



23-10 How US chip controls on China benefit and cost Korean firms

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INTRODUCTION

In late 2022, the US Department of Commerce issued landmark restrictions to prevent China's military from having access to advanced semiconductors. The so-called October 7 controls restrict semiconductors, or chips, needed for artificial intelligence (AI) and supercomputing and impose sweeping bans on US equipment, software, and expertise needed to make any advanced chips in China (BIS 2022a). Although directed at China, the controls are creating both collateral damage and new opportunities for other countries involved in a complex, globalized supply chain for chips. A case in point is South Korea, whose situation reflects that of many countries facing a challenging geopolitical environment.

Semiconductors are a foundation of the modern world—key to computers, phones, data centers, cars, and appliances—as well as modern warfare, used in tanks, satellites, and other weapons systems. Invented in the United States, initial buyers of semiconductors were largely NASA and the US military before a civilian market developed (Miller 2022). US firms dominate key parts of the supply chains that make chips, forming a choke point for technology competition between the United States and China. Although much of the attention is on the two superpowers, the future will be shaped just as much by choices made by other countries and companies.

This Policy Brief begins with an overview of the global semiconductor supply chain and US choke points within it for export controls on China. It then covers Korean firms' primary vulnerability to US export controls on China: large chip production facilities in China, which make around 40 percent of the memory chips for these firms. Those facilities rely on access to semiconductor manufacturing

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equipment (SME) from not only the United States but also other countries that have imposed controls on exporting advanced SME to China. The impact of the controls on Korean firms' chip sales to China is less significant.

Korean and other non-Chinese firms producing chips in China have secured exemptions from the rules. In the short term, US export controls have minimal impact on Korean firms' ability to keep making, albeit not upgrading, what they produce in China. US officials have made it clear this will continue for the coming years.¹ In the long term, this inability to upgrade in the memory chip business will mean the facilities in China will need to close or produce something else. The uncertainty is concentrated around the medium term: How long will it be until memory products produced by Chinese facilities become so outdated to be viable in the market?

Korean firms producing memory chips have benefited from the effect of the controls on their Chinese competitors, and the Korean economy could be boosted if Korean firms decide to invest in production at home rather than in China. The Korean case exemplifies the complex challenges that many countries will increasingly face due to US-China technology tensions, which are likely to intensify in the coming years.

As the United States increasingly expands its jurisdiction to chips made outside its borders, companies selling semiconductors in China now must navigate a thicket of new rules, and multinational firms producing semiconductors in China face an uncertain future for their investments. The United States should do more to reduce uncertainty for allies, finalizing long-term solutions rather than temporary waivers. It should also provide more detailed justification for its national security arguments, especially for memory semiconductors, to help convince other countries that its actions are not designed to protect the commercial interests of US firms.

KOREA, THE UNITED STATES, AND SEMICONDUCTOR SUPPLY CHAINS

The supply chains for semiconductors are some of the world's most globalized and complex, stretching from the United States and Europe to Asia. A typical chip can be designed in California with US-origin software; produced by engineers in Taiwan, Korea, or China with specialized equipment from the United States, the Netherlands, and Japan; and then tested, packaged, and integrated into devices in China or Southeast Asia.² Though some integrated device manufacturers such as Intel and Samsung are active in many stages of the semiconductor process, most firms—and sometimes countries—are highly specialized in a few links of the supply chain. The machines that make chips also have parts sourced from thousands of suppliers. In some parts of the chain, only one or a few firms are able to produce at the cutting edge (see figure 1 from Bown 2020).

1 Yuka Hayashi, "U.S. to Allow South Korean, Taiwan Chip Makers to Keep Operations in China," *Wall Street Journal*, June 12, 2023.

2 See Bown (2020), starting on page 17, for an excellent introduction to the semiconductor supply chain.

Though Samsung produces many types of semiconductors and devices, Korean companies primarily focus on production of memory chips: dynamic random-access memory (DRAM) and NAND memory.³ Fifty-six percent of Korean chip exports in 2022 were memory chips.⁴ Samsung and SK hynix, Korea's top producers, had 45 and 28 percent market share in DRAM, respectively, bringing Korean firms' total to 73 percent. Their only real competitor is US-based Micron, which holds 23 percent (TrendForce data). Samsung and SK hynix also control over half the global market for NAND, followed by US-based Western Digital, Kioxia, and Micron.⁵ Korean firms are thus essential to a highly consolidated, highly competitive memory market needed for phones, computers, servers, and more, and the memory market is essential for Korea's economy and its firms.

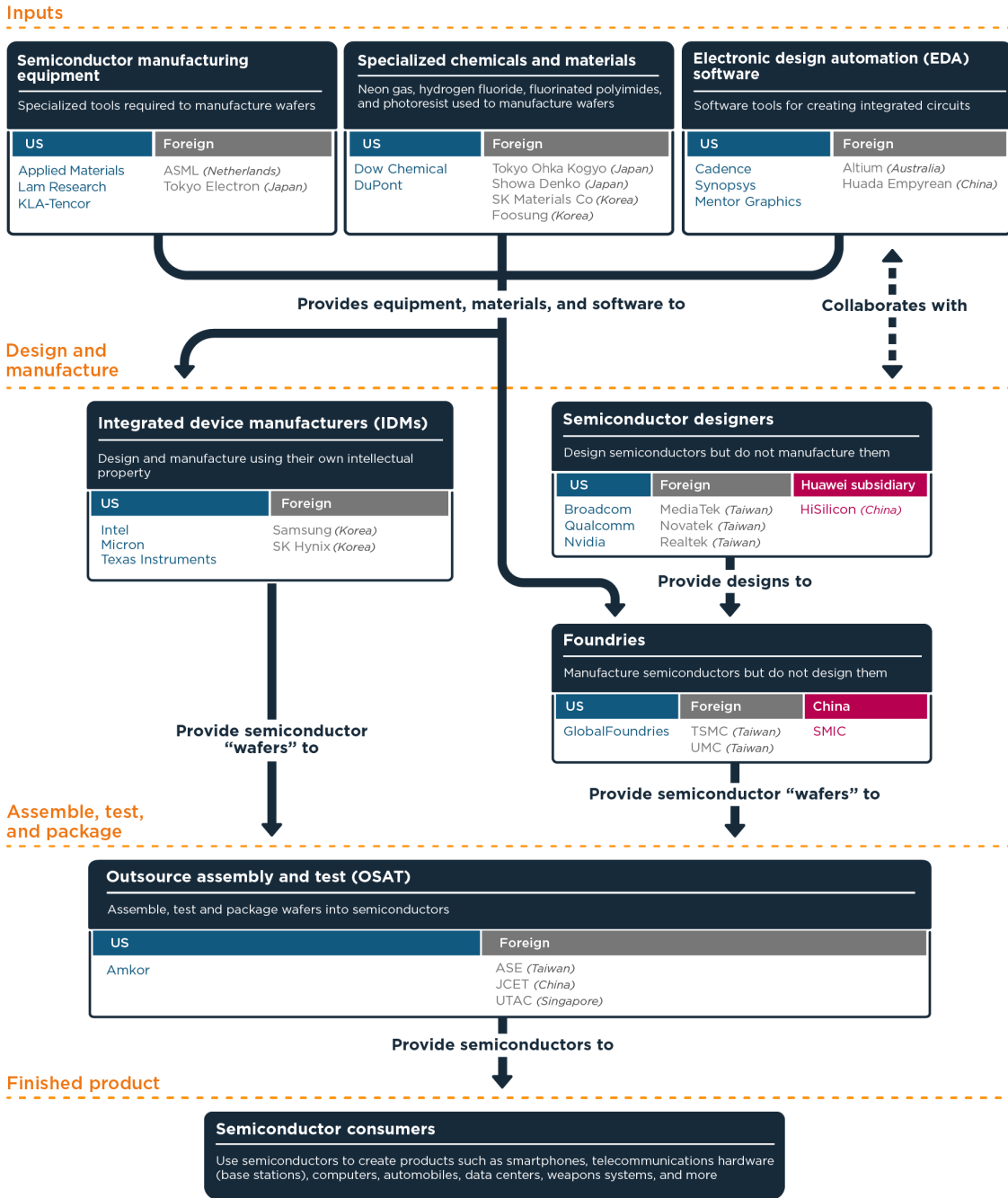
Korean firms' memory business is also reliant on China. Fifty-five percent of Korea's semiconductor exports in 2022 went to China.⁶ In the third quarter of 2022, SK hynix and Samsung made 25 and 10 percent of their revenue, respectively, in China.⁷ Korean firms make money from Chinese sales, but they also produce around 40 percent of their memory chips at facilities in China, which they have invested in for well over a decade. SK hynix produces over 40 percent of its DRAM at a facility in Wuxi, which it expanded in 2019.⁸ It also purchased NAND facilities in Dalian from Intel in a \$9 billion transaction scheduled to conclude in March 2025.⁹ Samsung's semiconductor fabrication facility in Xi'an, which it finished expanding in 2022 after a total investment¹⁰ of over \$25 billion, produces over 40 percent of its NAND memory supply—around 15 percent of the world supply.¹¹ China, however, is also a source of potential competition, intent on having its own firms compete with US, Korean, Japanese, and Taiwanese firms.

If Korean firms are key to the global memory market, as figure 1 shows, US firms' chip design software and chipmaking equipment are essential to the production of advanced chips made around the world. That gives the US government the ability to regulate the export of that equipment to China or to assert the right to control the export of chips designed or made with that equipment anywhere in the world.

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- 3 Flash memory sticks and memory in phones are NAND (which is not an acronym). Whereas NAND preserves data such as videos and photos to be stored indefinitely, DRAM is dynamic, temporarily holding data that gets fed in and out of other semiconductors, such as the main processor to run calculations and programs.
 - 4 Yoon Young-sil, "BOK Report Says Korean Semiconductor Exports Overly Dependent on China, US," *BusinessKorea*, May 30, 2023.
 - 5 Maki Shiraki and Makiko Yamazaki, "Kioxia, Western Digital Speed Up Merger Talks as Memory Chip Demand Slumps," Reuters, May 15, 2023.
 - 6 Yoon, "BOK Report Says Korean Semiconductor Exports Overly Dependent on China, US."
 - 7 Kim Eun-jin, "Samsung's and SK Hynix's Sales in China Drop by KRW4tn in Q3," *BusinessKorea*, November 23, 2022.
 - 8 Kim Jaewon, "SK Hynix Weighs Future of China Chip Plant after U.S. Tech Curbs," *Nikkei Asia*, October 26, 2022.
 - 9 Intel, "Intel Sells SSD Business and Dalian Facility to SK hynix," press release, December 29, 2021.
 - 10 Kim Eun-jin, "Samsung's 2nd NAND Flash Plant in Xian Goes Live," *BusinessKorea*, April 1, 2022.
 - 11 Ben Yah, "Samsung's NAND Flash Production in Xi'an Remains Unaffected amidst Lockdown, Says TrendForce," press release, TrendForce, December 24, 2021.

Figure 1
Modern semiconductor manufacturing is a globally integrated, multistage process

The stages and examples of companies involved in the semiconductor design and manufacturing supply chain

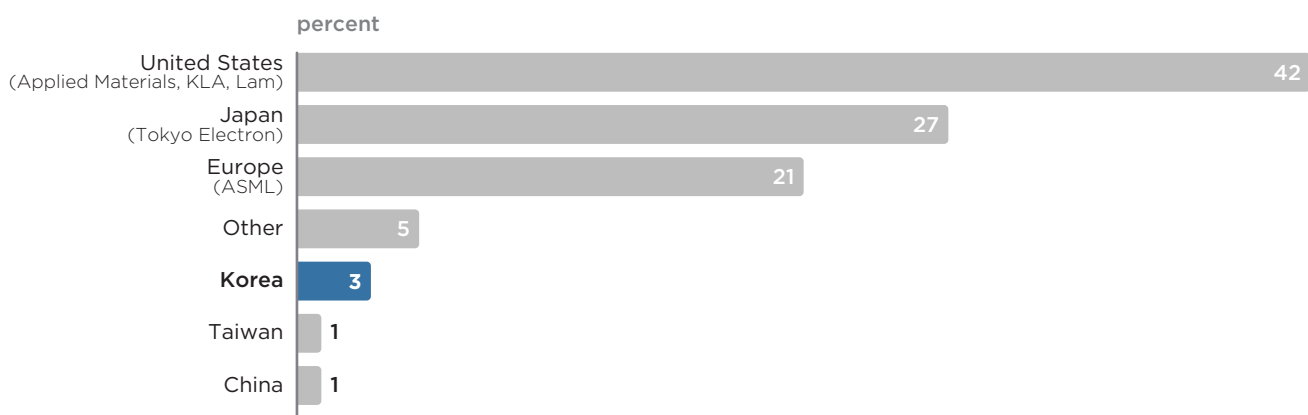


Note: The figure shows the stages and examples of companies involved in the semiconductor design and manufacturing supply chain. Examples of companies are illustrative.

Source: Bown (2020, figure 5, page 19).

Electronic design automation (EDA) software is essential for designing chips, and the top three EDA firms, totaling nearly 73 percent of the market share, are all based in the United States (Fuller 2020). Semiconductor manufacturing equipment (SME) involves some of the most complex and expensive machines ever produced—a single extreme ultraviolet lithography (EUV) machine from the Netherlands-based ASML now costs over \$300 million.¹² Figure 2 shows that US firms produced 42 percent of SME value added globally, followed by Japan (primarily Tokyo Electron) at 27 percent and Europe (primarily ASML) at 21 percent. Korea is not a major player in this market at only 3 percent.

Figure 2
Semiconductor manufacturing equipment market share, by value added, 2021



Source: Semiconductor Industry Association, *2022 State of the US Semiconductor Industry*, page 21.

A single chipmaking facility might have lithography machines from the Netherlands-based ASML along with other tools from Japan's Tokyo Electron and US-based Lam Research, Applied Materials, and KLA. All are at the top of their field for specialized functions in a multistep process, and few, if any, are interchangeable at the top end. US Undersecretary of Commerce Alan Estevez has said that American firms monopolize around 11 types of essential equipment.¹³

Memory producers are particularly dependent on upgrades and purchases of new SME, even more than companies like Taiwan Semiconductor Manufacturing Company (TSMC) that focus on producing logic chips. TSMC and Intel can keep making money from legacy production of logic chips for lower-tech devices, but 90 percent of demand for memory chips is concentrated at the cutting edge (Bauer et al. 2016). Older methods of production cannot fit enough memory on a small enough chip to be cost competitive. The memory market is more commoditized than that for logic chips and more cyclical, leading to fierce competition. Large-scale investment in upgrades and purchases of the latest chipmaking equipment are necessary to remain at the cutting edge.

12 Toby Sterling, "Intel Orders ASML system for Well over \$340 Mln in Quest for Chipmaking Edge," Reuters, January 19, 2022.

13 Special Event: *A Conversation with Under Secretary of Commerce Alan F. Estevez*, Center for a New American Security, October 27, 2022.

These machines are complex and can have hundreds of thousands of parts. Thus, even keeping existing capacity online requires continuous access to the producer's expertise, software, and parts. This makes Korean firms with operations in China vulnerable to US export controls that would disrupt access to SME or servicing from the US, Japanese, and Dutch providers to keep their operations online and competitive.

US SEMICONDUCTOR CONTROLS

Globalized supply chains present a challenge to traditional US export controls, which apply only to goods and technologies that are made in the United States or contain enough US content. Today, only around 12 to 20 percent of chips are made in the United States (Hufbauer and Hogan 2022). As the United States found out with its initial controls on Chinese telecom giant Huawei in 2019, foreign and even US-headquartered firms could keep supplying Huawei with chips as long as they were produced abroad with too little US content to fall under US jurisdiction; thus, the controls incentivized companies to produce outside the United States.

As Chad P. Bown (2020) recounts, the US government responded by using the foreign direct product rule (FDPR) to expand jurisdiction over chips made with US software and equipment, even if they were made abroad with zero US components, if they were bound for Huawei. That covered virtually all advanced chips it could buy. Whether American, Korean, Taiwanese, Japanese, or even Chinese, the United States could now force any chipmaker to choose between supplying Huawei with banned chips or being shut off from US components. The need for US technology and equipment trumped the revenue gains from selling to Huawei, which was finally dealt a heavy blow from US measures.

This control applied initially only to Huawei, but once it was used for this purpose, the United States could continue to expand the FDPR to new Chinese firms, forcing tough choices for chipmakers. The administration of President Joseph R. Biden, Jr. then threatened to apply a much broader FDPR on chips to Russia to deter an invasion of Ukraine. Although it did apply the FDPR, this economic weapon did not deter Vladimir Putin. The United States did, however, convince dozens of other countries, including Korea and the countries in the European Union, to join in on coordinated export controls on Russia, though they have been far from airtight. China would be the next target for new US controls.

President Biden's national security adviser, Jake Sullivan, laid out a strategy for export controls in September 2022. Sullivan argued that foundational technologies such as semiconductors were crucial to national security and thus necessitated "as large a lead as possible" over potential adversaries.¹⁴ The next month, the US Department of Commerce imposed a sweeping set of export controls focused on China and advanced semiconductors that would remake the global chips landscape. The controls were unilateral; no other countries initially agreed to join despite intense lobbying of Japan and the Netherlands.

14 Jake Sullivan, [Remarks by National Security Advisor Jake Sullivan at the Special Competitive Studies Project Global Emerging Technologies Summit](#), September 16, 2022, Washington.

The controls limited exports to China of a small number of the most advanced semiconductors, restricted exports of equipment and software needed to make a wider variety of chips, and regulated the activities of US persons and companies anywhere in the world to help produce advanced semiconductors in China.¹⁵ New FDPRs, which asserted jurisdiction over goods made abroad with US tech, were applied to the most advanced supercomputer/AI chips and to some entities on a particularly restrictive US trade blacklist (McCarthy et al. 2022). The Biden administration presented the new controls as a carefully targeted embodiment of the “small yard, high fence” strategy of focusing controls on national security threats, noting the importance of advanced semiconductors for military applications such as modeling weapons of mass destruction and hypersonic missiles.¹⁶ The controls are long and extremely complex, largely because of the detail required to narrowly define technologies and the scope. Although often billed as a “chip ban,”¹⁷ only a handful of chips produced today are powerful enough to trip the threshold for control to export to China: some used for the immense data needs of AI applications such as ChatGPT and others used mostly in supercomputers. None of these chips go into regular consumer devices.

Instead, the most important and impactful controls are on SME, aimed to prevent China from producing advanced chips. The thresholds set for devices that can make logic chips (14 or 16 nanometer [nm]) and memory (DRAM 16 nm half-pitch and 128-layer NAND) are years behind the global cutting edge but are about where Chinese firms such as the Semiconductor Manufacturing International Corporation and the Yangtze Memory Technologies Corporation (YMTC) were about to produce at scale.¹⁸ TSMC in Taiwan, for example, is moving to 2 nm chips for iPhones, and it produced 16 nm chips a decade ago.¹⁹ As a result, most of China’s current chip production does not trip the controls, allowing it to continue rather than causing a potential new chip shortage. China’s chip production, however, will fall further behind the cutting edge unless the thresholds are adjusted or until it can make advanced chipmaking equipment itself.

The controls immediately disrupted much of the chipmaking activity in China. Parts of the complex new rules were effective immediately, leaving firms little time to clarify which of their activities in China had suddenly become illegal. Engineers from American firms or with American green cards or passports immediately pulled out of Chinese fabrication facilities to avoid the risk of violating the new rules; later, however, ground rules were set that allowed chip production above the thresholds to proceed with American help (BIS 2022b). The US government recognized that many multinational firms, including TSMC,

15 US “persons” in the rules apply to US citizens, permanent residents, anyone in the United States regardless of nationality, and companies with US headquarters—including foreign branches and employees. See Wolf et al. (2023) for more detail.

16 Jake Sullivan, [Remarks by National Security Advisor Jake Sullivan on the Biden-Harris Administration’s National Security Strategy](#), October 12, 2022, Washington.

17 Rahul Rao, [“The U.S.-China Chip Ban, Explained,”](#) IEEE Spectrum, November 21, 2022.

18 The node of semiconductor manufacturing is often characterized by how many nanometers the features on a chip are: The smaller the number, the more circuits can fit on the same-sized chip, making it more powerful and use less power. In contrast, 3D NAND is measured in the number of layers.

19 See TSMC, [“16/12nm Technology,”](#)

SK hynix, and Samsung, produced semiconductors in China that were advanced enough for their operations to fall under the controls. It provided a temporary exemption for these non-Chinese firms, albeit without the ability to upgrade their operations there.²⁰ Thus, they did not face immediate disruption.

Unilateral controls would create an immense market opportunity for ASML and Tokyo Electron to help Chinese firms and others hoping to avoid US export controls “design out” US equipment makers. To make this far more difficult, the United States successfully convinced Japan and the Netherlands to apply similar controls, though they did not agree to do so until January 2023 (Allen, Benson, and Putnam 2023).

Whether memory semiconductors should have been included in this set of national security controls is debatable, considering their commoditized nature. When the administration of President Donald J. Trump put Fujian Jinhua, a Chinese DRAM producer indicted for stealing intellectual property from Micron, on a US export blacklist in 2018, it justified the move by saying the intellectual property theft threatened “the long term economic viability of U.S. suppliers of these essential components of U.S. military systems.”²¹ The Biden administration rejects the premise that the controls are an indirect contribution to national security through economic security, but it has not made a public, direct case for the relevance of memory chips to the national security concerns that justify the controls.

IMPACT ON KOREAN FIRMS

In the short term, the exemption for Korean and other non-Chinese firms largely worked as anticipated; SK hynix, for example, reported that its operations in China could “continue . . . without additional licensing requirements.”²² In addition, except for sales to the few Chinese firms subject to the most stringent FDPFR controls, most memory chip sales to China by Korean firms are not subject to US export controls.

Nevertheless, the way the exemption was done and communicated created more uncertainty than necessary. Korean firms were privately told that the one-year exemption was a temporary solution that would be renewed until the Commerce Department came up with a long-term fix with a specific technology threshold for each firm. Yet there was no public announcement of this sensible policy, nor has the long-term fix been forthcoming. Despite private assurances, Korean firms must seriously consider the risk that their exemptions may not be renewed, thus effectively forcing their facilities in China to suddenly shut down. After all, US-China relations and tech policy are far from certain, and influential

20 Special Event: *A Conversation with Under Secretary of Commerce Alan F. Estevez*, Center for New American Security, October 27, 2022.

21 US Department of Commerce, “*Addition of Fujian Jinhua Integrated Circuit Company, Ltd (Jinhua) to the Entity List*,” press release, October 29, 2018.

22 Andrew Salmon, “*SK hynix Wins Reprieve in US Chip War on China*,” *Asia Times*, October 12, 2022.

US politicians have publicly called for use of the exemptions as leverage.²³ The Commerce Department should prioritize finalizing this long-term solution to provide more certainty.

For Korean firms, this is a longer-term challenge with medium-term uncertainty. In the long term, Chinese memory production facilities representing billions of dollars of investment over decades will cease to be economically viable. Chinese alternatives for chipmaking equipment are far from the cutting edge and will remain so for the foreseeable future, leaving no way to upgrade unless the United States adjusts the thresholds. US policymakers are signaling they will not do this. As their Chinese production falls further behind the cutting edge, at some point those facilities will need to be closed down, with the equipment either sold to a Chinese firm for production that does not trip controls (otherwise support would be denied) or exported to another facility abroad, which would require permission from Chinese authorities. Such permission could well be denied. The policy of refusing upgrades is far more damaging to Korean memory producers due to the lack of trailing edge demand than it is for TSMC, which can keep making money on older logic chips at its Nanjing facility.

With the base case of continued extensions at current technology levels, the uncertainty is how long there will be demand for the current generation of Korean memory chips made in China. The longer there is demand, the more years over which the sunk cost of those facilities can be amortized, giving SK hynix and Samsung time to make new investments in other countries, such as Korea or the United States. Micron, their main DRAM competitor, has delayed its rollout of chips based on EUV equipment, which cannot be shipped to China, until 2025;²⁴ thus, demand for the current generation could last at least three years, if not longer.

The US government must make a credible national security case for the controls to demonstrate that they were not established to benefit Micron, the US DRAM market leader. Micron has far less production in China and therefore faces less of a financial hit than its Korean competitors, so the controls could give it a competitive advantage.

Despite valid concerns, the October 7 controls have been both a cost and a risk to Korean firms. In 2022 China-based YMTC was poised to add major competitive pressure, nearly reaching a deal with Apple to provide NAND for iPhones and reportedly reaching the cutting edge with a 232-layer NAND product.²⁵ The Yole Group²⁶ expected YMTC to double its share of the NAND market from 5 to 10 percent by 2027, before export controls were applied.²⁷ The US government has estimated that YMTC received \$24 billion in Chinese

23 Jo He-rim, "S. Korea Asks US to Give More Leeway on Chip Expansion in China," *Korea Herald*, May 14, 2023.

24 Anton Shilov, "Micron Delays EUV RAM to 2025, Lays Off 10% of Workforce," *Tom's Hardware*, December 22, 2022.

25 Josh Horwitz, "China's Memory Upstart YMTC Edges Closer to Rivals with 232-Layer Chip," *Reuters*, August 4, 2022.

26 Yole Group, *NAND Market Monitor Q2 2022*, Product Brochure, Lyon-Villeurbanne, France.

27 Jiaying Li, "Tech War: China's Top Memory Chip Maker YMTC Faces Headwinds amid Reports US Is Weighing Equipment Export Ban," *South China Morning Post*, August 3, 2022.

government subsidies, which it called a “low-cost threat to U.S.-based memory companies” (White House 2021); these subsidies would equally threaten Korean memory firms.

The controls shut off YMTC’s ability to get equipment to upgrade its NAND production to the cutting edge. Then, in December 2022, the United States added YMTC to the entity list, further restricting its access to US technology. Industry reports anticipated that YMTC would expand its production by 60 percent in 2023 before controls were imposed, but now its output is expected to decline by 7 percent.²⁸ The controls therefore constrained what was about to be a significant expansion of supply in a market already in a glut, helping Samsung, SK hynix, and other NAND players in a tough time. Samsung, for example, raised its NAND prices by 10 percent soon after YMTC’s troubles began. The controls are less important for Chinese DRAM producers because the largest player, Changxin Memory Technologies, focuses on legacy production estimated to be five years behind the leaders and is thus less of a threat.²⁹ It has not yet faced disruptions to its supply of chipmaking equipment, but if it does become a threat, it could be placed on the entity blacklist.³⁰

For Korea, the equipment controls have led its firms to invest more at home for cutting edge production rather than to continue investing in China (Allen 2023). This helps to reduce Korea’s long-term exposure to China, and it eases the risks of China stealing intellectual property from Korean firms. Funding from the US CHIPS and Science Act, however, has also led Korean firms to invest in the United States, likely including some production that would have been done in China. Samsung is investing tens of billions of dollars in advanced chip manufacturing in Texas due in part to generous subsidies, which should help defray some sunk cost of operations in China. Recent high-profile cases of espionage involving China and the theft of technology secrets from Korean firms³¹ also may have deterred cutting-edge investments in China even if the controls were not in place.

ECONOMIC COERCION AND BACKFILLING

In a move widely seen as retaliation for the restrictions on YMTC, in June 2023 China’s Cyberspace Administration used a cybersecurity review to justify blocking Micron memory products from being used in products with critical infrastructure applications in China.³² Eleven percent of Micron’s sales from the third quarter of 2021 to the third quarter of 2022 went to China, so it has a

28 TrendForce, “YMTC Could Abandon Market for 3D NAND Flash by 2024 Following US Government’s Decision to Place It on Entity List, Says TrendForce,” press release, December 16, 2022.

29 Michael Herh, “Korea Ahead of China in DRAM Technology by 5 Years,” *BusinessKorea*, May 31, 2022.

30 Qianer Liu, Cheng Leng, Eleanor Olcott, and Demetri Sevastopulo, “Chinese Chipmaker Plans Listing after Clearing US Export Controls,” *Financial Times*, May 9, 2023.

31 Soo-Hyang Choi, “Ex-Samsung Elec Executive Accused of Stealing Secrets for China Chip Factory,” Reuters, June 12, 2023.

32 Eleanor Olcott and Demetri Sevastopulo, “China Bans Micron’s Products from Key Infrastructure over Security Risk,” *Financial Times*, May 21, 2023.

substantial market it could lose.³³ Although Micron is only banned for a small subset of applications in China, Chinese buyers could take it as a government signal to stop all purchases while claiming their ban is a narrowly targeted security measure. This may be happening—Lenovo reportedly entirely stopped buying Micron products in response, not just for products destined for critical infrastructure.³⁴ When memory was scarce in 2022, this would have been a costly move for China because it badly needed all the supply it could get; now, however, with large inventories and overall oversupply, China can impose pain on Micron without risking its own access to memory chips. The winners of China's action could be SK hynix and Samsung, which would be able to take Micron's market share in China.

The Biden administration asked the Korean government to ensure its firms do not “backfill,” or sell China the chips it otherwise would have purchased from Micron.³⁵ The Korean government publicly demurred, saying it would leave the decision up to the firms, but then seemed to walk back that statement.³⁶

Although it is a worthy goal to counter Chinese coercion, an effective “no backfill” agreement would be difficult to implement. The memory market works through both direct sales and distributors, and sales are at a bottom with large inventories built up throughout the supply chain. They are, however, expected to pick up during the second half of 2023. Therefore, it is not clear how SK hynix or Samsung would know if a new order coming from China was a regular order or a backfill that otherwise would have gone to Micron. The cost in this market environment of foregone sales is also higher than usual.

Unlike ASML, which, when ordered not to sell to China, could just sell to other buyers in a long backlog without losing revenue, SK hynix and Samsung would be foregoing revenue when they need it most. The cyclical nature of the market—with a glut following a period of shortage—makes it challenging to determine the sales basis for a no backfill agreement. Any agreement that would, for example, keep market shares constant by shifting Korean sales outside of China to Micron, would need to be made at the government level; otherwise, it would risk major antitrust cases for carving up the market in this way. Nevertheless, the political backlash in the United States from backfilling its only DRAM player could imperil the license renewal process and create other risks, as evidenced by letters from influential congresspeople demanding that licenses for chipmakers not be used to backfill Micron.³⁷ Controls and Chinese retaliation have put Korean firms in an uncertain and perilous geopolitical environment in which the demands of Chinese and American authorities are impossible to fulfill simultaneously.

33 Micron, “Form 10-K: Annual Report Pursuant to Section 13 or 15(D) of the Securities Exchange Act of 1934 for the Fiscal Year Ended September 1, 2022,” US Securities and Exchange Commission, October 7, 2022.

34 Che Pan, “Tech War: China's Top Server Makers Stop Orders of Memory Modules Containing Micron Chips, Sources Say,” *South China Morning Post*, May 26, 2023.

35 Demetri Sevastopulo, “US Urges South Korea Not to Fill China Shortfalls If Beijing Bans Micron Chips,” *Financial Times*, April 24, 2023.

36 Sam Kim, “South Korea to Avoid Cashing In on China's US Chipmaker Ban,” Bloomberg, May 27, 2023.

37 Select Committee on the Chinese Communist Party, “Gallagher Statement on Micron Ban,” press release, May 23, 2023.

One area that has received far less attention is whether Korea will join the SME controls. Although its market share is currently small, Korean firms have significant expertise and could potentially take advantage of sales to China that US, Japanese, and Dutch firms can no longer legally do as well as help contribute that expertise to Chinese firms aiming to build a homegrown chip manufacturing equipment industry (Allen 2023). The minimal current market share for Korea means that any Chinese gains would not come at the expense of Korean firms, but the diplomatic cost with both Japan and the United States would be significant. In response, the controlling countries could restrict Korea's supply to Korea of key chipmaking tools or other inputs.

CONCLUSION

Export controls have become one of the most contentious battlegrounds in the technology competition between the United States and China. Semiconductors are key to advanced civilian and military applications. At least for now, the key role of US technology and firms at choke points in the global supply chain gives the United States an ability to apply effective controls on chips. Export controls aimed at China, however, have also embroiled countries such as Korea.

Export controls largely do not affect Korean firms' chip sales to China, but Korean firms have been some of the most impacted non-Chinese firms due to their large memory chip production facilities in China. Although the United States is unlikely to shut off access to the technology needed to keep the plants running for the foreseeable future, it has signaled that it will not allow new technology needed to upgrade those facilities; therefore, they will become uncompetitive over the next few years and will need to be shuttered or sold off. For future production, Korean firms will need to build new facilities at great (albeit subsidized) expense, amortizing the sunk costs of operations in China over the coming years.

At the same time, the controls have created significant benefits for Korean firms by shutting off Chinese competition for their memory businesses. Korean firms may also benefit from Chinese retaliation against Micron, their only serious competitor in DRAM; they may continue to expand sales in China at Micron's expense unless backfilling is stopped either due to company actions or an agreement between the US and Korean governments. It is not clear if this can be done, and benefiting from the tensions between superpowers comes with serious risks. Firms and governments must deal with much greater uncertainty and evaluate the risk of their dependence on both the United States and China.

The United States should do more to reduce unnecessary uncertainty, creating more long-term solutions to help allies navigating already challenging terrain without compromising on national security. It should also recognize the need for a more detailed national security justification for its measures to gain more international buy-in, especially when such measures have broad impacts on the civilian economy.

REFERENCES

- Allen, Gregory C. 2023. *China's New Strategy for Waging the Microchip Tech War*. CSIS Report, May 3. Washington: Center for Strategic and International Studies.
- Allen, Gregory C., Emily Benson, and Margot Putnam. 2023. *Japan and the Netherlands Announce Plans for New Export Controls on Semiconductor Equipment*. CSIS Report, April 10. Washington: Center for Strategic and International Studies.
- Bauer, Harald, Stefan Burghardt, Sid Tandon, and Florian Thalmayr. 2016. *Memory: Are Challenges Ahead?* McKinsey & Company, March 8.
- BIS (Bureau of Industry and Security). 2022a. *Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items; Supercomputer and Semiconductor End Use; Entity List Modification*. *Federal Register* 87, no. 197 (October 13): 62186-215. Washington: US Department of Commerce.
- BIS (Bureau of Industry and Security). 2022b. *FAQs for Interim Final Rule—Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items; Supercomputer and Semiconductor End Use; Entity List Modification*. Washington: US Department of Commerce.
- Bown, Chad P. 2020. *How the United States Marched the Semiconductor Industry into Its Trade War with China*. PIIE Working Paper 20-16 (December). Washington: Peterson Institute for International Economics.
- Fuller, Douglas B. 2020. *Cutting Off Our Nose to Spite Our Face: US Policy toward Huawei and China in Key Semiconductor Industry Inputs, Capital Equipment, and Electronic Design Automation Tools*. National Security Report. Laurel, MD: Johns Hopkins Applied Physics Laboratory.
- Hufbauer, Gary Clyde, and Megan Hogan. 2022. *CHIPS Act Will Spur US Production but Not Foreclose China*. PIIE Policy Brief 22-13. Washington: Peterson Institute for International Economics.
- McCarthy, Thomas J., Kevin J. Wolf, Shiva Aminian, Anne E. Borkovic, Jaelyn Edwards Judelson, Susan M.C. Kovarovics, Kimberly M. Myers, Tatman R. Savio, Jingli Jiang, Alasdair Kan, Brett R. Orren, Ragan W. Updegraff, and Thomas Krueger. 2022. *BIS Imposes New Controls to Limit the Development and Production of Advanced Computing and Semiconductor Capabilities in China*. *Akin Insights*, October 27. Akin Gump.
- Miller, Chris. 2022. *Chip War: The Fight for the World's Most Critical Technology*. New York, NY: Scribner.
- White House. 2021. *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth*. A Report by the White House, June. Washington.
- Wolf, Kevin J. Shiva Aminian, Anne E. Borkovic, Jingli Jiang, Jaelyn Edwards Judelson, Susan M.C. Kovarovics, Kimberly M. Myers, Thomas Krueger. 2023. *BIS Has New Authorities to Impose Controls over Activities of US Persons in Support of Foreign Military, Security, or Intelligence Services*. January. Akin Gump.



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