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The True Impact of Allied Export Controls on the U.S. and Chinese Semiconductor Manufacturing Equipment Industries

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There is a fierce debate in the United States and among its allies about the impacts of export controls, and nowhere is that debate more heated than in the semiconductor equipment manufacturing industry. Too often, however, this debate occurs without any grounding in real-world data or relevant historical Chinese policy context. This paper seeks to provide some of that grounding through a combination of Chinese policy document analysis and new financial and market share data for leading semiconductor equipment firms in China, the United States, Japan, and the Netherlands. What follows are a set of 10 key judgments based on the author's analysis.

1. **China's ambitions for eliminating dependence on foreign semiconductor manufacturing equipment started long before America's expanded usage of technology export controls.**

The first and most important argument among **critics** of U.S. export controls is that they weaken U.S. technology leadership by incentivizing China to eliminate U.S. technology from its semiconductor supply chain. However, reducing dependence on foreign semiconductor and semiconductor manufacturing equipment suppliers was official Chinese policy before the Trump administration's April 2018 export controls restricting sales of U.S.-designed chips to ZTE, a Chinese telecommunications firm, launched the new era of semiconductor export controls. "**The Roadmap of Major Technical Domains for Made in China 2025**," which was published in September 2015 and covered semiconductors and other sectors, included goals such as "replacement of imports with Chinese-made products basically achieved in key industries" by 2025. It set specific targets and deadlines for the degree of market share that Chinese companies were supposed to reach and by what date. **Targets** for the semiconductor manufacturing equipment sector include the following:

- 50 percent localization rate of 90-32 nanometer (nm) process equipment before 2020
- 50 percent localization of 90 nm lithography machines before 2020
- 30 percent localization rate of 20-14 nm process equipment before 2025
- Domestic production of immersion deep ultraviolet (DUV) lithography machines before 2025
- Domestic production of extreme ultraviolet (EUV) lithography equipment before 2030

As the Made in China 2025 technical document roadmap **stated**,

> "meeting domestic market demand, improving the self-sufficiency rate of integrated circuit products, meeting national security needs, and occupying the strategic product market have always been the greatest demand and driving force for the development of the integrated circuit industry."

Even earlier policies, though less well resourced, sought to dramatically reduce use of foreign semiconductors and semiconductor manufacturing equipment. For example, the 2006 "Medium Long Range Plan for the Development of Science and Technology" **explicitly called for** self-sufficiency in semiconductor technologies and initiated so-called "mega projects" to drive toward that goal.

For more than a decade, China's government has provided lavish subsidies in the form of tax breaks, free land, government grants, and equity infusions to a number of Chinese semiconductor equipment companies. Naura, one of China's leading domestic Semiconductor Manufacturing Equipment companies received **$1.3 billion** in state support in 2021, even before the imposition of the Biden administration's export controls. AMEC, another leading Chinese semiconductor equipment company, received a **similar equity investment** from the "Big Fund" in 2015. Simply put, China's goal of semiconductor equipment industry localization and robust policy support predated any modern effort to impose meaningful export controls on China's chip fabrication capabilities.

2. **There is not a simple relationship between export controls and China's rate of technological progress. China's greatest progress came in sectors with no export controls.**

A September 2024 analysis by **Bernstein Research**, an equity research firm, included a review of China's semiconductor self-sufficiency goals from the 2015 roadmap and found that "China has made impressive progress and likely will beat the 'Made in China 2025' targets for integrated circuit (IC) Design and Manufacturing, but may miss the goals for IC equipment and Materials." As the Bernstein analysis shows, the rate of China's progress toward self-sufficiency is best predicted by the market and technological complexities of each semiconductor market segment, not by the extent to which export controls were applied. It is certainly not the case that the segments in which China has made the most progress–or even devoted the most resources–are the areas in which the United States has applied export controls most forcefully.

That there is not a simple relationship between export controls and China's technological progress should be obvious given that China has made **rapid progress** in other technological domains—such as **solar cells** and **electric vehicles (EVs)**—where the United States applied no export controls and in some cases actively supported the rise of a Chinese supply chain. The United States applied no export controls in the case of the equipment used to manufacture silicon solar cells, yet today China **dominates** both production of solar cells and production of the equipment used to make them. This equipment is in many ways similar to (though less sophisticated than) the equipment used to make and process silicon wafers for semiconductors. In fact, one Chinese company, Naura, is a domestic leader in both manufacturing equipment for both solar cells and semiconductors. The biggest difference in Chinese outcomes between those two industries is not the presence or absence of export controls but the far greater technological complexity of producing semiconductor manufacturing equipment.

The EV maker Tesla made a major push into Chinese manufacturing in late 2018, launching deep partnerships with many local Chinese suppliers, such as battery-maker CATL. As a November 2024 commentary in a major Chinese state-run newspaper **stated**:

> Tesla's rapid growth in sales, fueled by its technological and branding advantages and backed by China's massive consumer market, has driven the rapid development of upstream and downstream supply chains. Today, the localization rate of parts for Tesla's Shanghai Gigafactory exceeds 95%, with more than 60 suppliers integrated into Tesla's global supply chain.

The Chinese EV supply chain, which Tesla helped dramatically increase in both scale and technological sophistication, is now also **supplying Tesla's competitors**. Defections of Tesla-trained skilled employees are also a challenge. An April 2024 New York Times report **claimed** that most of Tesla's early Chinese employees now work at competing Chinese firms. In a January Tesla earnings call, Tesla CEO Elon Musk **said** "The Chinese car companies are the most competitive car companies in the world. . . . Frankly, I think if there are not trade barriers established, they will pretty much demolish most other companies in the world."

The point here is not to suggest with unwarranted certainty that export controls would have definitively prevented China's rise in the solar and EV industries. Rather, it is to caution the reader against relying too heavily on cursory anecdotal evidence to reach conclusions about when export controls do or do not work and what the counterfactual outcome would have been if export controls were or were not applied. Much depends upon the state of the global market landscape, the complexity of the controlled technology, the current technological sophistication of the targeted country, the design of the export control regulations, and the robustness of the controls' implementation and enforcement. Only a detailed analysis can hope to reach anything approaching insight.

3. **Semiconductor export controls—as implemented thus far—have in different ways and at different times both helped and hindered Chinese firms.**

Just as foreign firms have supported Chinese competitor growth in solar cells and EVs in the absence of export controls, so have they done in semiconductor manufacturing. The major semiconductor manufacturing equipment providers all have major service businesses, where, among other things, they train customer companies on how to get the most out of their equipment. Prior to the **October 2022** changes in U.S. export controls, this could include assisting with the facility planning, installation, repairs, and operational troubleshooting of equipment as part of advanced chip manufacturing operations. Industry sources told CSIS that this sometimes included contract research and development (R&D) of advanced node semiconductor process technology on behalf of or in partnership with Chinese clients. At least as of November 2024, this is still legal in the case of providing support to Chinese legacy chip manufacturing operations.

By contrast, earlier U.S. export controls meaningfully reversed progress in some segments of the Chinese semiconductor sector, such as **NAND memory** manufacturing and **smartphone chip design**, though the durability of those setbacks, even if temporary, will depend on many factors. More recent export controls have also made life harder in many ways for Chinese semiconductor equipment firms, who can no longer legally obtain U.S. subcomponents or technical expertise.

Thus, it is simply wrong to say that export controls always, in isolation, accelerate Chinese technological indigenization and that making it easier for U.S. firms to export will always slow Chinese indigenization.

At the same time, it is unambiguously the case that the United States' use of semiconductor export controls, beginning with ZTE in April 2018, made a massive impression on both political and corporate leaders in China. **Speeches** at the time by Chinese leadership, including General Secretary **Xi Jinping**, indicate that ZTE was viewed as a turning point and justified China's aggressive pursuit of "self-reliance" in science and technology. Pony Ma, the chairman of Tencent, one of China's largest technology firms, **said** in May 2018, "The recent ZTE incident made us see clearly that no matter how advanced our mobile payment is, without mobile devices, without microchips and operating systems, we can't compete competently."

The evidence goes beyond talk to specific actions. China made significant changes to its semiconductor policy in the years following ZTE, and China's central government **directed** local governments to "do everything in their power" to promote the semiconductor sector. Some Chinese companies also took drastic measures to respond after ZTE. For example, Nikkei Asia **reported** that Yangtze Memory Technologies Corporation (YMTC)—one of China's most advanced semiconductor manufacturers—began a full-blown de-Americanization campaign in 2019 involving the full-time work of more than 800 staff (both YMTC and its suppliers). This included the establishment of multiple new major partnerships with domestic Chinese equipment producers. Of note, at the time when YMTC began this de-Americanization initiative, no significant U.S. export controls applied to the company. YMTC began their work based on fear of future controls, not the reality of current ones.

Combined, this provides strong evidence that the export controls did increase the desire of both the Chinese government and Chinese companies to increase the capabilities of local semiconductor equipment providers, but that is not the same thing as saying that export controls caused accelerated indigenization, which depends upon more than just desire.

4. **The Biden administration's 2022 export controls strengthened a policy approach to semiconductor equipment controls that began in 2019 during the first Trump administration.**

As with chip export controls, the first Trump administration launched the U.S. government's modern approach to semiconductor manufacturing equipment export controls. According to reporting by **Reuters**, the U.S. government successfully persuaded the Dutch government in July 2019 to cancel the export license of EUV lithography equipment to SMIC, China's most advanced logic chip foundry. In December 2020, SMIC was **added** to the U.S. Department of Commerce's Entity List, prohibiting the company from buying certain kinds of U.S. equipment, specifically, "items uniquely required for production of semiconductors at advanced technology nodes (10 nanometers and below, including extreme ultraviolet technology)."

In October 2022, the Biden administration **significantly expanded** U.S. export controls on semiconductor manufacturing equipment, including not only Entity List and end-use restrictions but also some country-wide export controls that applied to China as a whole (including a use of the U.S. persons rule). Just as importantly, the Biden administration made some of these controls more multilateral in nature, **engaging Japan** and the **Netherlands** to overhaul their export control policies for advanced semiconductor manufacturing equipment. Even though these controls did not entirely align with U.S. controls, this was important to ensure that Dutch and Japanese companies did not provide China with alternative sources for the items that the United States was no longer willing to sell.

5. **Chinese semiconductor equipment firms started very small but have grown rapidly. However, this rapid growth occurred both before and after export controls and took place during a period of massive Chinese equipment demand growth.**

China's domestic semiconductor manufacturing equipment industry has long been both small and technologically inferior to the global state of the art. To understand the growth trajectory of the Chinese semiconductor manufacturing equipment sector, CSIS gathered market data on how China's global semiconductor manufacturing equipment market share has changed over time across both supply and demand (see Table 1).

Table 1: Chinese Semiconductor Equipment Global Supply and Demand Share

Chinese Semiconductor Equipment Global Market Share						
	2008	2011	2014	2017	2020	2023
Share of Global Supply	0.2%	0.3%	0.4%	0.71%	1.3%	3.2%
Share of Global Demand*	6.4%	8.4%	11.7%	14.5%	26.3%	34.4%

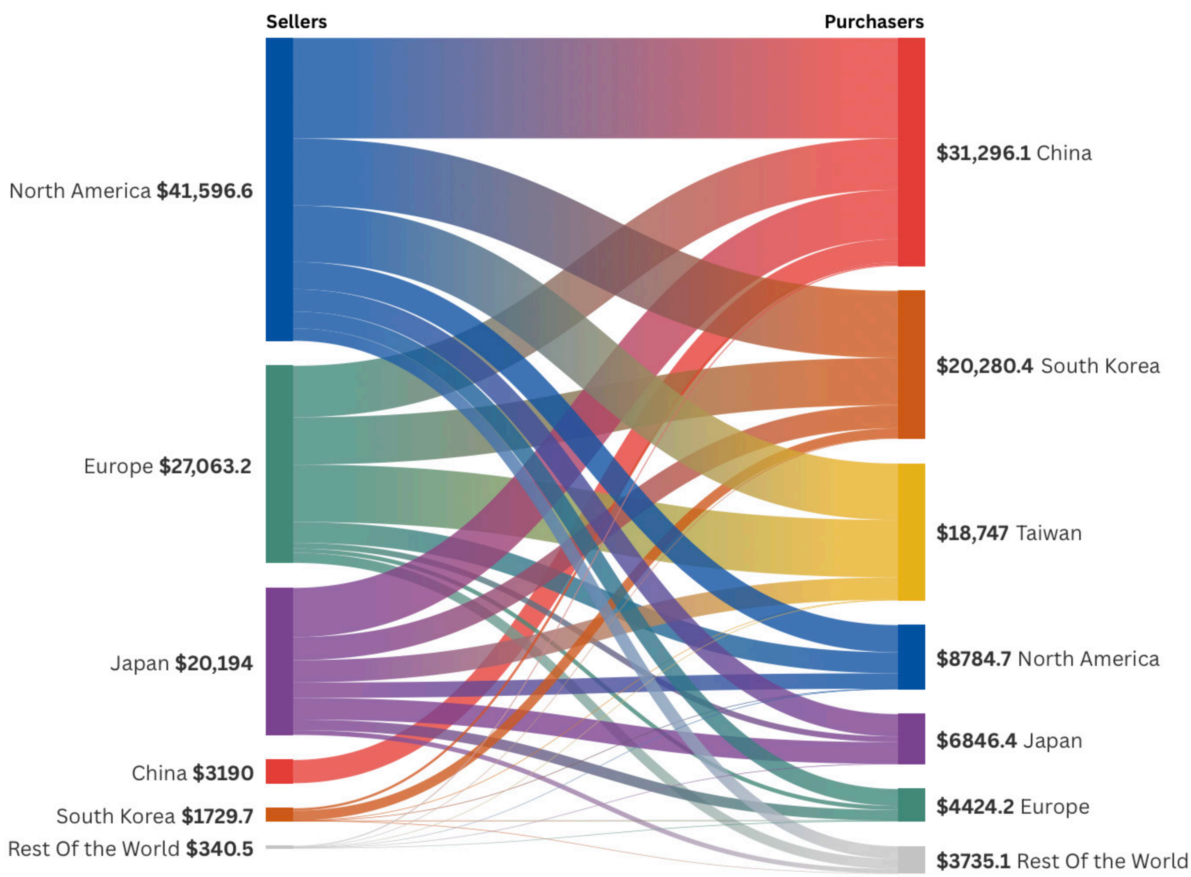
*Note: Includes Chinese-owned and foreign-owned semiconductor production facilities in China

Sources: CSIS Analysis; Semiconductor Equipment Association of Japan; "Semiconductor Equipment Database," TechInsights.

China has grown as both a supplier and as a buyer of semiconductor manufacturing equipment over the past 15 years. And while Chinese firms have in aggregate increased China's share of global supply, they remain quite small in comparison to foreign firms, providing only 3.2 percent of the equipment (by dollar value) globally and 9.6 percent of the equipment purchased by customers operating in China in 2023 (see Figure 1). Some industry sources, such as the research firm Sanford Bernstein, estimate that the Chinese domestic market share captured by Chinese equipment providers (aka Chinese self-sufficiency) is 15 percent. Whether the true figure is closer to 9.6 percent or 15 percent, the equipment that Chinese firms sell remains almost exclusively confined to legacy nodes and remains far behind the global state of the art. However, industry sources have told CSIS that Chinese equipment has grown in competitiveness compared with the legacy node equipment sold by leading global suppliers.

Until the Biden administration's **October 2022 export controls**, it was generally legal to sell critical subcomponents or expert consulting services to Chinese equipment firms, assisting with their growth in both sales and technological knowhow. In addition to voluntary foreign support, Chinese firms have benefitted from **industrial espionage** that has included **state-backed cyberattacks** on equipment companies. Chinese equipment firms have also benefitted from **hundreds of billions of dollars** in government investments, tax credits, and subsidies.

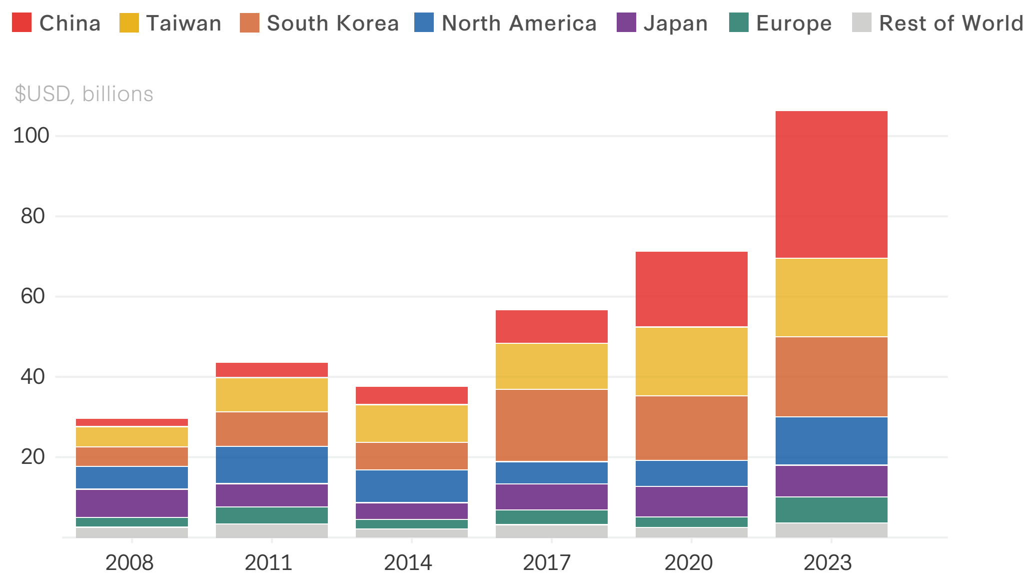
Figure 1: Global Semiconductor Manufacturing Equipment Supply and Demand by Region, 2023 ($USD, million)



Note: Supplier region refers to the country headquarters of the seller firm, which is not necessarily the same as the country from which the goods were exported; Buyer region refers to the location of the customer facility in which equipment is installed, whether that is a locally owned or foreign owned firm.

Source: CSIS Analysis; and "Semiconductor Equipment Database," TechInsights.

Figure 2: Semiconductor Equipment Demand by Region, 2008–2023

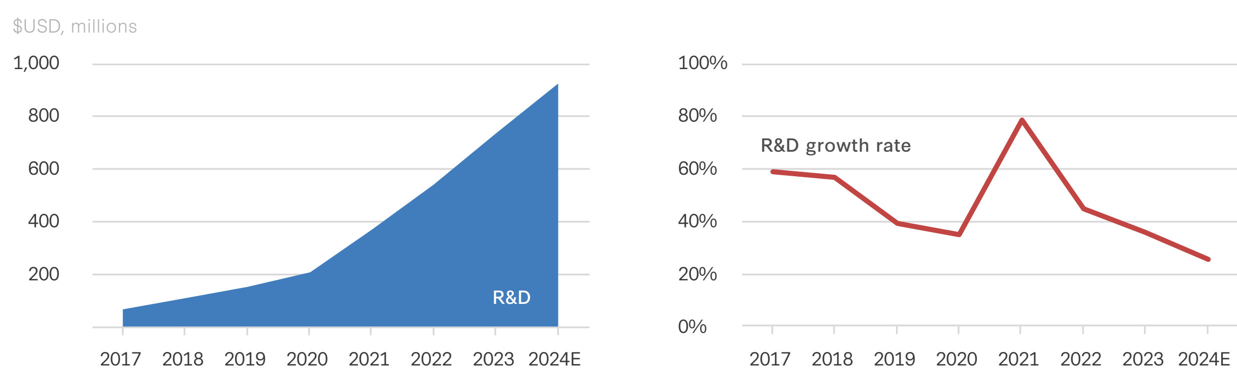


Source: "Statistical Data," Semiconductor Equipment Association of Japan, https://www.seaj.or.jp/english/statistics/index.html.

6. **R&D expenditures by Chinese semiconductor firms have grown explosively, though the rate of growth has decreased somewhat since 2021.**

Using public financial filings, CSIS has collected R&D expenditure data from the eight largest publicly traded Chinese semiconductor equipment firms (see Figure 3).

Figure 3: Chinese Semiconductor Equipment Firms' Annual R&D Expense & Growth Rates



Note: Selected firms include AMEC, Naura, AMCR Shanghai, Piotech, Kingsemi, Skyverse Technology, Jiangsu Leadmicro Nano Technology, and PNC Process.

Source: CSIS analysis; and corporate financial disclosures.

As the above data shows, the Chinese semiconductor equipment industry started out with comparatively low R&D expenditure but has shown extraordinary growth since the beginning of the Made in China 2025 policy era in 2015. Relative growth rates of R&D have slowed in the industry over the past two years, but growth in absolute terms remains very high. This data is not consistent with a simple story of "export controls caused a boom in the Chinese semiconductor manufacturing equipment industry" and instead shows that annual growth rates were very high both before and after the United States began imposing export controls.

One plausible interpretation of the data is that U.S. and Dutch export controls in the 2018-2020 period increased desire among both the Chinese government and Chinese equipment customers in strengthening the local equipment industry, but they did so without making it more difficult for Chinese firms to obtain help—even from U.S. experts and equipment subcomponent providers. The export controls of 2022 and 2023 may have further increased interest among the Chinese government and customers, but such interest and ability to productively absorb additional investment was already nearly maxed out.

However, the export controls of 2022 and 2023 also took extensive steps (e.g., extensive application of the Foreign Direct Product Rule and the U.S. persons rule, multilateralization of the controls) to make it more difficult for Chinese firms to obtain foreign help in advancing the reliability and competitiveness of their technology. Thus, the pace of revenue and R&D expenditure growth among Chinese equipment providers slowed somewhat (while remaining high in absolute terms). Again, this is a plausible interpretation that is consistent with the available data, but the available data is not sufficient in and of itself to definitively state that this is the correct interpretation.

Another plausible interpretation for slowing pace of growth—discussed in the next section—is that Chinese customers for semiconductor manufacturing equipment dramatically accelerated equipment purchases in an effort to **stockpile equipment** in anticipation of future export controls and that this surge of foreign imports stockpiling temporarily reduced demand growth for domestic equipment (while not changing China's long-term commitment to end reliance on imports).

There are some limitations in the R&D data, as not all of the companies are exclusively focused on the semiconductor equipment industry. Naura, for example, has lithium battery and photovoltaic business units which industry sources told CSIS are responsible for about 18 percent of the firm's revenue (and presumably comprised a comparable share of its R&D for at least some period), but these are not broken out in the firm's public financial reporting. Additionally, there are important Chinese semiconductor equipment firms that are not included in this analysis, such as Shanghai Microelectronics Equipment (SMEE) and Huawei's **recently established** semiconductor equipment subsidiaries, because they do report such data publicly.

The absence of Huawei's semiconductor equipment subsidiaries, in particular, could be an important missing source of data. Huawei's private investment in R&D and the semiconductor equipment that it produces for its own **secret network** of chip manufacturers would not be captured in any of the data sources used in this report. In October 2023, the Dutch newspaper NRC, citing anonymous ASML employees, **reported** that an employee who stole significant semiconductor manufacturing equipment technology secrets moved to China and now works for Huawei. This suggests that Huawei is making a significant investment in lithography equipment, as does a 2022 Huawei patent filed under the name "Extreme Ultraviolet (EUV) Lithography."

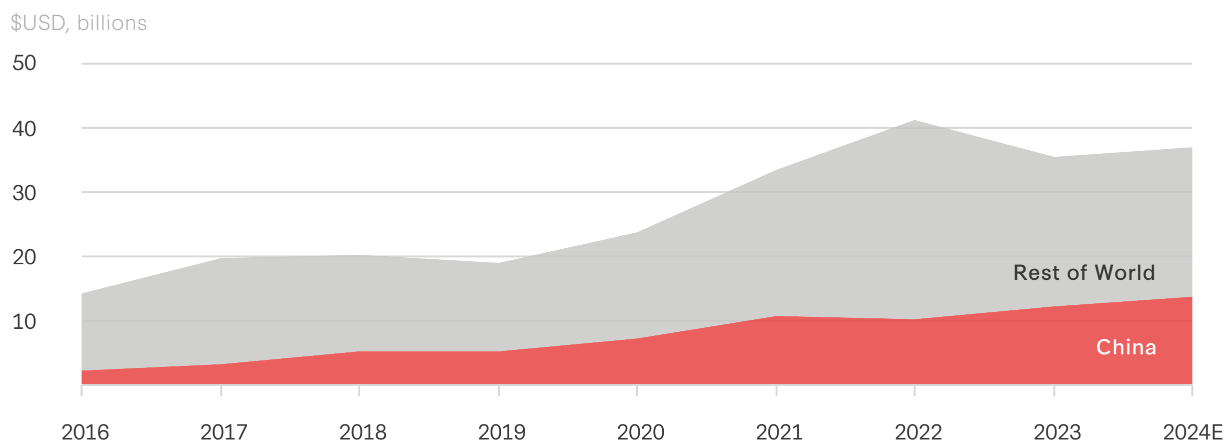
While these complications mean that the specific R&D values as presented have an error bar, the overall trajectory characterized is likely close to the reality of the Chinese semiconductor equipment industry as a whole.

7. **In the 2016-2024 period, leading U.S. and international semiconductor equipment firms continued to demonstrate strong Chinese revenue growth after imposition of increasingly strict export controls.**

The top three U.S. semiconductor manufacturing equipment providers are Applied Materials, Lam Research, and KLA Corporation. Together with ASML of the Netherlands and Tokyo Electron and Advantest of Japan, they comprise the six largest semiconductor equipment providers in the world by revenue. In their financial reports, these firms report the share of their revenue derived from China (not including Taiwan).

CSIS extracted and aggregated this data to show that these firms have grown revenue in China both before and after the United States began imposing export controls on semiconductor manufacturing equipment. For the top three U.S. providers, Chinese revenue growth outperformed growth in the rest of the world every year in the 2016-2024E period.

Figure 4: Top Three U.S. Semiconductor Manufacturing Equipment Firms' Revenue

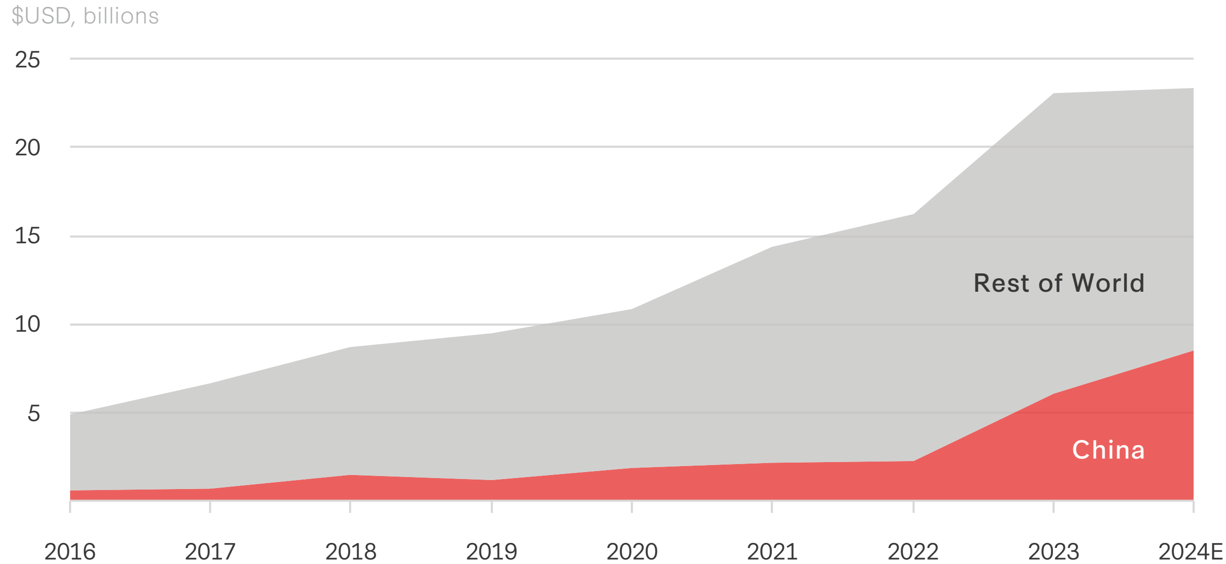


Note: Corporate fiscal year figures have been adjusted to calendar year; figures exclude services and non-semiconductor equipment product sales. Selected firms include Applied Materials, KLA, and Lam Research

Source: CSIS Analysis; and company 10-K/10-Q financial disclosures.

Similarly, ASML, the Dutch lithography equipment firm, also saw dramatic growth in sales of equipment to China that exceeded growth in the rest of the world.

Figure 5: ASML Equipment Revenue in China and Rest of World

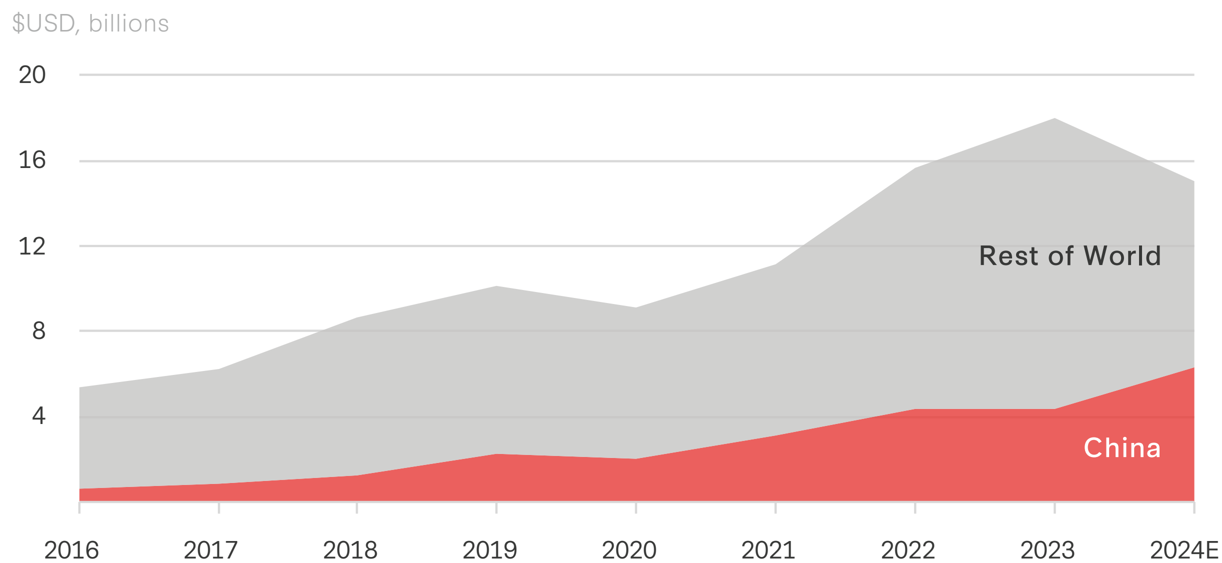


Note: Figures exclude services and non-semiconductor equipment product sales

Source: CSIS analysis; and company 10-K/10-Q financial disclosures.

Finally, the same is true of Tokyo Electron and Advantest, the two leading Japanese equipment providers. Both saw superior performance in China compared with the rest of the world.

Figure 6: Tokyo Electron and Advantest Revenue in China and Rest of World



Note: Figures include services revenue and cannot be directly compared with the equipment-only revenue used by other figures in this report. Figures reflect the April-March fiscal year.

Source: CSIS analysis; and company financial disclosures.

The most likely explanation for this is that Chinese firms have shifted their purchases of international equipment earlier so that they occurred prior to expected future export controls which the U.S. government has maintained since 2022 will be updated annually. Just as **Huawei built** up a U.S. chip stockpile equivalent to multiple years of demand during a period prior to U.S. export control loopholes being closed, Chinese semiconductor manufacturers have acquired a stockpile of U.S. and other foreign equipment in anticipation of strengthened export controls coming in the near future.

This "pulling demand forward" interpretation is the one that many executives in the semiconductor equipment industry have evidently reached. In July 2024, both the CEO of ASML and the CEO of ASM **said** during investor earnings calls that Chinese semiconductor manufacturers would likely decrease purchases of equipment soon, as they have struggled to "digest" all of the accelerated purchases of equipment and spare parts that they have made, effectively confirming that many tools that have been sold to China are still likely awaiting installation and remain unused. Similarly, in August 2024, a Lam Research executive likewise **described** "inventory stocking" behavior among Chinese customers over the past several years.

8. **Export controls changed the composition of equipment demand both technologically (decreasing the technological sophistication of demand in China) and geographically (shifting more demand outside of China) but likely did not change the overall demand trajectory.**

Decades before the Trump administration's April 2018 export controls on ZTE ushered in the modern era of semiconductor export controls, the U.S. policy goal for exports of semiconductor manufacturing equipment to China was already to restrict sales of advanced equipment to trusted U.S. allies and partners while allowing the sale of older, less advanced equipment to China. A 2002 U.S. government policy review of semiconductor technology exports to China **stated this explicitly**. Neither the Trump administration nor the Biden administration fundamentally changed this approach at a high level. Both administrations continued to allow the sale of legacy equipment, though they increased restrictions on sales of advanced equipment exports. In the case of the Biden administration, it also communicated an intent to end the "sliding scale" approach that allowed the sophistication of equipment exports to China to advance, but on a multiyear delay from the global state of the art.

As such, China has continued to be a large and growing market for equipment exports even after the more recent export controls, but Chinese firms have changed their focus from a rush to compete at the most advanced semiconductor technological nodes to maximizing both domestic self-sufficiency and global leadership in **legacy chip** production. China was likely to pursue a **massive expansion** of chip production capacity regardless of U.S. actions, but the export controls helped ensure that this capacity did not drive the U.S. and allies toward a strategic dependence on China for the most technologically advanced chips, such as those that power AI systems or high-end smartphones.

Moreover, the overall demand for semiconductor manufacturing equipment fundamentally depends on the overall demand for manufactured chips. As the demand for advanced chips grows, that demand will translate into demand for advanced equipment. And if China is not in a position to purchase advanced equipment, then the purchase and production will instead take place outside of China. The chief financial officer of ASML, Roger Dassen, **said** this explicitly during ASML's July 2024 earnings call with investment analysts:

> . . . the way we look at the demand for our tools is not from a specific geography. In this case, China. We look at—and that's the way we model our sales medium term and long term. We look at what is the global demand for wafers and whether those wafers are being produced in country X or country Y, at the end of the day, it doesn't matter. And I think that is very important to recognize in looking at your model. We don't have a specific China element in our models. It is the global demand for wafers that drives our modeling.

Accordingly, U.S. and allied controls did not so much destroy demand as change its composition. China is buying fewer advanced tools than it would have otherwise and is instead purchasing more legacy tools. The advanced tools that would have been sold to China have instead been sold to places like the United States, Taiwan, South Korea, Japan, and Europe. Likewise, given that many foreign players are wary of investing in legacy nodes due to fears of Chinese overcapacity, the tools are being largely sold to China for those production lines, not elsewhere. Chinese firms are also likely **attempting to use** many "node-agnostic" or "backwards compatible" equipment tools not subject to a control to bolster their advanced node efforts.

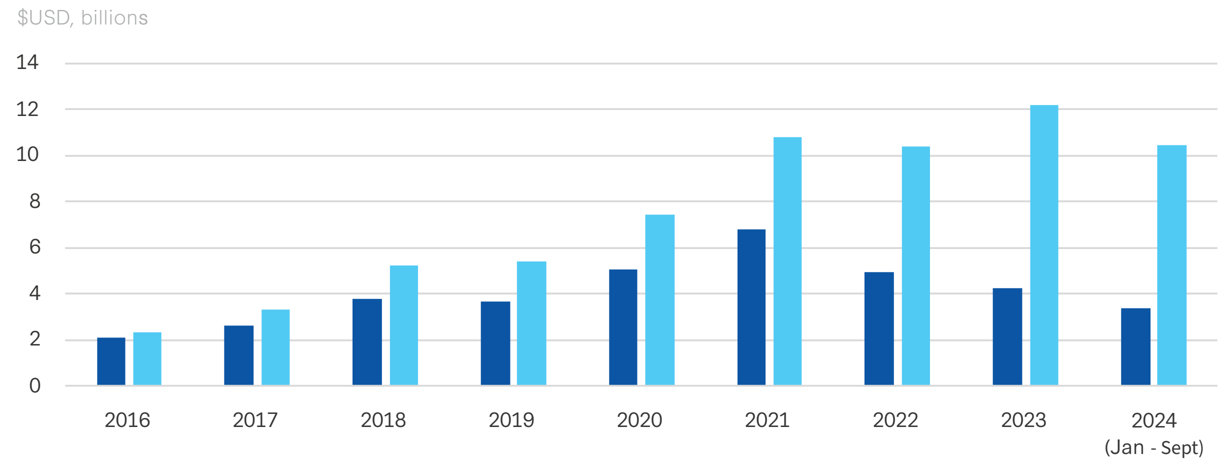
9. **Increased application of semiconductor equipment export controls coincided with and likely caused U.S. equipment firms to ensure that sales to China did not ship from the United States and/or were manufactured outside the United States.**

CSIS has produced an estimate of the Chinese semiconductor equipment revenue of each of the top three U.S. semiconductor equipment companies by taking their topline revenue from China and subtracting the share reported as services and non-semiconductor equipment businesses (e.g., display, printed circuit board inspection). This figure would include any semiconductor manufacturing equipment sales to China from these three firms shipped from any of their facilities worldwide, whether those facilities are in the United States or elsewhere.

U.S. trade data provided by the International Trade Commission (ITC) reports the dollar value of all U.S. exports based on six-digit North American Industry Classification System (NAICS) codes. The NAICS Code for "Semiconductor Machinery Manufacturing" is **333242**, which covers all front-end semiconductor manufacturing equipment. CSIS collected ITC trade data for all U.S. exports of 333242 goods to China. This figure includes any semiconductor manufacturing equipment sales made from U.S. soil, whether those sales are made by U.S.-owned or internationally owned firms. In practice, the top three U.S. semiconductor manufacturing equipment companies—Applied Materials, Lam Research, and KLA Corporation—tend to dominate 333242 exports to nearly all countries.

Based on these two data sets, one can see that U.S. equipment sales to China by U.S. firms have increasingly become exported from non-U.S. countries since 2016 and especially after 2019 (see Figure 7).

Figure 7: Comparing Firm-reported Equipment Sales to China with U.S.-China Equipment Exports Data



Note: Semiconductor equipment exports to China from U.S. International Trade Commission DataWeb under NAICS code 333242. Semiconductor equipment sales data from 10-K/10-Q reports.

Source: CSIS analysis; "DataWeb," U.S. International Trade Commission, https://dataweb.usitc.gov/; and 10-K/10-Q reports.

From 2016 to 2020, the ratio of sales to exports grew 34 percent, from 1.1 to 1.5. However, from 2021 to 2024, the ratio nearly doubled, from 1.6 to 3.1. In other words, exports to China and sales to China used to be nearly identical, but sales overwhelmingly outgrew exports in the post-2020 period, the same period when the United States adopted significantly stricter export controls. Industry sources told CSIS that much of the change was originally due to U.S. firms seeking to legally avoid export controls that—in the absence of strict usage of the Foreign Direct Product Rule—only applied to exports from U.S. soil. This interpretation is consistent with the remarks of KLA CEO Rick Wallace, who discussed how some versions of U.S. semiconductor equipment export controls did not apply to U.S. companies manufacturing their equipment abroad and shipping from abroad during the company's 2020 **Q3 earnings call**. The exchange is important and worth quoting at length:

> **Question:** Regarding the Department of Commerce ruling, and I know it's still very early, and I'm sure you're awaiting clarity on how broader now the rules will be pursued. But if you think about what's been written to date, the major ruling is for manufacturing in the U.S. and considering you do make tools and assemble tools offshore, is your first interpretation that you will not be impacted in terms of shipping into China based on kind of what you read today?
>
> **Rick Wallace:** Our understanding at this point is, this will impact the tools that are manufactured in the U.S., which are manufactured for us in California. We have three major manufacturing sites; Israel, Singapore and here. So there is a potential impact depending on the customer. And our final understanding of the ruling [is that it] will impact tools that come out of California.

In short, export controls that do not include strict implementation and enforcement of the Foreign Direct Product Rule or U.S. persons rule can incentivize U.S. firms to move production offshore, costing the United States manufacturing jobs. In recent years, U.S. semiconductor manufacturing equipment firms have doubled-down and expanded their non-U.S. manufacturing operations. Both **KLA Corporation** and **Applied Materials** have committed to major expansions of their Singapore manufacturing facilities, while **LAM Research** has built out its largest manufacturing site in Malaysia.

In quantitative terms, this is one of the most striking effects of the export controls as implemented thus far, and it clearly illustrates the risk that countries take by applying export controls that do not apply extraterritorially in industries where off-shoring some or all production is relatively easy. As one Japanese business executive **stated**, his company will "develop duplicate supply chains—one for the U.S.-led economic bloc and one for [the] China-led bloc."

Industry sources told CSIS that, more recently, both U.S. and international semiconductor equipment companies are being required by their Chinese customers to remove all U.S. citizens from their supply chain and ship from outside the United States when selling to China.

This fact shows that there is really no turning back from the export control path that the United States and its allies have gone down. Half measures incur nearly all of the costs of an aggressive export control policy—in terms of incentivizing U.S. firm outsourcing, foreign substitution, and Chinese indigenous investment—while delivering comparatively few of the strategic benefits.

10. **There is no change in U.S. or allied policy that will persuade the Chinese government and Chinese firms to abandon their semiconductor equipment de-Americanization and decoupling efforts. However, the United States can take steps to make those efforts more difficult and to extract more strategic benefits in semiconductor and AI competition.**

Critics of export controls oftentimes make two related arguments. First, revenues from China can be reinvested in R&D and thus contribute to increased U.S. technological competitiveness, including against Chinese firms. Second, prohibiting exports increases willingness on the part of Chinese firms and the Chinese government to invest in competitors to U.S. firms, decreasing U.S. technological competitiveness.

However, these arguments assume that the strategic approach of the Chinese government and Chinese firms depends solely or primarily upon U.S. actions, which is contradicted by the review of Chinese policy at the beginning of this paper and from the experience of the EV and solar industries.

Consider a thought experiment: What would be the likely policy response of the Chinese government if the United States decided to begin unrestricted exports of nuclear submarines to China? U.S. nuclear submarines are widely regarded as **the best** in the world, and China's spies have long devoted major efforts to **stealing** U.S. submarine technology secrets.

Presumably, therefore, China would leap at the chance to buy U.S. nuclear submarines on the open market. And, under the logic of the above two arguments—increased U.S. revenue and decreased Chinese investment—these sales would increase, not decrease, the U.S. technological advantage in nuclear submarine technology. Are American policymakers fools for using export controls to block nuclear submarine sales to China?

Of course not.

Even if a hypothetical reckless U.S. president and Congress were to allow China to buy as many submarines as U.S. firms could make, China would never accept that this state of affairs is likely to continue on a permanent basis. China would obviously take the submarines they could get and reverse engineer the technology as fast as possible and transfer that technology to their domestic submarine industry, which they would continue to financially support. The increased revenue from R&D for U.S. firms is not going to make nearly as much of a difference as China's hands-on opportunity to reverse engineer U.S. technology. Neither would the lost sales among Chinese submarine manufacturers decrease China's commitment to supporting a domestic industry. This is not to even mention the grave risks to national security of a hypothetical Chinese navy equipped with U.S.-built nuclear submarines.

This admittedly extreme thought experiment bears consideration because, while some in the West question whether semiconductor manufacturing equipment deserves to be viewed as a strategic technology of major importance to national security, China's leaders do not. This belief is evident not only in words but also the deeds, whether that be Chinese **state-backed espionage** against equipment firms, aggressive **reverse engineering** of purchased Western equipment, or the astonishing amount of financial resources dedicated to indigenization.

There is simply no policy that the United States could articulate that would persuade China to abandon its goals of de-Americanization and decoupling in the semiconductor equipment sector. As the United States and allied governments consider reforms to semiconductor equipment controls, they should focus less on how to change China's goals and more on how to make achieving those goals as expensive and complicated as possible. ■

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