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"What does the China-US rivalry mean for the semiconductor industry?"

Authors, alphabetically by surname:

- *Dr. Rogier Creemers, Assistant Professor in Modern Chinese Studies at Leiden University and Principal investigator of the NWO Vidi Project "The Smart State: Big Data, Artificial Intelligence and the Law in China".*
- *Hung-Wen Lin, Author of "Chip Island: How TSMC and Taiwan Triumph".*
- *Dr. Dong Ting, Research fellow at Tsinghua University's Centre for International Security and Strategy (CISS).*

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What does the US-China rivalry mean for the semiconductor industry?

Response 1 of 3

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November 2024

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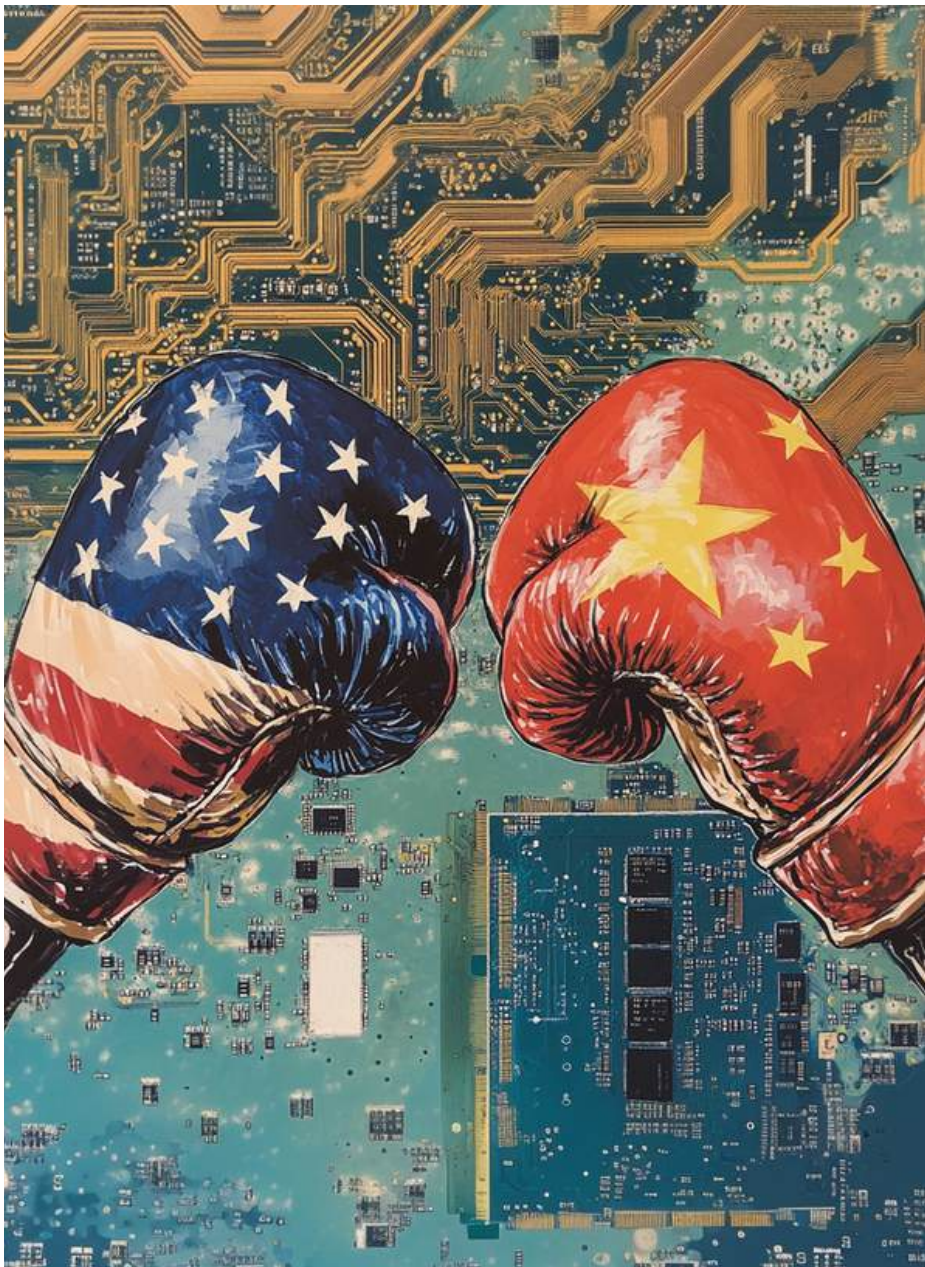

Escalating Sanctions

During the first Trump administration, the US started imposing semiconductor-related sanctions against China. At first, these sanctions were targeted: companies on the Department of Commerce's export control list, such as telecommunications manufacturers Huawei and ZTE Corporation, were barred from acquiring high-end chips whose production involved American technologies. The highest-end semiconductor manufacturing tools, ASML's EUV lithography machines, were also never approved for export to China, as the Dutch government never granted an export licence.

The Biden administration has since expanded these sanctions to encompass the entirety of the country and across a broader swathe of the semiconductor spectrum, effectively putting a hard ceiling on China's ability to access sophisticated computing equipment. The administration's first package of sanctions came into effect in October 2022, and they have since been upgraded in response to continuing progress in Chinese semiconductor

production capabilities and tactical responses made by global businesses. For instance, Huawei debuted a smartphone containing 7nm chips made with less advanced tools already in China, while Nvidia has tweaked some of its AI chips to bring them just under the sanctions' thresholds. However, in October 2023, controls were tightened in response to these adaptive measures, effectively closing some loopholes and further raising parameters concerning less advanced DUV lithography machines.

In the meantime, the Biden administration has also sought the support of other major players in the semiconductor industry, most notably the Netherlands and Japan. Both countries have joined in with export controls of their own, albeit with lukewarm enthusiasm: the Chinese market is a lucrative one for their businesses, and they may feel more vulnerable to possible Chinese retaliation against perceived efforts to curtail its technological ambitions.

Nevertheless, Washington remains steadfast in its ambition to put a hard ceiling on Chinese semiconductor capabilities. At present, it is looking at two specific issues. On the one hand, Chinese companies are bypassing limitations on hardware exports to China by using cloud services outside of China, which are not subject to sanctions. On the other hand, in addition to blocking the further sale of foreign advanced semiconductor manufacturing equipment to China, the US is now considering imposing controls on the supply of maintenance services, spare parts, and consumables to already-installed machinery. This would effectively degrade China's equipment base. However, Washington would again need the support and collaboration of Japan and the Netherlands for such controls to be effective, and both countries are very hesitant to join in further unilateral action.

Consequences

These sanctions have had significant direct impacts on China's semiconductor industry, as well as its digital sector more broadly. In the months after the October 2022 sanctions package, China's semiconductor output reduced by 17%. Huawei, once the largest smartphone manufacturer in the world, saw its market share decline precipitously for a period of time. However, it is now recovering, due in no small part to the rapid response and adaptation of Chinese suppliers to the export controls.

In effect, the sanctions have provided an important boost for China's domestic semiconductor industry. Until the imposition of sanctions, Chinese efforts to attain greater degrees of chip sophistication did not meet with much success. Even domestic hardware manufacturers, such as Huawei, preferred to purchase high-end chips from established industry leaders, most notably, Taiwan Semiconductor Manufacturing Company Limited (TSMC). Now this dependency has been weaponied, incentives for Chinese firms have shifted: it is now in their interest that a domestic, sanctions-proof source of advanced chips develops as quickly as possible. This new interest by domestic firms reinforces longer-standing

governmental efforts to catch up in semiconductor technology. The Shanghai-based firm Semiconductor Manufacturing International Corporation (SMIC) now supplies 7nm chips at scale, and is reportedly preparing the production of 5nm chips by repurposing older manufacturing tools. This process is more costly and less efficient than industry leader TSMC's capabilities, but it provides a basis for further development and future catch-up.

There is also the possibility of Chinese retaliation, most notably in the area of rare earth elements. Chinese companies process over 85% of global supply, resulting in significant global dependencies. In June of this year, Beijing issued new regulations imposing strict reporting requirements on rare earth exporters, after it had already banned the export of rare earth processing and magnet manufacturing technologies.

Such measures would signal an effective rupture of the global semiconductor ecosystem, which has hitherto developed on the principle of efficiency and free flows of goods across borders. As a result, firms such as Intel, Nvidia, ASML, TSMC and many others could amortise the enormous expenses associated with the development of cutting edge chip technologies over a huge market. Now, these firms not only suffer directly from their inability to supply Chinese customers, but face growing competition as their Chinese counterparts mature. In late September, Nvidia's share price dropped by over 4% after Chinese regulators ordered domestic forms to opt for domestic chips, accompanied by a 20% increase in the valuation of local chip makers Cambricon and SMIC. Weeks later, 50 billion EUR was wiped from ASML's market capitalisation after the company's quarterly results were weaker than expected. This was largely due to concerns surrounding China, which accounts for a fifth to a quarter of the company's revenue.

As profit opportunities for semi-conductor firms decrease, costs grow. The obligation to verify end use customers, for instance, is both costly and fraught with risk. In late October, the Financial Times reported that Taiwanese chip foundry TSMC had notified US authorities that some of its chips might have ended up in Huawei products through intermediary companies in third-party countries. While TSMC claimed it had not sold any chips to Huawei directly since 2020, these indirect product flows are extremely difficult and costly to trace. The US Department of Commerce has launched an investigation to verify whether TSMC sufficiently carried out due diligence on this customer, with fines or other sanctions a possibility.

To conclude, it is worth reflecting on the broader trajectory of technological development behind the semiconductor sanctions. US decision makers believed that limiting Chinese access to key technologies would block that path. However, China may well discover alternative paths to similar (or at least sufficient) levels of semiconductor performance across the many sections of the production and supply chain. Ironically, that will strengthen their innovative potential, and perhaps worsen the problem that the sanctions were intended to tackle.

About the Author

Rogier Creemers is a Lecturer in Modern Chinese Studies at Leiden University. With a background in Sinology and International Relations, and a PhD in Law, his research focuses on Chinese domestic digital technology policy, as well as China's growing importance in global digital affairs.

He is the principal investigator of the NWO Vidi Project "The Smart State: Big Data, Artificial Intelligence and the Law in China". For the Leiden Asia Centre, he directs a project on China and global cybersecurity, funded by the Dutch Ministry of Foreign Affairs. He is also a co-founder of DigiChina, a joint initiative with Stanford University and New America.

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What does the US-China rivalry mean for the semiconductor industry?

Response 2 of 3

Hung-Wen Lin
Author of "Chip Island: How TSMC and Taiwan Triumph"
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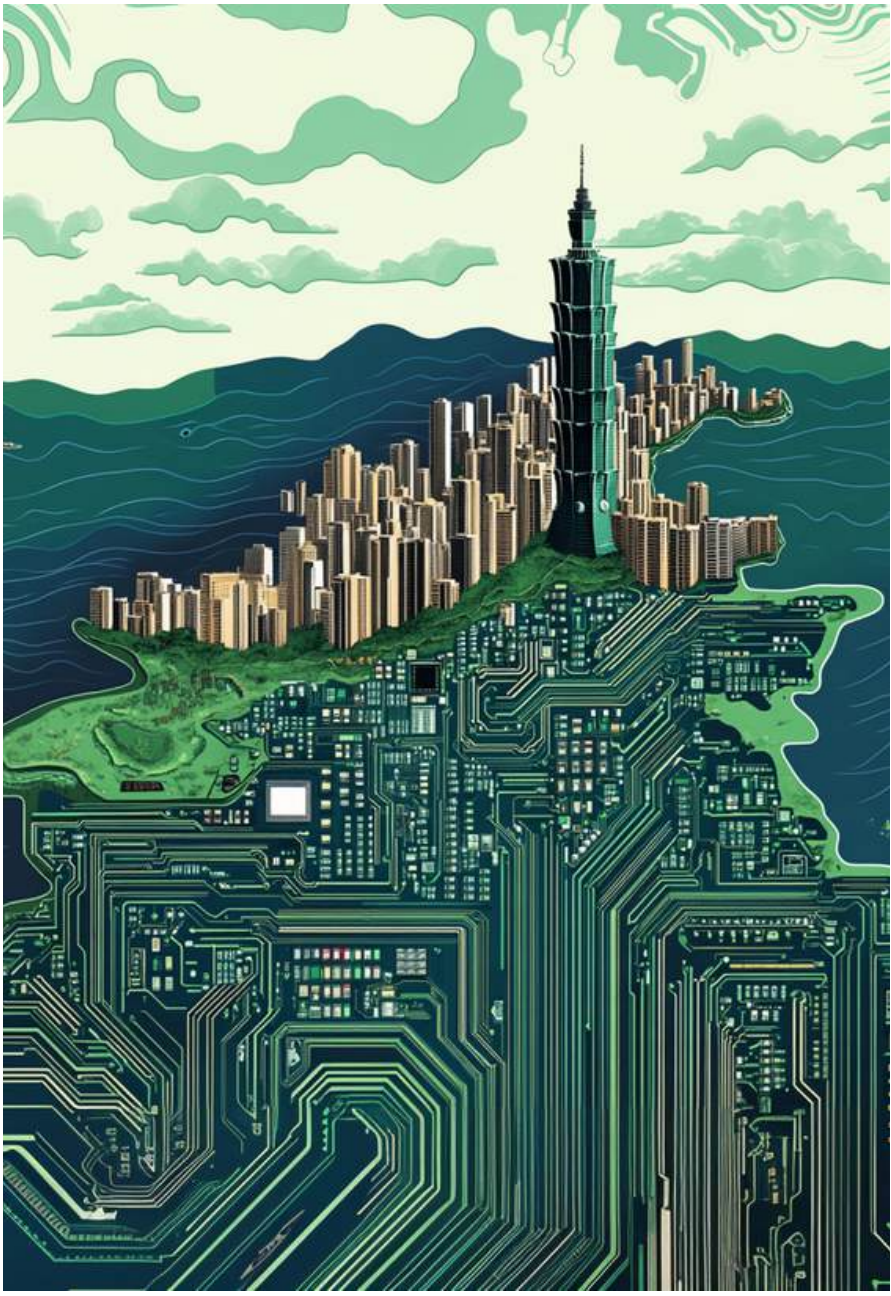
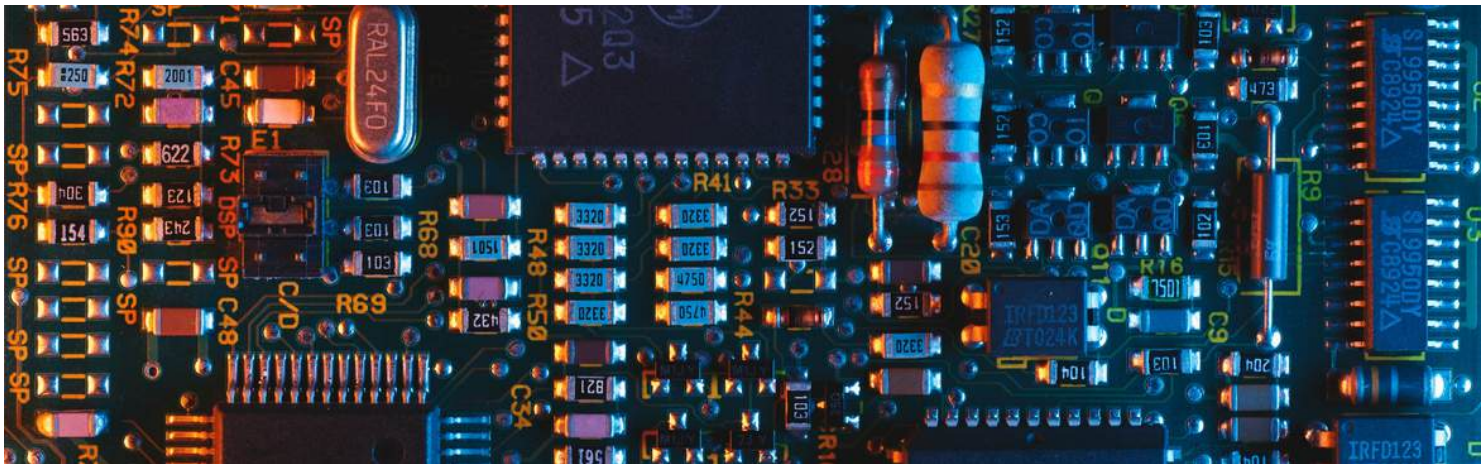
US-China Confrontation: The Semiconductor Industry's Evolution in Four Directions

In recent years, spurred by the intensifying U.S.-China confrontation, nations around the globe have significantly ramped up their investments and subsidies in the semiconductor industry, aiming to bolster security and resilience. This strategic shift has triggered substantial adjustments within the semiconductor ecosystem. The questions we must grapple with are profound: How will the supply chain transform with these heightened investments? What are the implications of "reshoring" and "friendshoring"? And most importantly, can national industrial policies prove effective in this evolving landscape? In other words, what does the US-China rivalry mean for the semiconductor industry?

Since 1993, shortly after the founding of Taiwan Semiconductor Manufacturing Corporation (TSMC), I have closely reported on the semiconductor industry and observed its development first-hand. From this vantage point, I have identified four potential future directions that warrant our careful attention and consideration.





Direction 1: Slower-than-Expected Supply Chain Localization

Under the auspices of free trade and globalisation, nations have cultivated their semiconductor industries by capitalising on their unique strengths, resulting in efficient specialisation. This technological advancement and corresponding price reduction have accelerated the swift adoption of PCs, smartphones, and AI, effectively democratising technology.

Currently, countries such as the United States, Europe, and Japan are making substantial investments aimed at bolstering national security and ensuring supply chain resilience. However, the semiconductor sector is characterised by high costs and significant entry barriers. Many investment initiatives face hurdles; for instance, Intel has postponed its European investments. Only a select few companies, like TSMC, which possess robust financial and technical capabilities, can meet their investment commitments.

Consequently, my first observation is that despite these substantial investments and new supply chain initiatives, the anticipated outcomes will be slower to materialise. Local supply chains will constitute only a minor portion of the overall scale, with essential semiconductor manufacturing continuing to rely on the well-established infrastructure in Asian countries. TSMC founder Morris Chang has noted that while the United States may need to produce critical components, such as military chips, domestically, large-scale manufacturing resumption is unlikely to succeed—a perspective with which I concur.

Direction 2: Specialisation Amid Geopolitical Tensions

The high manufacturing costs in Europe and the United States have been a persistent issue. For example, TSMC's WaferTech plant in Washington state, established in 1996, has maintained low production due to significantly higher costs compared to Taiwan. Consequently, the global share of U.S. semiconductor manufacturing has declined from the highest at 30% to 10%, unable to compete with the cost efficiency of Asian companies. In the current climate of geopolitical tension, countries are focusing on their specialised sub-industries. The United States, for instance, excels in electronic design automation (EDA) software, IP silicon, and integrated circuit (IC) design companies such as Nvidia and Qualcomm, as well as in extreme ultraviolet (EUV) equipment from the Netherlands' ASML. Meanwhile, Japan is a leader in photoresists and chemical materials, Taiwan in foundries like TSMC, and South Korea in memory manufacturers such as Samsung and SK Hynix. These nations will continue to develop their strengths, thereby gaining more leverage in international negotiations. Over the past five to six years of U.S.-China confrontation, leading companies have not only retained their competitiveness but many have also increased their market share and influence. Developing irreplaceable technologies within a protectionist environment enhances negotiating power, as demonstrated by Japan's 2019 restrictions on critical materials export to South Korea, which impacted Samsung's production yields.

Direction 3: China's Independent Development

The US-China confrontation will likely result in the emergence of two distinct camps, effectively creating "one earth, two worlds." In response to US sanctions, China has been, and will continue to endeavour to develop its own systems, establishing local standards and architectures, thereby decoupling from Western hardware and software. With strong governmental support, Chinese companies will replace foreign components with domestic suppliers, achieving comprehensive import substitution.

In this divided landscape, each camp will seek to form alliances to bolster their influence. The U.S.-led CHIP4 alliance, comprising the United States, Japan, South Korea, and Taiwan—what I term CHIP4+1 with the inclusion of the Netherlands—includes prominent semiconductor nations, thus positioning it advantageously for future development.

China, however, faces substantial challenges in securing allies and must depend on domestic efforts for all semiconductor-related technologies. This places tremendous pressure on its talent, technology, and capital. Overcoming advanced technology sanctions will be formidable, and China will likely focus on investing in mature processes. This approach may lead to overcapacity and price wars, similar to the current situation in the electric vehicle market.

Direction 4: The Suitability of Subsidy Policies

Are subsidy policies universally effective? The subsidies and policy guidance that benefit Asian countries may not be suitable for the U.S. or EU. Given the U.S.'s leadership in new products and technologies, it should prioritise technical innovation and product development over manufacturing subsidies. The CHIPS Act's emphasis on subsidising TSMC and Samsung in order to relocate manufacturing to the U.S. has limited success prospects due to the high costs and challenges in establishing competitive manufacturing capabilities domestically.

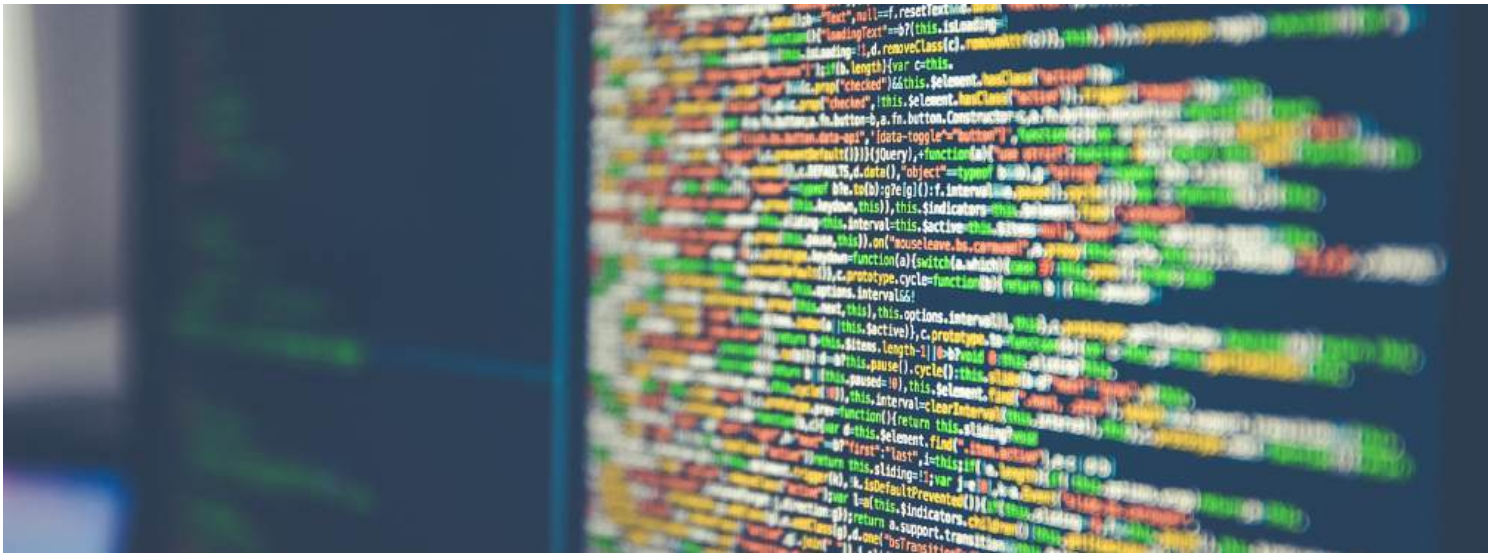
The economic realities underscore that subsidy-driven semiconductor policies are likely to fall short of expectations. Even highly successful companies like TSMC and Samsung face significant cost pressures when moving production to the U.S., EU, or Japan. This is not a reflection of a lack of capability but rather a recognition of the comparative advantages that different regions hold.

National industrial policies should therefore focus on leveraging each country's inherent strengths. The U.S., with its robust innovation ecosystem, should continue to excel in research and development, leaving high-volume manufacturing to regions with established cost efficiencies. By playing to each nation's strengths and specialising in what they do best, a more effective and sustainable global semiconductor ecosystem can be cultivated.

Concluding Takeaways

Last July, I published my book "How TSMC and Taiwan Triumph" in Taiwan, followed by Japanese and Korean editions. I was invited to speak there about semiconductor policies. I believe Japan's decision to subsidise TSMC's Kumamoto plant is a sound policy. Wafer manufacturing should be entrusted to TSMC, while Japan focuses on strengthening its key industries in equipment, materials, and chemicals, to leverage its most advanced and critical technologies. Despite TSMC's dominance in advanced processes, it depends on equipment and materials from the United States, Japan, and the Netherlands. Taiwan's success story is one of concentrating talent and resources on semiconductors after enduring numerous industrial failures.

Former President Trump's assertion that Taiwan took American jobs is, in my view, incorrect. TSMC has, in fact, created more American jobs by manufacturing for U.S. companies like Apple and Nvidia, enabling them to market their products globally. By supporting its clients' success, TSMC has grown alongside them, contributing to the global economy.



I agree that the U.S. will slow down China's development due to the need for security and resilience, because China uses unfair competition and subsidies to dump the world at low prices, not only in semiconductors, but also in electric vehicles and various consumer goods. However, I am also worried about the following rise of anti-globalization or even protectionism, and their potentially fatal impact on the development of the global semiconductor industry.

This collaboration underscores the importance of resilient supply chains, which are crucial for national security amid geopolitical tensions. However, the trajectory of industry development is governed by established principles and trends, and moves forward in alignment with comparative advantages. This enduring pattern of industrial specialisation is set to continue moulding the global landscape for the foreseeable future, potentially spanning the next decade or more. Such is my conclusion on the evolving dynamics of the semiconductor sector.

About the Author

Lin Hung-wen is a seasoned journalist with a focus on the semiconductor and high-tech industries in Taiwan. He served as deputy editor-in-chief of Business Today Magazine and a columnist specialising in industry research and trend analysis.

Lin has authored several books, including Exploration of Competitiveness, co-authored by MK Tsai, Chairman of MediaTek and The 21 Lessons about the Business Giant Samsung. His most recent work, Chip Island: How TSMC and Taiwan Triumph, was also translated into Japanese and Korean, and is expected to be published in English in the first half of 2025.

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Narrations of the history of the semiconductor industry abound. According to P. R. Morris, author of A History of World Semiconductor Industry, its origins can be traced back to the 1880s and the lamp industry, with applications in both households and military technology. The conduct of the two World Wars gave impetus for the birth of the semiconductor as a device today. One account maintains that the low rate at which American munitions actually hit their designated targets during the Vietnam War led to continued military support for American semiconductor development.

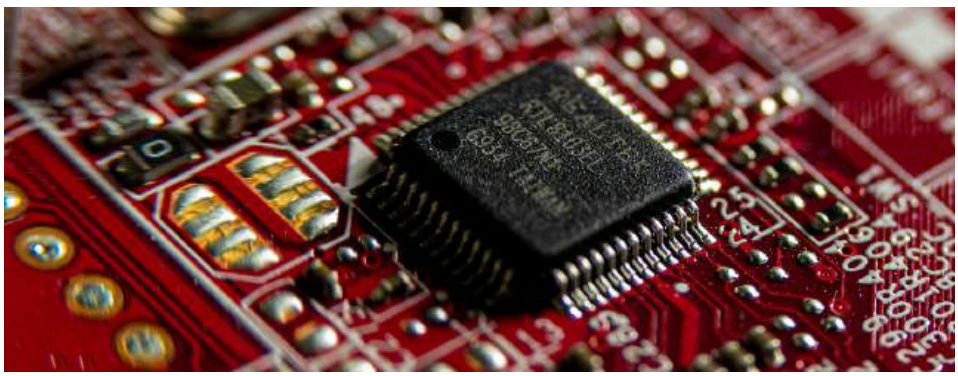
In today's digital age, semiconductors are not luxury goods but basic necessities for economic development and social well-being in all countries, as indispensable as water and electricity. From smartphones to home appliances to transportation systems, they are embedded in virtually every aspect of our daily lives. However, semiconductors have unmistakably become synonymous with the rivalry between the United States and China. Initially, the Trump administration launched a new policy of semiconductor export controls targeting China, citing national security concerns.

Subsequently, both the Trump and Biden administrations broadened and intensified the scope of punitive actions against China. These actions included placing major Chinese semiconductor companies like Semiconductor Manufacturing International Corporation (SMIC) on the Entity List in December 2020, implementing comprehensive export controls in October 2022 that restrict China's access to advanced chips and manufacturing equipment. These were further strengthened in 2024 with clarified rules to tighten restrictions on advanced computing, supercomputing items and semiconductor manufacturing equipment. The U.S. also coordinated with allies such as Japan and the Netherlands to limit semiconductor equipment exports to China. The U.S. government enacted the CHIPS and Science Act in August 2022, providing $52 billion in subsidies to boost domestic semiconductor manufacturing while explicitly prohibiting recipients from expanding advanced chip production in China. These measures collectively demonstrate a systematic effort to constrain China's semiconductor industry development.

As stated by U.S. National Security Adviser Jake Sullivan, the Biden administration's semiconductor policy toward China is to maintain "as large of a lead as possible" given "the strategic environment we are in today." This sentiment was echoed by Vice President Kamala Harris, who, upon accepting the Democratic Party's presidential nomination, declared that she would "make sure that (the U.S.) leads the world into the future on space and artificial intelligence. America, not China, wins the competition for the 21st century" –a conviction her Republican opponent, Donald Trump, would not find issue with.

In response to incessant unilateral measures by the U.S. and U.S.-led multilateral campaigns against China in the semiconductor sector, China has taken significant steps to protect its own industry interests. China's regulatory measures on the export of raw and semi-processed materials used in the global semiconductor industry chain have raised concerns abroad. Still, it is essential to note that from a Chinese perspective, China's ambition in developing its semiconductor sector is not to replace the U.S. or any other economy in the global telecommunications technology ecosystem. In the global semiconductor supply chain, China has been, and remains, a big buyer and a manufacturer at the primary stage of the production process. This position makes China far from being a direct competitor to giants such as the U.S., South Korea, Japan, or Taiwan region. China first entered the market through assembly and packaging, relying on its abundance of lower-skilled labour to turn wafers manufactured elsewhere into finished semiconductors. The figures of China's semiconductor industry growth are often cited as a key illustration of the perceived Chinese threat. For example, from 2001 to 2016, China's share of global value-added in the semiconductor industry grew nearly fourfold, from 8% to 31%. By 2019, China accounted for 20% of total global semiconductor exports.

However, the other part of the story is often less widely told: today, China remains the world's largest consumer of semiconductors, purchasing more than 50% of the world's chip output. Moreover, China continues to be an important market for global semiconductor companies. U.S. restrictions have been carefully designed to allow American firms to continue selling certain types of chips to China, as maintaining access to the Chinese market remains crucial for many U.S. semiconductor companies. Semiconductor production is a complex process, and in the most valuable areas such as electronic design automation (EDA) software, manufacturing equipment, central processing units (CPUs), graphics processing units (GPUs), and advanced logic chips, China still lags far behind leading suppliers like Taiwan Semiconductor Manufacturing Company (TSMC), Samsung, ASML, Intel, Nvidia, Synopsys, and Cadence.



The recent research findings released in August 2024 by the Information Technology & Innovation Foundation (ITIF), a well-known technology policy think tank in the United States, also indicate that even for future chips, China's research and development (R&D) intensity is far behind that of the United States and the European Union.

As expected, China not only protested against punitive actions by the U.S. and its allies, but also responded with measures of its own.

Although U.S. sanctions have indeed impacted Chinese companies such as Huawei, SMIC, and Hikvision, they have not completely disrupted China's progress in semiconductors. Huawei continues to produce new smartphones, and SMIC can still produce 7nm chips, although not on a large scale. Despite restrictions on EDA software, China's chip design industry continues to thrive.

China also took what it views as legitimate actions in defence of its self-interests. For example, in May 2023, China's Cyberspace Administration conducted a cybersecurity review of Micron Technology, a process that became mandatory for all critical information infrastructure operators purchasing from foreign vendors after the implementation of China's Cybersecurity Law in 2017. The review concluded that Micron's products posed "serious network security risks", though specific details of the alleged risks were not publicly disclosed, leading to a ban on its products in certain infrastructure projects, especially those that handle critical information. In July 2023, China placed germanium and gallium under its export control regime. These minerals are essential raw materials for manufacturing electronics and semiconductors, with China controlling about 80% of global germanium production and 94% of gallium production.

This move was widely interpreted as China's response to U.S. restrictions on advanced semiconductor manufacturing equipment (such as

ASML's extreme ultraviolet lithography machines and applied materials' etching tools) that are critical for producing cutting-edge chips. However, while China's control over these minerals gives it some leverage, the impact is less severe than U.S. equipment restrictions because these materials are more substitutable and able to be stockpiled compared to the highly specialised semiconductor manufacturing equipment that China seeks to acquire.

However, this does not mean that China's path in the future will be smooth sailing. In the context of U.S.-China rivalry, China faces several critical challenges. Expanding production capacity requires massive capital investment and time to achieve economies of scale, particularly with restricted access to advanced equipment. The path to high-value chains remains blocked as U.S. controls specifically target sophisticated segments like EUV lithography and advanced chip design. These restrictions also deter potential customers who worry about geopolitical risks and reliability, making it harder for Chinese firms to capture market share in high-end chips. The innovation environment suffers too, as limited access to global R&D networks and talent pools, which are direct consequences of technological barriers, constrains China's technological advancement.

The answer to these challenges lies in openness and cooperation, not in forced decoupling and confrontation. The semiconductor industry chain is composed of numerous small ecosystems, each with a highly optimised industrial structure dominated by one or two leading companies. All ecosystems are closely interconnected, so any subtle change will have a ripple effect. Therefore, cutting off semiconductor industry development in any country or concentrating the manufacturing capability of such an essential commodity in the hands of a few countries and companies will have particularly worrisome consequences.

Beyond the bilateral context, the U.S. semiconductor containment of China not only hurts Chinese companies but has also put firms from other countries, such as South Korea, in a dilemma. They need to continue operating in China to maintain market share, while at the same time, U.S. policy restrictions create great uncertainty for these companies' investments and technology upgrades in China. This not only affects the global competitiveness of South Korean companies but also poses more challenges for South Korea in formulating its own industrial policies. In the long term, the protectionist trend exhibited by the current U.S. approach will be extremely destructive to the global economy.

Perhaps individual companies in their respective countries will enjoy the benefits brought by the protective umbrella, but more companies and more industries will bear, to varying degrees, potentially higher costs, less market access, and restrictions to the free flow of technology and knowledge. For example, thanks to strong semiconductor demand, South Korea's exports have maintained growth for ten consecutive months this year, although lower than expected, and business confidence has already fallen to its lowest level in half a year.

The New York Times had a widely circulated report last year, with a rather thought-provoking ending, stating that U.S. officials in charge of export controls have fully viewed this as a techno-nationalist competition. Semiconductors are not a zero-sum game with only one winner and many losers; such competition need not exist. A country's position in semiconductors should be determined by the efficiency, quality, and sustainability of its products and services, not by its ability to squeeze others out of the market by any means necessary.

About the Author

Dong Ting is a resident research fellow at Tsinghua University's Center for International Security and Strategy (CISS). Her primary research interests include non-traditional security challenges such as technology, energy, and maritime, among others. She teaches a course on science, technology and international relations. Before working at Tsinghua University, Dr. Dong worked as a Boya Postdoctoral scholar at Peking University. She earned her Ph.D. from the China Institute of Contemporary International Relations. Dr. Dong's research findings have been published in peer-reviewed journals in both English and Chinese and shaped into project reports in conjunction with leading foreign institutions and think tanks. Her book, The Logic of U.S Asia-Pacific Maritime Strategy (in Chinese) published in 2020 by World Scientific Publishing.

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