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Contents

Introduction 1

Export Controls and the Cold War Analogy 3

The Current Chip Export Control System 5

Effectiveness of Cold War Controls 6

Where the Cold War Analogy Breaks Down 7

New Export Control Challenges 9

China's Response 11

Circumventing Export Controls 11

Accelerating Self-Sufficiency 12

Improved Performance in Domestic Chips 13

The Key Role of Huawei 13

Rapid Advances in Domestic Manufacturing Equipment 14

Working Around Export Controls 14

Alternative Technologies 15

Costs and Risks for the United States 17

Revenue and R&D Impacts on U.S. Firms 17

Moving Beyond National Security 20

Trade Bargaining Chips 20

Controls for Revenue Generation 21

A Positive Agenda for Technology Leadership 23

About the Authors 25

About CSIS 27

Endnotes 28

Introduction

Technology competition cannot be won by export controls alone. Controls may delay an adversary's access to certain technologies, but durable leadership depends on the capacity to innovate faster through sustained investment in research, talent, advanced manufacturing, and commercialization. Semiconductor export controls should therefore be treated as a limited instrument within a broader strategy to strengthen U.S. technological leadership, not as a substitute for that strategy. This report uses the recent expansion of U.S. and allied semiconductor controls on China to make that case.

In October 2022, the Biden administration imposed new restrictions on the export of semiconductors, semiconductor manufacturing equipment (SME), and related technology to China.[1] The objective was to slow China's progress in technologies—especially advanced AI—deemed essential to U.S. national security by limiting access to critical chips, tools, and know-how. These restrictions built on company-specific measures established during the first Trump administration and sought to impose broader structural constraints on China's semiconductor ecosystem. Similar restrictions by U.S. allies reinforced the U.S. approach.

This trend has revived an older policy instinct: the belief that restricting access to critical technologies can preserve a strategic advantage over a rival power. The Cold War export control regime is a natural reference point. But today's semiconductor contest differs sharply from the Cold War environment in the structure of the target economy, the character of the technology, and the organization of global supply chains. Those differences shape this report's central conclusion: Controls may be necessary for specific national security choke points, but they cannot carry the burden of technology strategy.

Export Controls and the Cold War Analogy

Numerous observers have compared the current export controls on semiconductors with U.S. and allied restrictions on the export of strategic technologies to the Soviet bloc during the Cold War. Like current chip controls, these were intended to limit the technological advances of a potential adversary. In fact, some analysts have suggested resurrecting elements of the Cold War multilateral regime of technology controls to limit China's ability to challenge Western leadership in foundational technologies such as semiconductors.[2]

However, the conditions that enabled Cold War controls to support Western technological leadership no longer exist. A closer look at the Cold War restrictions in the context of today's semiconductor export controls highlights the challenges that confront current U.S. and allied policymakers seeking to slow China's advances in AI by limiting access to advanced chips, chipmaking equipment, and related technologies.

Cold War export controls originated in 1949 as a policy tool for the United States and its allies to prevent the Soviet bloc from acquiring Western military and dual-use technologies (with commercial and potential military applications). The basic division between military items and dual-use goods remains central to the current U.S. export control system, although the statutory framework and control lists have evolved substantially since the Cold War. The regime was predicated on a complex array of U.S. statutes and regulations, as well as the Coordinating Committee for Multilateral Export Controls (COCOM), an informal agreement between the United States and its allies.

In the Cold War milieu of the 1980s, exports of "weapons" and "defense articles and services" were controlled by the State Department pursuant to authority derived from the Arms Export Control Act of 1976 (Title 22, Section 2778, of the U.S. Code) and its statutory antecedent, the Battle Act of 1954.[3] The State Department administered these controls pursuant to the International Traffic in Arms Regulations and the U.S. Munitions List on military items such as nuclear weapons, missiles, military aircraft, warships, and submarines.[4]

Exports of dual-use goods, technology and services were regulated by the U.S. Department of Commerce, subject to review by the Department of Defense, pursuant to the Export Administration Act of 1979 (Title 50, Section 4601 et. seq., of the U.S. Code), the Export Administration Regulations, and the Commerce Control List.[5] Controlled dual-use categories included a broad range of products and technologies: computers, telecommunications equipment, specialized alloys and machine tools, semiconductors, sensors, avionics systems, and nuclear-related equipment and materials.[6]

The purpose of the controls was to maintain Western technological superiority and to prevent or delay the acquisition of strategic technologies by the Soviet bloc. This effort is viewed by some observers as a success, notwithstanding the wholesale leakage of restricted items to the Soviets and their Eastern European allies. Critics of the COCOM controls argue that the Soviet Union's trailing technological position throughout the Cold War was due to its isolation from the global economy and pervasive rigidities in its centralized planning system, which impeded absorption and exploitation of the numerous Western technologies that Soviet intelligence services did manage to acquire.[7]

In sharp contrast to the Soviet Union, contemporary China is deeply embedded in the global economy and has proven extraordinarily adept not only at acquiring foreign technologies but at rapidly adapting and diffusing them internally, augmenting its own formidable innovative capabilities and, in some cases, achieving global market leadership in areas such as solar cells, electric vehicles (EVs), and LEDs.[8]

Further, today's global semiconductor industry is extraordinarily disaggregated, with value added by myriad specialized firms embedded in supply chains that sometimes consist of thousands of entities and extend through many countries, including China. In order to monitor this system, regulators must track millions of transactions all over the globe. Comparable commercial effects did arise in some Cold War-era dual-use sectors, including machine tools, where controls could affect the competitiveness and revenues of Western firms. But the scale and centrality of China in today's semiconductor market make the current revenue and innovation consequences broader and more immediate than in most Cold War-controlled sectors.

In short, semiconductor restrictions may slow China's development in the short run, but they also risk slowing the progress of Western firms by reducing revenues, weakening research and development (R&D) incentives, and accelerating Chinese substitution. Given China's growing indigenous capabilities, export controls are unlikely to constrain a dynamic, well-funded, and technologically advanced rival over the long term unless they are paired with a stronger affirmative strategy.

To understand why, it is useful to first examine how the current semiconductor control system works and then to assess why that system faces far more difficult conditions than Cold War controls did.

The Current Chip Export Control System

Congress granted the president broad authority over export controls in the Export Control Reform Act of 2018.[9] The current semiconductor restrictions operate through several facets of the dual-use control system.

- The Export Administration Regulations (EAR) are administered by the Bureau of Industry and Security (BIS) in the U.S. Department of Commerce. A license issued by the BIS is required for exports of designated products and technologies to a number of countries, including China. Designated products in the semiconductor sector currently include advanced semiconductor devices, SME capable of making such devices, and associated technology; also subject to these regulations are certain activities by U.S. persons in support of fabrication facilities in China that make advanced chips.[10]
- The Entity List designates parties for which a license is required for all or designated products, based on national security concerns. Many Chinese semiconductor design firms, manufacturers, and makers of SME and their affiliates are currently on the Entity List. For many covered transactions, the licensing policy is a presumption of denial or otherwise highly restrictive review.
- Deemed export rules restrict the release of controlled technology to foreign nationals inside the United States, including through employment, research, or technical collaboration. These rules can affect the ability of U.S. firms and research institutions to hire and deploy talent in advanced semiconductor work.
- De minimis rules apply the EAR to products that contain U.S.-origin inputs above a specified threshold, even if the products are manufactured in third countries.[11]
- Foreign Direct Product (FDP) rules apply the EAR to foreign-made products if they are the “direct product” of U.S.-made equipment, software, or technology. In semiconductor controls, FDP rules have become especially important because they can reach foreign-made chips, equipment, and technology tied to U.S.-origin tools or software, including through Entity List footnotes and product-level technology controls. The rules can therefore extend U.S. jurisdiction beyond goods physically made in the United States, even when the finished product contains no U.S.-made component.
- U.S. allies have issued parallel restrictions on exports of semiconductor products and technology to China, including critically important SME manufactured in Germany, Japan, and the Netherlands. The allied controls are not as restrictive as those of the United States, which is a point of friction within the Western alliance.
- The United States restricts all exports subject to the EAR, while the Netherlands and Japan restrict only a defined list of advanced tools.

- U.S. allies do not utilize rules equivalent to U.S. FDP rules.
- U.S. allies have no equivalent of the U.S. "person" rules that restrict the activities of personnel in Chinese-based chipmaking plants.
- In general, the allied controls are limited to SME, not semiconductor devices.[12]
- The Biden administration used the phrase "small yard, high fence" to characterize its objective in chip export controls (i.e., to limit their use to a small number of critical strategic items).[13]

Nevertheless, under both the Biden and second Trump administrations, the "yard" encompassed by U.S. controls has steadily grown.

The initial controls restricted the export of advanced logic chips used to train and run AI models, as well as SME used to produce those devices. The controls have been expanded to cover high bandwidth memory (HBM) for AI; additional types of SME used to produce HBM; dynamic random-access memory (DRAM) and advanced packaging; tools and software designed to improve the performance of deep ultraviolet lithography systems; and hardware and software tools related to functions such as deposition, ion implantation, annealing, metrology, cleaning, and inspection.

The application of U.S. FDP rules was expanded to such a degree that one analyst commented that it "could conceivably be used to control all of the SME made by any company on earth."[14] Indeed, the number of semiconductor firms on the Entity List has grown dramatically, now encompassing a broad range of companies in many countries, including design firms, chip manufacturers, toolmakers, and investment vehicles.[15]

The expanding scope of today's controls highlights the central problem with relying too heavily on the Cold War analogy. Unlike many Cold War–era controls, the semiconductor restrictions seek to govern a fast-moving, globally distributed, commercially indispensable technology ecosystem. The result is a control regime that must operate in conditions far less favorable to denial, enforcement, and allied coordination than those faced by Cold War policymakers.

Effectiveness of Cold War Controls

Cold War export controls are credited by some analysts with preserving a technological lead by the United States and its allies over the Soviets, but they were far from fully effective.[16] Soviet and Eastern European intelligence services fielded large and sophisticated procurement and espionage networks that were able to obtain many restricted items, so that controls tended to delay rather than deny acquisition. Techniques included

- arranging illegal trade diversion through third countries;
- recruitment of agents within the United States and allied militaries, government, industry, and academia;
- using Soviet bloc-owned entities incorporated in the United States to acquire prohibited technology;

- exploiting official scientific exchanges; and
- collecting vast amounts of open-source scientific and technical information available in the United States and allied countries.[17]

The Soviets were known to have legally and illegally obtained controlled technologies related to radars, acoustical and electro-optical sensors, computers, microelectronics, precision machine tools, structural materials, laser guidance and navigation, propulsion, and structural materials, most of which were utilized in ballistic missile, aircraft, and tactical weapons systems.[18]

Some companies in U.S.-allied countries deliberately evaded export restrictions.[19] In the early 1980s, the Soviets received computer numerical controls, clearly restricted under COCOM rules, from Japan's Toshiba Machine, the trading company Itochu, and the Norwegian state-owned firm Kongsberg, enabling the Soviets to reduce the acoustic signatures of their submarines.[20] In the same decade, the French machine tool maker Forest Line exported milling machines subject to COCOM controls to the Soviet Union, where they were used to fabricate fuselages and turbine blades for high-performance jet engines.[21] Despite pervasive leakage in the COCOM regime of export restrictions, the Soviets were unable to overcome U.S. and allied technological superiority.

Where the Cold War Analogy Breaks Down

China today is far more innovative and adaptive than the Soviet Union ever was. While the Soviets were able to acquire vast quantities of proscribed Western technologies, they proved unable to absorb and exploit them, a fact ascribed by observers to the sclerotic nature of the centralized Soviet system and the absence of a large and dynamic civilian economy comparable to those of the United States and its allies. Several features of the Soviet economic and administrative system limited its ability to translate access to Western technology into broader productive capacity:

- Central planning, production quotas, and fragmented ministerial control impeded the retooling of plants, retraining of workers, and reconfiguration of supply chains necessary to incorporate Western equipment and technology.[22]
- Enterprise managers were rewarded for quantitative output and had little motivation to risk the disruption of production that introduction of new technology entails.[23]
- Silos separating different sectors and ministries prevented the diffusion of new technologies even when a given segment of the defense establishment mastered a particular Western capability.[24]
- Soviet basic science was strong, but the country's applied research capabilities were defective across many sectors, impeding the exploitation of imported technology as well as that of homegrown basic discoveries.[25]
- Soviet science was impaired by ideological dogmatism—Einstein's theory of relativity, for example, was denounced as "bourgeois, reactionary, and incompatible with Marxism-Leninism."[26]

Contemporary China, by contrast, is proving not only as ingenious as the Soviets in obtaining prohibited Western semiconductor technologies, but also far more capable of absorbing those technologies, adapting them, and using them as springboards for further innovation. Unlike the Soviet Bloc, China is deeply integrated into the global economy and quite familiar with the technologies that the United States and its allies are restricting, many of which were already embedded in Chinese products and fabrication facilities when the export controls were introduced.[27] China expert and Dartmouth professor Jennifer Lind observes that "the Chinese have gotten where they are precisely through engagement with high-tech countries . . . and technology transfer followed from that. The Chinese, in other words, unlike the Soviet Union, were connected to the rest of the world, and they were absolutely interested in building up through technology transfer and through these export linkages to these other economies."[28]

Chinese capabilities in applied research also completely eclipse those of the Soviet Union in terms of sheer breadth across sectors and integration with mass production for civilian and military industries. China is a central hub for global manufacturing, which has facilitated successful and continuous innovation in EVs, telecommunications equipment, renewables hardware, and automated industrial systems.[29] Indeed, China now ranks 10th in the Global Innovation Index, highest among the 36 upper-middle income countries included.[30]

China has built a large and dynamic export-oriented civilian manufacturing base, with domestic enterprises constantly learning and adopting current best practices through trade, foreign direct investment, and integration into global value chains. The Soviet economy was comparatively isolated from the global economy and oriented toward heavy industry and defense, with the civilian sector lagging badly in technology and quality of output. This distinction matters even if Cold War controls were not designed principally to disrupt Soviet production of commercial goods: Today's controls target technologies that sit at the center of China's civilian industrial base as well as its military and AI ambitions.

New Export Control Challenges

The differences between the Cold War environment and today's semiconductor ecosystem create a new set of export control challenges. Current U.S. and allied controls share the Cold War objective of denying or delaying an adversary's access to strategically critical technologies, and they rely on some familiar methods, including controls on choke points such as extreme ultraviolet (EUV) lithography equipment and advanced graphics processing units (GPUs). But the conditions under which these controls operate are far less favorable.

In the first place, current semiconductor export restrictions are attempting to control high-volume dual-use technologies that are critical to the entire civilian digital economy, with the same chips that power smartphones and data centers also supporting military applications of AI. There is no close Cold War analogy, notwithstanding COCOM controls on some dual-use technologies.

Second, unlike most Cold War weapons systems, which developed over capital-intensive cycles of one or two decades or more, chip architectures and performance improve on one- to three-year cycles. Semiconductor innovation occurs simultaneously across design, electronic design automation (EDA) tools, materials, equipment, manufacturing, and packaging, with upstream breakthroughs often opening new pathways for downstream users in ways that even highly competent regulators cannot anticipate. The velocity and scope of semiconductor innovation make it difficult to design export controls that remain relevant, avoid self-inflicted harm, and actually restrict Chinese capabilities; U.S. regulators have already needed to revise device and tool thresholds within a year or less to capture new products and workarounds.

Third, the economies and manufacturing operations of the United States, its allies, and China are deeply intertwined and mutually dependent, making near-term decoupling difficult if not impossible. Consider that semiconductor value chains are polycentric and global, with value added by many actors in multiple countries—China prominent among them—so that any allied controls have ripple effects on the entire global chain.[31] In addition, China, as the largest consumer of semiconductor products in the world, has been an important market for U.S. and allied sales of advanced semiconductor devices, equipment, and materials.[32]

China is so thoroughly embedded in U.S. and allied supply chains that it can exert leverage through withholding materials critical to Western semiconductor and other high-tech companies. For example, China processes 99 percent of the world's gallium, which is a critically important material used in semiconductors, EVs and solar cells.[33] China has used prospective and actual bans on critical materials whose production it dominates (e.g., gallium, germanium, and graphite) as bargaining chips in trade negotiations with the United States.[34] In the case of gallium, China can process 1,600,000 kg of gallium per year. To put that in perspective, Japan, the second largest processor, has a processing capability of about 10,000 kg per year—0.6 percent that of China.[35]

This means that enforcing the semiconductor export controls requires monitoring millions of transactions, third-country transfers, shipments of chips incorporated into other products, and transfers of intangibles such as chip designs, intellectual property, and software updates—complexities that Cold War export regulators did not confront.[36] And as in the Cold War, coordination between the United States and its allies complicates this challenge.[37]

These structural differences matter because export controls do not operate against a passive target. Their effectiveness depends not only on what the United States and its allies restrict, but also on how China adapts. China's response shows that while controls can slow access to certain technologies, they can also stimulate circumvention, domestic substitution, and innovation around controlled choke points. The result is not simply delay—it is a stronger Chinese incentive to build more of the semiconductor stack within its own borders.

China's Response

Circumvention, Substitution, and Innovation

Circumventing Export Controls

While export controls have unquestionably slowed the development of China's chip industry over the short run, they have proven only partially effective in shutting off access to Western chips, technology and chipmaking equipment in the longer term.

Large numbers of semiconductor devices can fit inside containers the size of shoe boxes, and proscribed chips are often integrated into end products, making them difficult to detect. Unsurprisingly, there are widespread reports of smuggling prohibited devices into China. In 2024, the *New York Times* reported on a "bustling" market in Shenzhen in which "hundreds or thousands" of restricted chips were being traded.[38]

Erich Grunewald and Tim Fist of the Center for a New American Security concluded in a 2025 report that based on available evidence, the smuggling of AI semiconductors to China "has been occurring at a scale that significantly undermines U.S. attempts to restrict [China's] access to advanced AI." The report also found, via a search of three Chinese online marketplaces, 132 domestic listings for export-controlled chips, along with photos of the smuggled goods. The average quantity of export-controlled GPUs per listing was about 1,200 for GPU server listings and 400 for GPU card listings, or an imputed stock estimated at 100,000 H100 GPUs as of December 2024. Chinese chip sellers interviewed for the study said that they worked with multiple distributors, used overseas shell companies, and employed simple but effective tricks (e.g., relabeling chip shipments as toys or tea).[39]

Chinese companies designated as targets of export controls dissolve themselves and reemerge under different names. In one instance cited by the *New York Times*, Sugon, a Chinese firm that provided advanced computing technology to the Chinese military, was put on the U.S. Entity List, so a group of its former executives created a new company, Nettrix, after which "Nvidia, Intel and Microsoft quickly formed ties with the new firm."[40]

A 2025 CSIS study on the impact of export controls on trade in EDA tools documented the mechanisms being used to circumvent EDA export restrictions, including use of shell companies and other intermediaries to bypass restrictions, formation of joint ventures between Chinese companies and partners based in third countries, purchase of EDA tools from third-country vendors, and software piracy.[41]

Accelerating Self-Sufficiency

For decades, Chinese policymakers have sought to reduce reliance on foreign microelectronics through initiatives such as Made in China 2025 (MIC2025). Until now, those efforts have fallen well short of their targets, constrained by steep technological barriers, misallocated funding, and coordinated international export controls. MIC2025's objective was 70 percent localization of Chinese chip consumption by 2025, and while authoritative current localization data is not publicly available, Goldman Sachs estimated in 2025 that domestic suppliers met only 14 percent of China's chip demand in 2024, a figure the firm estimated would rise to 37 percent by 2030.[42]

It is impossible to measure precisely how much export controls have accelerated China's drive toward self-sufficiency, because there is no observable counterfactual showing where China's semiconductor capabilities would stand absent the controls. The available evidence nevertheless points in the same direction: Controls have increased the urgency, political priority, and market incentives behind China's localization efforts.

As a 2024 CSIS report observed, "Politics aside, Chinese companies largely prefer to utilize the most advanced semiconductor tools and technologies, most of which are produced in the United States and allied nations. Under normal circumstances (i.e., in the absence of recent export control trends), Chinese firms would likely continue to purchase and utilize U.S. technology in areas in which it is industry leading."[43] Export controls, however, have added significant momentum to China's long-standing efforts to achieve chip self-sufficiency.

- **Domestic Sourcing:** For the first time, Chinese semiconductor-consuming companies face the prospect of a complete cutoff of access to advanced foreign chips and tools, or of sourcing subject to the vagaries of smuggling and other gray channels. As a result, in addition to the government's ongoing exhortations, users of chips and SME are motivated as never before to turn to domestic sources.
- **Delete America**: Domestic chip consumers are reportedly making greater use of Chinese-made chips, which do not match the performance of leading U.S. devices, but are less expensive and good enough for many applications. This trend was encouraged by China's central government through "Document 79," also known as "Delete America," a

directive that was circulated to domestic firms, telling them to procure technology from domestic firms even in situations in which foreign alternatives are superior.[44]

- **Learning by Doing:** Increased domestic sourcing by local consuming firms provides Chinese semiconductor firms with added revenues and continuous feedback on quality issues, allowing for iterative improvements. In 2026, Moore Threads, a Chinese maker of AI chips, reported a tripling of its revenues for 2025, "reflecting how local semiconductor firms are expanding rapidly amid Beijing's push for self-sufficiency."[45]
- **Boycotts:** Although the U.S. government shifted policy on Nvidia H20 chips from a presumption of denial to case-by-case licensing review, Chinese authorities have continued encouraging domestic firms to use Chinese-made chips and are preparing new rules to cap the total number of advanced AI chips they can import.

Improved Performance in Domestic Chips

China's domestic semiconductor ecosystem is also showing signs of progress in developing AI chips and, increasingly, in demonstrating that those chips can support advanced AI workloads. While performance and production constraints remain, recent developments suggest Chinese firms are beginning to assemble more capable domestic alternatives across both hardware and AI training infrastructure. Two developments in early 2026 illustrate this progress:

- In January 2026, Alibaba disclosed that it had delivered 100,000 units of its most advanced AI chip, the Zhenwu 810E, which is said to be competitive with Nvidia's H20, "carving out a larger share of China's fast-growing AI chip market, as domestic players push to reduce reliance on Nvidia amid strong demand for AI computing power and ongoing uncertainty around US export controls."[46]
- Also in January 2026, Chinese AI firm Z.ai said that its new image generation model was trained on chips made by Huawei Technologies, "making it the first powerful open-source model to be developed on an entirely domestic training stack." The achievement "proved the feasibility of developing powerful multimodal models without US semiconductors, as Beijing pushes for self-sufficiency in China's AI industry amid US export restrictions on cutting-edge chips."[47]

The Key Role of Huawei

Huawei, the world's largest telecommunications equipment manufacturer, offers the most dramatic example of a Chinese company galvanized by export controls into an all-out drive toward self-sufficiency. Since 2017, successive U.S. administrations have imposed an array of restrictions on Huawei and its affiliates, including on the sale of semiconductors, in an effort to cripple its supply chain. Huawei has responded with a series of dramatic moves to end its dependency on foreign technology.

- The company states that in 2023 it was able to replace over 13,000 foreign components and redesign over 4,000 circuit boards to eliminate foreign-made devices.[48]

- Huawei diversified its supply chain by investing in front-end companies and packaging and testing facilities. In 2021, it established a subsidiary, Huawei Precision Manufacturing, that enabled it to bring more of Huawei's high-precision, high-value-added manufacturing in house, rather than outsourcing it to specialized foreign electronics manufacturing services and original design manufacturers.[49]
- Huawei has continued to launch new products powered by its own chips, such as the 5G-capable Kirin 9000, reportedly created by its in-house design unit, HiSilicon.[50]
- A major study by the Information Technology and Innovation Foundation (ITIF) noted in October 2025 that Huawei's share of the global telecommunications market grew from 32 percent in 2018 to 34 percent in 2024, and concluded that "U.S. techno-economic power is weaker than most think, and sanctions often hurt U.S. competitiveness more than China's."[51]
- At the same time, Huawei's progress should not be overstated. The company appears to maintain some reliance on Taiwan Semiconductor for advanced-node fabrication, underscoring that China's turn toward self-sufficiency remains partial and uneven even as it has accelerated.

The Chinese government is implementing measures to replace foreign chips in government servers and PCs with domestically made devices. In 2024, the government introduced guidelines requiring microprocessors made by Intel and Advanced Micro Devices (AMD) to be replaced by Chinese versions. State-owned enterprises have been directed to make a similar transition by 2027.

Rapid Advances in Domestic Manufacturing Equipment

China's self-sufficiency in SME has advanced quickly enough to surprise some observers. According to the China Semiconductor Industry Association, the country's self-sufficiency in SME surged from 25 percent in 2024 to 35 percent in 2025.[52] While such a claimed leap invites some skepticism, progress has been dramatic in key industry segments such as etching and thin-film deposition, where localization has reportedly reached 40 percent.[53]

- U.S. and allied export controls are credited with encouraging domestic users to reduce their reliance on foreign SME. Industry reporting indicates that Chinese chipmakers installing new production lines are now required by the government to source at least 50 percent of their tools domestically.[54]
- China's Naura Technology Group now supplies Semiconductor Manufacturing International Corporation, China's largest chipmaker, with over 60 percent of the oxidation and diffusion furnaces used in its 28-nanometer (nm) production lines.[55]
- The Chinese government and private investors are reportedly investing heavily in leading domestic makers of SME, including Naura, Piotech, and Advanced Micro-Fabrication Equipment.[56]
- In January 2026, researchers at Fudan University and the Chinese Academy of Sciences disclosed the creation of fiber integrated circuits, fully flexible fiber chips that are integrated

and embedded in stretchable strands as thin as a human hair, at a density that rivals that of a PC's central processing unit.[57]

- In the same month, the China Institute of Atomic Energy announced the development of a high-energy hydrogen ion implanter—a "microscopic scalpel"—for use in semiconductor manufacturing processes requiring acceleration of ions to embed them in silicon wafers, "potentially unblocking a bottleneck in the country's efforts to fortify key supply chains."[58]

Working Around Export Controls

Some export controls aimed at choke points in the Chinese semiconductor ecosystem have proven effective thus far, but their impact may well be transitory. A group of senior Chinese scientists reported in early 2026 that Western export controls had contained China's rise in three principal areas: (1) EDA, used for semiconductor design, (2) silicon wafers, an essential chipmaking material, and (3) EUV lithography equipment, currently produced only by ASML of the Netherlands.[59]

The controls have in fact forestalled China's acquisition of EUV lithography equipment, foreclosing the manufacture of chips at the 2- and 3-nm nodes needed to support the most advanced AI systems. The group of senior Chinese scientists called for a national effort to build a "Chinese ASML" by 2030, calling on domestic industry to "abandon illusions and prepare for struggle," an effort that is now underway.[60]

- In December 2025, Reuters reported that researchers at a secret site in Shenzhen had succeeded in a Manhattan Project-type effort to build a prototype EUV lithography machine, which fills an entire factory floor and is currently undergoing testing. The tool was reportedly built by a team of former ASML engineers, who reverse engineered an ASML EUV machine.[61] Huawei reportedly participated in this project and is engaged in other EUV-related R&D efforts.[62] According to some analysts, these reports may represent "propaganda and domestic hype," but a cautionary note is appropriate, given China's recent record of confounding skeptics in the semiconductor and AI space.[63]
- As an interim workaround, Chinese firms are using older lithography equipment to obtain outcomes similar to those achieved through use of ASML EUV machines. In 2024, Huawei and its SME affiliate, SiCarrier, patented a process, self-aligned quadruple patterning, which may enable them to produce devices similar to chips made using EUV.[64]

Alternative Technologies

According to a 2024 CSIS study, Chinese firms are reportedly making significant progress in utilizing hybrid bonding, together with advanced packaging technologies, to combine chips with different functions into a single packaged unit—"heterogenous integration"—thereby producing "chiplets" that are potentially competitive with the performance of advanced AI devices fabricated with EUV technology.[65]

Hybrid bonding is a method used to vertically connect fabricate wafers using closely spaced copper pads, creating an extremely short interconnect distance between different kinds of chips, enabling

3D stacking. The 2024 CSIS report makes note of a worrying example: the Jasminer X4, a crypto mining device that employs DRAM-to-logic hybrid bonding in a stack packaged together, the "first demonstrated commercial use of DRAM-to-logic hybrid bonding," illustrating Chinese engineers' ability to "work around U.S. regulations to manufacture high-performance chips."[66]

The report observes that U.S. export controls "may well have created a generation of Chinese innovators that seek to push the boundaries of semiconductor technology via advanced packaging," having been "forced to invent new technologies to design around U.S. regulations." The report concludes that the shift from copying to innovating "is a potential sea change in U.S.-China technological competition."[67] Chinese manufacturers are heavily dependent on imported equipment for their advanced packaging operations; according to one source, domestic equipment suppliers meet only about 14 percent of the country's demand for back-end equipment.[68] The major foreign equipment producers are based in Germany, Hong Kong/Singapore, Japan, the Netherlands, South Korea, and the United States.[69]

In 2025, a former Department of Commerce official characterized U.S. and allied restrictions on transfers of EDA design tools to China as a "true choke point," given that such tools are necessary for the design of chips at the most advanced nodes (7, 5, 3, and 2 nm and below), where complexity makes automated design essential.[70] Chinese government and industry leaders have long recognized the country's reliance on foreign EDA tools as a significant vulnerability and have been engaged in an effort to develop an indigenous capability for a number of years.[71]

In May 2025, the Trump administration imposed a broad control on software from leading U.S. EDA firms but lifted that measure in July as a concession in trade negotiations.[72] Targeted controls on advanced EDA software, however, predated the May 2025 action and continue to apply. This short-lived U.S. action served only to underscore the fact that China's weakness in EDA can be weaponized, and China has not abandoned its pursuit of self-reliance in this critical area. In August 2025, Empyrean Technology, China's top semiconductor design software company, disclosed that it had achieved breakthroughs in design tools for memory chips and panel displays, providing "fresh evidence of how China is slowly moving towards self-sufficiency in critical areas such as [EDA] for chip design and operating systems."[73]

China's progress in advanced packaging also depends on imported equipment. Unlike some other semiconductor choke points, the advanced packaging equipment sector is diversified and not dominated by U.S. firms; leading suppliers are based in Austria, Germany, Japan, Singapore, and the Netherlands, as well as in the United States. This makes packaging a more difficult area for unilateral U.S. controls to shape and increases the importance of allied alignment.

China's adaptation is only one side of the policy equation. Semiconductor export controls also impose costs on the countries that deploy them, especially when the controlled technologies are central to the revenues of globally competitive industries. As noted above, the same measures intended to limit China's capabilities can reduce revenues for U.S. firms, weaken incentives for R&D, encourage foreign and Chinese firms to design out U.S. technology, and complicate allied coordination.

Costs and Risks for the United States

Revenue and R&D Impacts on U.S. Firms

Export controls have compelled U.S. semiconductor device and equipment firms to forgo sales of restricted products to China. There is no reliable aggregate estimate of foregone revenues, because the restrictions change frequently and company disclosures are limited. Even so, available evidence and informed estimates suggest that the commercial impact is substantial.

The Federal Reserve Bank of New York released a study in April 2024 reporting that announcements of U.S. export controls were associated with negative effects on affected U.S. semiconductor firms, including a 2.5 percent decline in stock prices, and an 8.6 percent decline in revenue.[74] At the same time, the market impact has not been uniformly negative. The market capitalization and revenues of several major U.S. SME firms recovered and increased significantly through 2024 and 2025, buoyed in part by the global AI boom and strong demand for advanced manufacturing capacity.[75]

Nvidia designed the H20 GPU to comply with Biden-era rules on exports of advanced chips to China. The H20's performance placed it below the threshold established by the BIS. But in January 2025, the BIS placed restrictions on exports of the H20 and a similar device made by AMD to China.[76] Nvidia recorded a revenue loss of $2.2 billion in the first quarter of 2026, which it attributed to lost H20 sales.[77]

The Trump administration subsequently reversed the restrictions on export of the H20 to China, an indicator that the original restriction was excessive, but the revenues lost as a result of the original ban are unlikely to be recovered. Controls affect a subset of U.S. semiconductor device sales to

China, so that their revenue impact varies according to the extent of decoupling that occurs as the controls are expanded or relaxed.

The ITIF released a study in November 2025 that modeled the impact on U.S. semiconductor revenues based on various degrees of decoupling of the U.S. and Chinese semiconductor ecosystems. The report noted that in 2024, China accounted for 24 percent of the global chip market, and that U.S. firms supplied 50.4 percent of that demand ($77 billion). The study concluded that even a 25 percent decoupling would result in annual lost revenues to U.S. firms of $19.2 billion.[78] Between 2015 and 2024, the U.S. semiconductor industry invested an annual average of 18.3 percent of its revenues in R&D to develop the next generation of globally competitive chips. ITIF calculates that industry R&D investments would decline by an annual $3 billion under a 25 percent decoupling scenario.[79]

With respect to SME, a 2025 CSIS study found that Chinese semiconductor manufacturers were designing out U.S. chipmaking equipment produced by firms including Lam Research, Applied Materials, and KLA Tencor, reflecting both top-down pressure from government officials and bottom-up pressure to minimize exposure to existing and potential U.S. export controls.

A long-standing Chinese effort to replace U.S.-made SME in Chinese chipmaking plants "went into overdrive" when the United States imposed new export controls on semiconductor technology in October 2022, with leading chip manufacturers collaborating with domestic SME makers to accelerate their development of competitive tools.[80] In interviews conducted for the 2025 report, the authors found that Chinese chipmakers have also turned to non-U.S. third countries such as Germany, Japan, South Korea, Taiwan, and the Netherlands as sources for SME, reflecting the fact that these countries' restrictions on exports to China are not as stringent as those of the United States.

Allied-nation SME firms are thus cutting into U.S. companies' China markets and are reportedly warning customers that progressively tightening U.S. controls make U.S.-based firms—even those that are not currently restricted—high-risk sources of vital tools.[81] Foreign makers of SME are also designing out U.S. technology and parts to avoid coming under the extraterritorial reach of U.S. controls, which restrict export of machines to China that (1) exceed a de minimis threshold of restricted U.S. content or (2) are subject to FDP rules, which restrict exports to China of certain products that are the "direct product" of U.S.-origin restricted software, equipment, or other technology.[82]

Some U.S. SME firms have released figures on revenues foregone as a result of U.S. export controls. In late 2025, Applied Materials, the leading U.S. maker of SME, reported that as a result of recently imposed export restrictions on its sales to China, it would experience an annual reduction in revenues to the tune of $710 million.[83]

The commercial effects of export controls raise a broader governance concern. As the regime expands and affects larger portions of the semiconductor market, it becomes easier for policymakers to use export controls for purposes beyond their original national security rationale.

This shift risks weakening the credibility, discipline, and predictability that an effective export control system requires.

Moving Beyond National Security

Chip export controls are being used in ways that are unrelated to the narrow national security objectives set forth by the Biden administration in 2022. Those controls were justified as necessary because "these items and capabilities are used by the PRC to produce advanced military systems including weapons of mass destruction; improve the speed and accuracy of its decision making, planning and logistics, as well as of its autonomous military systems; and commit human rights abuses."[84]

Recent events have raised the fundamental question of whether U.S. chip export controls have come unmoored from their original national security purpose–and, indeed, whether they remain a viable policy tool at all. Over the past few years, export controls have changed a great deal.[85] Recent measures by the second Trump administration are indicative of a rudderless policy with, at best, a tangential relationship with national security.

Trade Bargaining Chips

On July 15, 2025, Commerce Secretary Howard Lutnick announced that the BIS would allow the export of Nvidia's H20, AMD's MI308, and equivalent artificial intelligence chips to China.[86] Some have welcomed this development, but questions exist as to if the measure was part of a coherent scheme to limit the scope of the controls to items that are truly critical to national security, or a transactional move disconnected from such concerns. Lutnick characterized the move as linked to a deal with China on that country's export restrictions on rare earths and magnets. Treasury Secretary Scott Bessent reportedly framed the deal as part of the broader U.S.-China negotiations in Geneva and London, suggesting that the United States used it as leverage in exchange for concessions sought from China.[87]

The announcement came three months after the BIS had placed restrictions on the export of Nvidia's H20, AMD's MI308, and equivalent chips to China because they were contributing to China's development of artificial intelligence in ways that were harmful to U.S. national security.[88] At the time, Dartmouth's Jennifer Lind described the deal as "suggest[ing] that under the Trump administration, what gets banned or permitted is not being driven by careful calculations about the effect on Chinese military power—but rather on political whim and personalist politics. This is ruinous for a functioning export control regime."[89]

Controls for Revenue Generation

On August 10, 2025, the New York Times reported that Nvidia and Advanced Micro Devices would be required to pay the United States 25 percent of the revenues derived from the sale of advanced AI chips to China, which could bring in over $2 billion to the federal government.[90] The 25 percent tax on U.S. AI chip sales to China drew sharp criticism from Republican and Democratic members of Congress, industry representatives, and former U.S. trade officials.

On August 11, 2025, House Select Committee on China Chairman John Moolenaar (R-MI) expressed concern about the U.S. government receiving a share of the proceeds from advanced chip sales to China, arguing that tying export licenses to government revenue could create incentives to approve sales that strengthen China's AI capabilities.[91] Raja Krishnamoorthi (D-IL), ranking member of the House Select Committee on the Strategic Competition Between the United States and the Chinese Communist Party, criticized the measure as a misuse of export controls, arguing that tying export licenses to government revenue could compromise national security objectives and signal that U.S. security restrictions were negotiable.[92] Chris Padilla, a former assistant secretary at the BIS during the George W. Bush administration, criticized the arrangement, arguing that using national security export controls to generate payments from companies could set a dangerous precedent and put U.S. military personnel and technological advantages at risk.[93]

Some legal observers contend that the 15 percent payments are de facto export taxes, which are inconsistent with Article I, Section 9, Clause 5, of the Constitution, which provides that "No Tax or Duty shall be laid on articles exported from any State."[94]

The Senate version of the 2026 National Defense Authorization Act (NDAA), passed on October 9, 2025, contains a bipartisan amendment, the Guaranteeing Access and Innovation for National Artificial Intelligence (GAIN AI) Act, which would give U.S. customers a right of first refusal with respect to semiconductor products before a chipmaker could secure an export authorization for those products. Although the it was dropped from the NDAA, the concepts underlying GAIN AI are apparently still being considered by policymakers. U.S. officials are reportedly weighing measures requiring foreign countries who purchase U.S. AI chips in amounts surpassing specific numerical thresholds to invest in U.S. data centers and provide government-to-government security guarantees.[95]

These trends reflect what scholars Jennifer Lind and Michael Mastanduno characterize as the "politicization of export controls." [96] Once created, the controls represent a regulatory regime that can be invoked by government officials and political leaders to pursue diverse objectives far removed from their original grounding in national security concerns.

Taken together, these risks do not mean that export controls should be abandoned. But controls *should* be treated as a limited instrument within a comprehensive strategy for technological competition. If the United States seeks durable leadership in semiconductors and other foundational technologies, it must pair carefully targeted denial measures with a broader agenda aimed at strengthening its own innovation system.

A Positive Agenda for Technology Leadership

Historical experience suggests that durable technological leadership depends less on slowing competitors and more on accelerating domestic innovation. During the Cold War, Western technological superiority rested much more on sustained investments and early procurement of innovative products than on efforts to restrict Soviet access to strategic technologies. If export controls are to contribute effectively to U.S. national security today, they should be integrated into a broader strategy focused on strengthening the foundations of U.S. technological leadership in research funding, talent training, and acquisition, as well as incentives for investment in advanced manufacturing.

In May 2023, a CSIS study observed that "the important question is not how to hold China back [in terms of chip export controls], as the U.S. capability for doing that is limited, but rather how to stay ahead."[97] The need to "run faster" by fostering innovation to counter threats from Chinese state-backed industrial policies has long been recognized by the U.S. semiconductor industry. In order to maintain leadership in chips, the United States must outpace competitors by investing in technological frontiers, an effort that requires strong public-private collaboration.[98]

Semiconductor export controls can help delay China's access to specific technologies, but they cannot substitute for a broader strategy of technological leadership. The Cold War lesson is instructive chiefly because it underscores the importance of national innovation capacity where Western advantage rested not only on denying strategic technologies to adversaries, but also on pushing ahead through sustained investment in research, talent, manufacturing, and commercialization.

In today's far more integrated and dynamic semiconductor ecosystem, the key strategy is to ensure that the United States continues to strengthen the foundations of its own innovation system that are needed to make technological leadership durable, while avoiding short-term measures that harm the long-term growth of the industry.

Too often, U.S. policymakers appear to assume that American leadership in semiconductor design and equipment is an enduring advantage that can be leveraged indefinitely. That assumption is risky. Export controls can protect security-sensitive choke points, but using them for short-term trade bargaining, revenue generation, or broad industrial rationing undermines their credibility and encourages China and other firms to design around U.S. technology. If a control is essential for national security, it should be stable, defensible, and coordinated with allies; if it can be negotiated away in the next trade round, it will not command durable support from industry or allied governments.

A more effective strategy would pair narrowly tailored controls with affirmative measures to strengthen the U.S. innovation base. First, export controls should be limited to clearly identified national security choke points and grounded in stable licensing standards that allies and industry can understand. Second, the United States should expand long-term federal support for semiconductor research, including materials, advanced packaging, lithography, memory, EDA, and manufacturing science. Third, policy should strengthen the talent pipeline through science, technology, engineering, and mathematics (STEM) education, immigration pathways for highly skilled technical workers, and training programs linked to fabrication plants, equipment makers, and design firms. Fourth, the United States should use procurement, tax incentives, and public-private partnerships to accelerate commercialization of frontier technologies, particularly in areas where private firms underinvest due to uncertain returns or broad spillovers. Finally, allied coordination should focus not only on denial measures but also on shared investment, supply chain resilience, and common standards that preserve the advantages of an open innovation ecosystem.

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Endnotes

1 Mikołaj Barczentewicz, "US Export Controls on AI and Semiconductors: Two Divergent Visions," International Center for Law & Economics, March 24, 2025, https://laweconcenter.org/resources/us-export-controls-on-ai-and-semiconductors-two-divergent-visions/.

2 Carnegie Endowment for International Peace, "What the U.S.-China Tech Wars Mean for Main Street," May 1, 2019, https://carnegieendowment.org/events/2019/05/what-the-us-china-tech-wars-mean-for-main-street.

3 Arms Export Control Act, 22 U.S.C. § 2778, "Control of Arms Exports and Imports," (1976) https://uscode.house.gov/view.xhtml?req=(title:22%20section:2778%20edition:prelim).

4 National Research Council, *Finding Common Ground: U.S. Export Controls in a Changed Global Environment* (Washington, DC: National Academies Press, 1991), https://www.nationalacademies.org/read/1617/chapter/8; and Ramon Marks, "Commentary—Can Export Controls Win a New Cold War: A Historical Case Study," Jamestown Foundation, June 22, 2023, https://jamestown.org/commentary-can-export-controls-win-a-new-cold-war-a-historical-case-study/.

5 Defense Institute of Security Assistance Management, *The Management of Security Assistance* (Washington, DC: Defense Institute of Security Assistance Management), 5, https://apps.dtic.mil/sti/tr/pdf/ADA449546.pdf.

6 U.S. General Accounting Office, Export Controls: U.S. Policies and Procedures Regarding the Soviet Union (Washington, DC: U.S. General Accounting Office, May 1990), 10-11, https://www.gao.gov/assets/nsiad-90-185fs.pdf.

7 Jennifer Lind and Michael Mastanduno, "Hard Then, Harder Now: CoCom's Lessons and the Challenge of Crafting Effective Export Controls Against China," *Texas National Security Review* 8, no. 4 (Fall 2025), https://tnsr.org/2025/09/hard-then-harder-now-cocoms-lessons-and-the-challenge-of-crafting-effective-export-controls-against-china/.

8 Sheena Chestnut Greitens, Rana Siu Inboden, and Adam I. Klein, *China's Authoritarian Exports* (Austin, TX: Robert Strauss Center for International Security and Law, University of Texas at Austin, July 2025), https://www.strausscenter.org/wp-content/uploads/Chinas-Authoritarian-Exports.pdf.

9 Christopher A. Casey and Karen M. Sutter, "U.S. Export Controls and China," Congressional Research Service, *In Focus*, March 24, 2022, https://www.congress.gov/crs-product/IF11627.

10 Bureau of Industry and Security, "Determine What Is Subject to the EAR," https://www.bis.gov/licensing/determine-what-is-subject-to-the-EAR.

11 Bureau of Industry and Security, "Commerce Strengthens Export Controls to Restrict China's Capability to Produce Advanced Semiconductors for Military Applications," press release, December 2, 2024, https://www.bis.gov/press-release/commerce-strengthens-export-controls-restrict-chinas-capability-produce-advanced-semiconductors-military.

12 Jing Zhang et al., "Japan and the Netherlands Agree to New Restrictions on Exports of Chip-Making Equipment to China," Mayer Brown, February 28, 2023, https://www.mayerbrown.com/en/insights/publications/2023/02/japan-and-the-netherlands-agree-to-new-restrictions-on-exports-of-chipmaking-equipment-to-china.

13 Barath Harithas and Andreas Schumacher, "Where the Chips Fall: U.S. Export Controls Under the Biden Administration from 2022 to 2024," CSIS, *Commentary*, December 12, 2024, https://www.csis.org/analysis/where-chips-fall-us-export-controls-under-biden-administration-2022-2024.

14 Gregory C. Allen, "Understanding the Biden Administration's Updated Export Controls," CSIS, December 11, 2024, https://www.csis.org/analysis/understanding-biden-administrations-updated-export-controls.

15 Alison J. Stafford Powell, Paul Amberg, and Rob O'Brien, "US Department of Commerce Significantly Expands Controls Targeting Indigenous Production of Advanced Semiconductors in China," Baker McKenzie, *Global Sanctions and Export Controls Blog*, December 6, 2024, https://sanctionsnews.bakermckenzie.com/us-department-of-commerce-significantly-expands-controls-targeting-indigenous-production-of-advanced-semiconductors-in-china/.

16 David Atkinson and Francis Maude, "Cocom," Parliamentary Debates, Commons, 5th ser., vol. 164, December 21, 1989, https://hansard.parliament.uk/commons/1989-12-21/debates/9fe9d412-016b-4c6e-95c2-cbba20dd928c/Cocom; Marks, "Commentary—Can Export Controls Win a New Cold War"; and Lind and Mastanduno, "Hard Then, Harder Now."

17 Director of Central Intelligence, *The Technology Acquisition Efforts of the Soviet Intelligence Services* (Langley, VA: CIA, June 1982), https://www.cia.gov/readingroom/docs/CIA-RDP84B00049R001403390009-8.pdf.

18 James Plousadis, "Soviet Diversion of United States Technology: The Circumvention of Cocom and the United States Reexport Controls, and Proposed Solutions," *Fordham International Law Journal* 7, no. 3 (1983): 566–67, https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=1095&context=ilj.

19 Ibid., 576–78.

20 Lily Ottinger "The Cold War History of Export Controls," ChinaTalk, https://www.chinatalk.media/p/learning-from-cocom.

21 David E. Sanger, "4 in France Arrested in Soviet Sale," *New York Times*, April 23, 1988, https://web.archive.org/web/20150525091920/http://www.nytimes.com/1988/04/23/business/4-in-france-arrested-in-soviet-sale.html.

22 CIA, *The Impact of Technological Transfer on the USSR* (Langley, VA: CIA, June 1974), 8, https://www.cia.gov/readingroom/docs/CIA-RDP85T00176R000900010003-4.pdf.

23 Chi Ling Chan, "Fallen Behind: Science, Technology and Soviet Statism," *Intersect: The Stanford Journal of Science, Technology, and Society* 8, no. 3 (2015): 5–6, https://ojs.stanford.edu/ojs/index.php/intersect/article/view/691/659.

24 Ibid., 8.

25 CIA, *The Impact of Technological Transfer*, 3.

26 Chan, "Fallen Behind," 5.

27 Michael Mastanduno, remarks in "Cold War Lessons for Export Controls Against China," *Texas National Security Review*, November 4, 2025, https://tnsr.org/2025/11/cold-war-lessons-for-export-controls-against-china/.

28 Jennifer Lind, remarks in "Cold War Lessons for Export Controls Against China," *Texas National Security Review*, November 4, 2025, https://tnsr.org/2025/11/cold-war-lessons-for-export-controls-against-china.

29 Fan Feifei, "Innovations Speed Modern Industrial Journey," *China Daily*, October 19, 2025, https://www.chinadailyhk.com/hk/article/621984; Benjamin Plackett, "China Accounts for More Than Half of Leading Output in the Applied Sciences," *Nature*, December 3, 2025, https://www.nature.com/articles/d41586-025-03715-z.

30 Scott Kennedy, *The Power of Innovation: The Strategic Value of China's High-Tech Drive* (Washington, DC: CSIS, March 2026), 34, https://www.csis.org/analysis/power-innovation-strategic-value-chinas-high-tech-drive.

31 Kirti Gupta, Chris Borges, and Andrea Leonard Palazzi, "Collateral Damage: The Domestic Impact of U.S. Semiconductor Export Controls," CSIS, *Commentary*, July 9, 2024, https://www.csis.org/analysis/collateral-damage-domestic-impact-us-semiconductor-export-controls.

32 Trelysa Long, "Decoupling Risks: How Semiconductor Export Controls Could Harm U.S. Chipmakers and Innovation," Information Technology and Innovation Foundation, November 10, 2025, https://itif.org/publications/2025/11/10/decoupling-risks-semiconductor-export-controls-harm-us-chipmakers-innovation/.

33 Aidan Powers-Riggs, Brian Hart, and Matthew P. Funaiole, "The U.S.-China Trade Truce Has Not Solved the Gallium Problem," CSIS, *Commentary*, May 11, 2026, https://www.csis.org/analysis/us-china-trade-truce-has-not-solved-gallium-problem.

34 Kandy Wong, "China's Gallium Grip Looms over Trump's Beijing Visit as Critical Deadline Nears," *South China Morning Post*, February 20, 2026, https://www.scmp.com/economy/china-economy/article/3344151/chinas-gallium-grip-looms-over-trumps-beijing-visit-critical-deadline-nears.

35 U.S. Geological Survey, *Mineral Commodity Summaries 2026: Gallium* (Reston, VA: U.S. Geological Survey, 2026), https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-gallium.pdf.

36 William Alan Reinsch, Matthew Schleich, and Thibault Denamiel, "Insight into the U.S. Semiconductor Export Controls Update," CSIS, *Critical Questions*, October 20, 2023, https://www.csis.org/analysis/insight-us-semiconductor-export-controls-update.

37 Gregory C. Allen and Isaac Goldston, *Understanding U.S. Allies' Current Legal Authority to Implement AI and Semiconductor Export Controls* (Washington, DC: CSIS, March 2025), https://www.csis.org/analysis/understanding-us-allies-current-legal-authority-implement-ai-and-semiconductor-export.

38 Sujai Shivakumar, Charles Wessner, and Thomas Howell, "The Limits of Chip Export Controls in Meeting the China Challenge," CSIS, *Commentary*, https://www.csis.org/analysis/limits-chip-export-controls-meeting-china-challenge.

39 Erich Grunewald and Tim Fist, *Countering AI Chip Smuggling Has Become a National Security Priority* (Washington, DC: Center for a New American Security, June 2025), https://www.cnas.org/publications/reports/countering-ai-chip-smuggling-has-become-a-national-security-priority.

40 Ana Swanson, "China's A.I. Industry Has Access to Plenty of Advanced Nvidia Chips," *New York Times*, August 4, 2024, https://www.nytimes.com/2024/08/04/technology/china-ai-microchips-takeaways.html.

41 William Alan Reinsch and Altynay Junusova, *The Double-Edged Sword of Semiconductor Export Controls: Electronic Design Automation* (Washington, DC: CSIS, October 2025), 29–33, https://www.csis.org/analysis/double-edged-sword-semiconductor-export-controls-electronic-design-automation.

42 "Made in China 2025 and Semiconductors," Semi-Literate, December 20, 2020, https://semiliterate.substack.com/p/made-in-china-2025-and-semiconductors; "Ask the Experts: Is China's Semiconductor Strategy Working?" Center for Security and Emerging Technology, September 1, 2022, https://cset.georgetown.edu/article/ask-the-experts-is-chinas-semiconductor-strategy-working/; and Alice Li, "Where Has China's Push for Chip Self-Reliance Taken It?," *Korea Times*, February 21, 2026, https://www.koreatimes.co.kr/business/20260221/where-has-chinas-push-for-chip-self-reliance-taken-it.

43 William Alan Reinsch et al., *The Double-Edged Sword of Semiconductor Export Controls: Introduction and Advanced Packaging Technologies* (Washington, DC: CSIS, October 2024), 10, https://www.csis.org/analysis/double-edged-sword-semiconductor-export-controls.

44 Ibid., 10–11.

45 Ann Cao, "Chinese AI Chipmaker Moore Threads Sees Tripling Revenue amid Self-Sufficiency Push," *South China Morning Post*, January 22, 2026, https://www.scmp.com/tech/big-tech/article/3340836/chinese-ai-chipmaker-moore-threads-sees-tripling-revenue-amid-self-sufficiency-push.

46 Ann Cao, "Alibaba AI Chip Push Hits 100,000 Mark, Beating Local Rival Cambricon," *South China Morning Post*, January 30, 2026, https://www.scmp.com/tech/article/3341860/alibaba-ai-chip-push-hits-100000-mark-beating-local-rival-cambricon-sources.

47 Vincent Chow, "Zhipu AI Breaks US Chip Reliance with First Major Model Trained on Huawei Stack," *South China Morning Post*, January 14, 2026, https://www.scmp.com/tech/tech-war/article/3339869/zhipu-ai-breaks-us-chip-reliance-first-major-model-trained-huawei-stack.

48 Dashveenjit Kaur, "What Three Years of US Sanctions Did to Huawei," *Tech Wire Asia*, March 21, 2023, https://techwireasia.com/2023/03/what-three-years-of-us-sanctions-did-to-huawei/.

49 "Huawei Reshapes Supply Chain for the Digital Era," Huawei, March 2022, https://www.huawei.com/en/huaweitech/publication/202203/huawei-reshape-supply-chain-digital-era; Reinsch et al., *The Double-Edged Sword of Semiconductor Export Controls: Semiconductor Manufacturing Equipment*, 26–27. https://www.csis.org/analysis/double-edged-sword-semiconductor-export-controls-semiconductor-manufacturing-equipment.

50 Che Pan, "While under US Sanctions, Where Did Huawei Get Advanced Chips for Its Latest Mate 60 Pro Smartphone?" *South China Morning Post*, September 2, 2023, https://www.scmp.com/tech/big-tech/article/3233166/while-under-us-sanctions-where-did-huawei-get-advanced-chips-its-latest-mate-60-pro-smartphone.

51 Rodrigo Balbontin, "Backfire: Export Controls Helped Huawei and Hurt U.S. Firms," Information Technology and Innovation Foundation, October 27, 2025, https://itif.org/publications/2025/10/27/backfire-export-controls-helped-huawei-and-hurt-us-firms/.

52 Eunice Xu, "The Great Chip Leap: China's Semiconductor Equipment Self-Reliance Surges Past Targets," *South China Morning Post*, January 9, 2026, https://www.scmp.com/tech/big-tech/article/3339366/great-chip-leap-chinas-semiconductor-equipment-self-reliance-surges-past-targets.

53 Woo Seung-ho, "China's Semiconductor Equipment Self-Sufficiency Push Intensifies; Tech Leak Arrests Surge 42%," *Seoul Economic Daily*, January 20, 2026. https://en.sedaily.com/finance/2026/01/20/chinas-semiconductor-equipment-self-sufficiency-push.

54 Reuters, "China Mandates 50% Domestic Equipment Rule for Chipmakers, Sources Say," December 30, 2025, https://www.reuters.com/world/china/china-mandates-50-domestic-equipment-rule-chipmakers-sources-say-2025-12-30/.

55 TrendForce, "China's Domestic Chip Equipment Adoption Beats 2025 Target at 35%, Led by NAURA, AMEC," January 12, 2026, https://www.trendforce.com/news/2026/01/12/news-chinas-domestic-chip-equipment-adoption-beats-2025-target-at-35-led-by-naura-amec/.

56 Eunice Xu, "The Great Chip Leap: China's Semiconductor Equipment Self-Reliance Surges Past Targets," *South China Morning Post*, January 9, 20206, https://www.scmp.com/tech/big-tech/article/3339366/great-chip-leap-chinas-semiconductor-equipment-self-reliance-surges-past-targets.

57 Zhang Tong, "Chinese Scientists Shrink Semiconductor Chip into Fibre as Thin as Human Hair," *South China Morning Post*, January 24, 2026, https://www.scmp.com/news/china/science/article/3341025/chinese-scientists-shrink-semiconductor-chip-fibre-thin-human-hair.

58 Zhang Tong, "Could China's Ion Implanter 'Scalpel' Carve Out Secure Hi-Tech Chip Supply Chains?" *South China Morning Post*, Jauary 18, 2026, https://www.scmp.com/news/china/science/article/3340321/could-chinas-ion-implanter-scalpel-carve-out-secure-hi-tech-chip-supply-chains.

59 Coco Feng, "Top Chip Leaders Urge National Drive to Build 'China's ASML' amid US Curbs," *South China Morning Post*, March 5, 2026, https://www.scmp.com/tech/article/3345557/top-chip-leaders-urge-national-drive-build-chinas-asml-amid-us-curbs.

60 Ibid.

61 Ibid.

62 Roberto Frazzoli, "Taking Stock of China's EUV Lithography Efforts," Power Electronics News, February 17, 2026, https://www.powerelectronicsnews.com/taking-stock-of-chinas-euv-lithography-efforts/.

63 Ibid.

64 Anton Shilov, "SMIC and Huawei could use quadruple patterning for China-made 5nm chips: Report," Tom's Hardware, March 24, 2024, https://www.tomshardware.com/tech-industry/semiconductors/smic-and-huawei-could-use-quadruple-patterning-for-chinese-5nm-chips-report

65 William Alan Reinsch et al., *The Double-Edged Sword of Semiconductor Export Controls: Introduction and Advanced Packaging Technologies*, 15.

66 Ibid., 20.

67 Ibid., 20.

68 "How Do Advanced Packaging Equipment and Materials Enable Heterogeneous Integration?" TSPA Semiconductor, https://tspasemiconductor.substack.com/p/how-do-advanced-packaging-equipment.

69 "Semiconductor Equipment Supply Chain Ecosystem for Advanced Packaging," , IEEE Electronics Packaging Society, December 5, 2024, https://r6.ieee.org/scv-eps/wp-content/uploads/sites/58/2024/10/eps2412a.pdf; and "Advanced Packaging Equipment and Materials," TSPA Semiconductor.

70 Pablo Valerio, "U.S. Restricts EDA Software Sales to China," EE Times, May 30, 2025, https://www.eetimes.com/u-s-restricts-eda-software-sales-to-china/.

71 "PRC Pursues Chip Design Software Dominance," Jamestown Foundation, March 15, 2024, https://jamestown.org/prc-pursues-eda-software-dominance/.

72 Karen Freifeld and Surbhi Misra, "As Trade War Truce with China Holds, US Lifts Curbs for Chip Design Software and Ethane," Reuters, July 3, 2025, https://www.reuters.com/world/china/siemens-says-us-has-lifted-chip-software-curbs-china-bloomberg-news-reports-2025-07-03/.

73 Coco Feng, "Tech War: Chinese EDA Leader Empyrean Announces Breakthroughs in Chip Design Software," *South China Morning Post*, August 19, 2025, https://www.scmp.com/tech/article/3322366/tech-war-chinese-eda-leader-empyrean-announces-breakthroughs-chip-design-software.

74 Reinsch et al., *The Double-Edged Sword of Semiconductor Export Controls: Semiconductor Manufacturing Equipment*, 25, https://www.csis.org/analysis/double-edged-sword-semiconductor-export-controls-semiconductor-manufacturing-equipment

75 Stanford Institute for Human-Centered Artificial Intelligence, "Economy," in *The 2025 AI Index Report* (Stanford, CA: Stanford University, 2025), https://hai.stanford.edu/ai-index/2025-ai-index-report/economy.

76 "U.S. Issues Export Licensing Requirements for Nvidia, AMD Chips to China," Reuters, April 16, 2025, https://www.cnbc.com/2025/04/16/us-issues-export-licensing-requirements-for-nvidia-amd-chips-to-china.html.

77 "NVIDIA Beats Q1 Expectations, Warns of $8B Q2 Hit from H20 China Export Curbs," TrendForce, May 29, 2025, https://www.trendforce.com/news/2025/05/29/news-nvidia-beats-q1-expectations-warns-of-8b-q2-hit-from-h20-china-export-curbs/.

78 Treysa Long, *Decoupling Risks: How Semiconductor Export Controls Could Harm U.S. Chipmakers and Innovation* (Washington, DC: Information Technology and Innovation Foundation, November 2025), https://www2.itif.org/2025-semiconductor-export-controls.pdf.

79 Ibid.

80 William Alan Reinsch et al., *The Double-Edged Sword of Semiconductor Export Controls Introduction and Advanced Packaging Technologies*, 15.

81 Ibid., 19–22.

82 Ibid., 10-12

83 Nisha Gopalan, "Applied Materials Sees $710M Hit from China Curbs. Here's What You Should Know," Investopedia, October 3, 2025, https://www.investopedia.com/applied-materials-sees-710m-hit-from-china-curbs-heres-what-you-should-know-11823701.

84 Bureau of Industry and Security, "Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC)," press release, October 7, 2022, https://www.bis.gov/press-release/commerce-implements-new-export-controls-advanced-computing-semiconductor-manufacturing-items-peoples.

85 Nicholas Gordon, "U.S.-China Chip War: How Trump's Nvidia-AMD Deal Has Redefined Washington's Export Control Policy," *Fortune*, August 14, 2025, https://fortune.com/asia/2025/08/14/us-china-trump-revenue-share-export-controls-nvidia-amd/.

86 Kif Leswing, "Commerce Secretary Lutnick Says China Is Only Getting Nvidia's '4th Best' AI Chip," CNBC, July 15, 2025, https://www.cnbc.com/2025/07/15/howard-lutnick-says-china-is-only-getting-nvidias-4th-best-ai-chip.html.

87 Elaine Kurtenbach and Will Weissert, "Deal with Beijing Will Speed China's Export of Minerals to the US, Treasury Secretary Says," Associated Press, June 27, 2025, https://apnews.com/article/china-trade-earths-tariffs-trump-463ae8d6ccba15b56c7d4d31d3fc42a1.

88 "U.S. Confirms New Export Curbs on Nvidia and AMD Chips," *Wall Street Journal*, April 16, 2025, https://www.wsj.com/livecoverage/stock-market-trump-tariffs-trade-war-04-16-25/card/u-s-confirms-new-export-curbs-on-nvidia-and-amd-chips-fBcQ4j5ueZDe5fdxpKoQ.

89 Gordon, "U.S.-China Chip War."

90 Tripp Mickle, "U.S. Government to Take Cut of Nvidia and AMD A.I. Chip Sales to China," *New York Times*, August 10, 2025, https://www.nytimes.com/2025/08/10/technology/us-government-nvidia-amd-chips-china.html.

91 Maria Curi, "Trump Draws GOP Criticism on Nvidia AI Chip Deal," Axios, August 11, 2025, https://www.axios.com/pro/tech-policy/2025/08/11/trump-draws-gop-criticism-on-nvidia-ai-chip-deal.

92 Ari Hawkins, "Trump Defends Deal to Sell Nvidia Export-Control License," *Politico*, August 11, 2025, https://www.politico.com/news/2025/08/11/trump-defends-deal-to-sell-nvidia-export-control-license-00503778.

93 Christopher Padilla, "Statement of Christopher Padilla," testimony before the U.S. Senate Committee on Banking, Housing, and Urban Affairs, January 18, 2018, https://www.banking.senate.gov/imo/media/doc/Padilla%20Testimony%201-18-18.pdf.

94 "The AI Export Tax Won't Fly," *Wall Street Journal*, August 17, 2025, https://www.wsj.com/opinion/the-ai-export-tax-wont-fly-trump-nvidia-constitution-80fa9c9d; and Michael C. Dorf, "Are Trump's Deals with Nvidia and AMD Constitutional?" Verdict, August 19, 2025, https://verdict.justia.com/2025/08/19/are-trumps-deals-with-nvidia-and-amd-constitutional.

95 Alexandra Alper and Stephen Nellis, "US Mulls New Rules on AI Chip Exports, Including Requiring Investments by Foreign Buyers," Reuters, March 5, 2026, https://www.reuters.com/world/us-mulls-new-rules-ai-chip-exports-including-requiring-investments-by-foreign-2026-03-05/.

96 Lind and Mastanduno, "Hard Then, Harder Now."

97 William Allen Reinsch, Emily Benson, Thibault Denamiel, and Margot Putnam, *Optimizing Export Controls for Critical and Emerging Technologies: Semiconductors, Quantum Technology, AI, and Biotechnology* (Washington, DC: CSIS, May 2023), https://www.csis.org/analysis/optimizing-export-controls-critical-and-emerging-technologies.

98 President's Council of Advisors on Science and Technology, *Ensuring Long-Term U.S. Leadership in Semiconductors* (Washington, DC: Executive Office of the President, January 2017), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_ensuring_long-term_us_leadership_in_semiconductors.pdf.

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