian states, there is no shortage of failures of industrial policies. Major corporations are betting on the government's support for diversification. One major reason for the relative success of industrial policies in East Asia was policy consistency across different administrations. Among democracies in the Indo-Pacific or even Europe, that consistency is not a given. A change in government could reverse once-supportive policies. For example, while the CHIPS Act was a bipartisan effort, the IRA came into existence as partisan legislation[33] whose promises may be re-evaluated should power change hands after an election.

Tit-for-tat export controls

The tit-for-tat export control measures deployed by both the US and China affected nations and companies at every segment in the value chain. Mergers and acquisitions in the sector are becoming increasingly challenging with regulators from both superpowers monitoring every transaction for national security implications.

China for its part has put in place policies restricting the export of minerals affecting Japanese and Dutch companies that rely on it for the manufacture of SMEs.

Conclusion

Whether the US can hold on to its semiconductor supremacy depends on the success of its industrial policy and how quickly Beijing succeeds in domestic industry indigenization.

As the Chinese government nudges its domestic industry toward indigenization, Chinese companies such as Huawei, Tencent, Xiaomi, and other large conglomerates will work to address their comparative weaknesses in segments such as design and IP. The Chinese government has significantly increased its R&D expenditures over the last few years. Strategic mergers and acquisitions have become increasingly fraught, especially in the sale of advanced technologies such as photolithography or design and IP.

In this tit-for-tat environment, two factors will determine whether the US holds onto its leadership position: whether the US is successful with its industrial policies at home and on friendly shores, and whether Beijing succeeds in indigenizing the technology supply chain.

As the Chinese government nudges its domestic industry toward indigenization, large conglomerates such as Huawei, Tencent, and Xiaomi will work to address their comparative weaknesses.

Researcher bio: Rob York and Akhil Ramesh

Rob York

Director for Regional Affairs, Pacific Forum

Rob York is Director for Regional Affairs at Pacific Forum. He is responsible for editing Pacific Forum publications.

Prior to joining Pacific Forum, Rob worked as a production editor at the *South China Morning Post* in Hong Kong.

A PhD candidate in Korean history at the University of Hawaii at Manoa, Rob is a regular commentator on inter-Korean and Indo-Pacific affairs, and a regular contributor to *NK News, South China Morning Post, American Conservative, Journal of American-East Asian Relations*, and *China Review International*, as well as conducting numerous interviews in various media outlets.

His research agenda at Pacific Forum includes trade and its relationship with security, media analysis, countering disinformation, and human rights.

Akhil Ramesh

Senior Resident Fellow, Pacific Forum

Akhil Ramesh is Senior Resident Fellow at Pacific Forum where he conducts research on supply chains, East Asia and on topics at the intersection of security policy and trade policy in the broader Indo-Pacific region.

Prior to joining Pacific Forum, Akhil worked with the Australian Department of Foreign Affairs and Trade on geo-economic issues in southern India. Prior to that, Akhil worked at think tanks in New York City and Washington D.C. He holds an M.S. global economics from New York University and certificate in business and geopolitics from HEC Paris business school.

With research interests at the nexus of geoeconomics and security policy, he is currently working on a number of research projects related to infrastructure development in Asia, supply chains, grand strategy in the Indo-Pacific. His analysis has been widely featured in publications such as Bloomberg, and published across global and regional journals such as *Nikkei Asia, South China Morning Post, The Hill, The Diplomat, National Interest, Economic Times* and *Hindustan Times*.

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