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U.S. Semiconductor Export Controls and their Implications to Korea

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[Background] In October 2022, the United States implemented its most stringent semiconductor export control measures to date, and in October 2023, these measures were further expanded. These controls primarily target two facets of the Chinese semiconductor industry: chip manufacturing and the use of AI chips in data centers.

Regarding chip manufacturing, the U.S. seeks to limit China's ability to manufacture chips by controlling the export of semiconductor manufacturing equipment (SME). Notably, in October 2023, the U.S. export control agency, the Bureau of Industry and Security (BIS) broadened the scope by including nearly all types of SMEs necessary for advanced semiconductor fabrication and expanded the list of countries under control.

In the area of AI chips, the BIS has brought 'AI chips' under regulatory oversight. In addition, the export of 'AI chips' falls under the Foreign-Direct Product Rule (FDPR), which requires U.S. approval even for production outside the U.S. territory. Subsequently, in October 2023, BIS expanded the scope of AI chips under control, bringing almost all existing data center AI chips under export control.

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[Fabrication of Chips] Analyzing the impact on China's chip-making capacity, comparisons based on customs data before (Jan-Sep 2022) and after (Jan-Sep 2023) the October 2022 export control provide valuable insights. Figure 1 illustrates several key observations:

1. Overall, SME imports from China saw a marginal change (an increase of 2.6%). However, excluding imports from the Netherlands, which has a near monopolistic status in DUV (Deep Ultraviolet) tools, Chinese SME imports dropped by 7.8% after the export control.

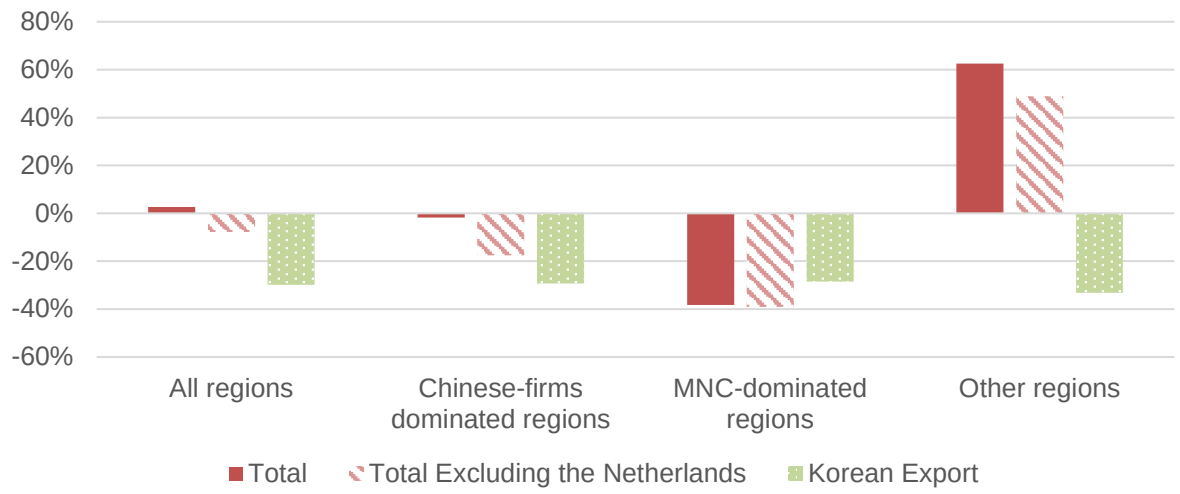
2. This decline is even more pronounced in regions dominated by Chinese firms (Beijing, Shanghai, Anhui, and Hubei), where SME imports fell by 17.6% if imports from the Netherlands were excluded.

3. Regions dominated by multinational corporations (MNCs) experienced the most significant impact, with a substantial 40% decline. Notably, these regions are also affected by the CHIPS Act's guardrail provision, which limits substantial expansion.

4. The 'other regions', which primarily focus on legacy semiconductor production, saw a substantial increase in SME imports, about 49%, even after excluding imports from the Netherlands.

5. Korea, which produces SMEs that complement U.S. SMEs, experienced a notable decline in SME exports to China across all regions.

Figure 1. Chinese Imports of SMEs by Region and Partner



Note: 'Chinese-firms dominated regions' include Beijing, Shanghai, Anhui, and Hubei, where manufacturing facilities of SMIC, YMTC, and CXMT are located. The 'MNC-dominated regions' are Shaanxi, Liaoning, Jiangsu, and Fujian, where manufacturing facilities of Samsung Electronics, SK Hynix, TSMC, and UMC are located. This regional classification is based on Kim et al. (2023). The comparison in the figure shows the changes in imports from January to September 2023 compared to the same period in 2022. The data is sourced from the General Administration of Customs of the People's Republic of China.

Recent anecdotal evidence further supports the above analysis. Applied Materials, in its 10-Q reports filed in August 2023, noted a decline in China's revenue share from 31% to 22% when comparing the nine months ended July 2022 and 2023. Interestingly, Lam Research's September 2023 quarterly report highlighted an increase in China's revenue share from 48% to 26% during the third quarter of 2023 compared to the same quarter in 2022. However, the same Lam Research report attributed the shift to 'increased spending of China customers for mature node equipment.'

The first lesson to be learned from these facts is that export controls have proven to be detrimental to both domestic Chinese firms and MNCs operating in China. Ongoing discussions between the Korean and U.S. governments have partially mitigated the adverse effects, as evidenced by the BIS's re-designating of Samsung Electronics and SK Hynix as validated end-users (VEUs). This designation allows continued SME supply to Korean semiconductor manufacturers in China. However, the ban on the import of Extreme Ultraviolet (EUV) lithography tools—critical for the production of advanced Dynamic Random-Access Memory (DRAM) chips of 14nm (1a generation) and beyond—remains in place, posing a challenge to SK Hynix's use of EUV technology in its Chinese facilities.

Second, in response to export control, China is increasing its capacity for legacy semiconductors. Given that the memory and foundry sectors are the primary targets of export controls, the above evidence shows China's strategic investment in legacy semiconductor technologies is becoming more significant. This strategic focus is consistent with China's pursuit of self-sufficiency, starting with legacy semiconductors and extending to achieving autonomy in the upstream segments of the semiconductor value chain. Oh (2023) highlights substantial technological advances by SME makers such as NAURA, AMEC, SMEE, and ACM Research, supported by robust support from Chinese government subsidies to strengthen advanced node semiconductor manufacturing capabilities.

[Use of AI Chips] Regarding the impact on the use of AI chips, the most recent export control implemented in October 2023 covers both 'high-end AI chips' (ECCN 3A090.a) and 'low-end AI chips' (ECCN 3A090.b). Notable examples of 'high-end AI chips' include Nvidia A100 and H100, which are crucial for training large-scale AI models in data centers. Conversely, 'low-end AI chips' offer lower performance but cost-effective options suitable for inference, lightweight AI model training, or prototyping such models.

In the short term, the lack of viable alternatives means that data centers and major tech firms in China are likely to face challenges in meeting their requirements for developing large-scale

AI models. Key U.S. companies such as Nvidia, AMD, and Intel serve as the primary suppliers of these critical AI chips, and finding substitutes is a significant hurdle for developers in China. However, this also translates into a shrinking AI chip market for designers like Nvidia, AMD, and Intel. Specifically, Nvidia anticipates a substantial decline in fourth-quarter 2023 sales in China due to the impact of export control measures.[1] Additionally, U.K.-based AI chipmaker Graphcore has shut down its operations in China, attributing the decision to the restrictions imposed by U.S. export controls.[2] Gina Raimondo, the U.S. Secretary of Commerce, underscored the strict regulatory stance by emphasizing the swift scrutiny of any chip redesigned to facilitate AI functionalities.[3] So, more to come.

On the other hand, the restrictions in the AI chips market are poised to have a ripple effect, negatively impacting the demand for high bandwidth memory (HBM). Modern AI chips, renowned for their robust computational performance, require the rapid transmission of large amounts of data across numerous cores operating in parallel. The prominence of HBM as a pivotal component in AI chips reflects this industry trend. A decline in demand for AI chips would, therefore, affect the sales of major players in the HBM market, such as SK Hynix and Samsung Electronics.

In response to these challenges, China is forced to turn to domestically manufactured chips and will heavily invest in supporting domestic chip designers to create alternatives to U.S.-sourced AI chips. Notable companies such as Huawei, Biren Technology, Baidu, and Alibaba have experience in designing advanced AI chips. Additionally, SMIC's recent success in producing 7nm node logic chips demonstrates progress. However, there is still a technological barrier to overcome, as China still lacks the capacity to produce its own HBM or other types of DRAM, which is critical for high-performance applications. The design, foundry, and memory bottlenecks pose significant challenges to China's aspirations to become a self-sufficient AI leader. The Chinese government is expected to provide substantial subsidies to address these bottlenecks in the near future.

[Implication to Korea] Regarding implications for Korea, it is imperative to understand the opportunities and challenges posed by U.S. export controls on China. Leveraging these circumstances requires the creation of strong incentives to strengthen Korea's weaker facets.

First, the export controls present opportunities by easing the intense competition with China.

[1] https://www.reuters.com/technology/nvidia-forecasts-fourth-quarter-revenue-above-estimates-2023-11-21/
[2] https://www.bloomberg.com/news/articles/2023-11-22/nvidia-rival-graphcore-pulls-out-of-china-citing-export-rules?utm_source=website&utm_medium=share&utm_campaign=copy
[3] https://fortune.com/2023/12/02/ai-chip-export-controls-china-nvidia-raimondo/

For instance, Chinese projects such as YMTC and CXMT, which are central to the 'Made in China 2025' initiative, will have to deal with the repercussions of export controls. Export control measures could give Samsung Electronics and SK Hynix the leverage to avoid the intense competition from Chinese memory manufacturers.

Although Korea's AI chip design industry is still nascent, capitalizing on this momentum could include exploring niche markets such as AI model inference in specific applications such as self-driving cars, finance, healthcare, and smart manufacturing systems. While direct competition with the world-leading AI chip designers may be challenging, Korea's robust foundry and memory capabilities and significant AI end-user demand provide a fertile ground for growth. Strong government support for AI framework research, AI chip prototyping, and fostering startups becomes pivotal in this pursuit. The U.S., China, the E.U., and Japan are all in this race. We cannot afford to fall behind. Now is the time to act.

Second, the U.S. commitment to a multilateral export control regime underscores the importance of active participation in mitigating disruptions to the global semiconductor supply chain. The recent U.S. move to implement a 0% de minimis threshold for certain lithography equipment in October 2023 underscores the significant consequences of a lack of international cooperation. This action means that even a small U.S. contribution to semiconductor manufacturing equipment (SME) produced outside the U.S. borders will require a U.S. license for exports and re-exports. While the Bureau of Industry and Security (BIS) may rarely resort to such stringent measures, its implementation sets a precedent. As a close U.S. ally, Korea may find it challenging to avoid compliance if asked to participate in such efforts.

Third, Korea needs to strengthen the semiconductor supply chain, which is of paramount importance to Korea's strategic interests. A critical issue is that manufacturing facilities in China lack Extreme Ultraviolet (EUV) tools, thus limiting their capability to produce 1a generation and advanced DRAM chips. While there are few alternatives, Korea must proactively seek and cultivate potential substitutes. Overcoming administrative barriers and providing robust infrastructure investments are pivotal to bringing manufacturing back to Korea. At the same time, diversification of manufacturing locations is also crucial for Korea's semiconductor industry. Korean semiconductor manufacturing industry needs to implement a strategic step-by-step approach to seek cost-effective alternatives outside Korea's borders. Initiating this process by establishing packaging sites for memory producers and securing robust support from local governments is fundamental. This strategic pursuit entails transitioning Korean plants in China to manufacture 1a-generation DRAM chips, a process that could occur within the next two to three years. Taking proactive steps at this time is imperative to secure future capabilities and

opportunities in the semiconductor landscape.

Fourth, strengthening the upstream segment of the value chain requires a significant focus on enhancing support for the SME industry in Korea. Given the critical role of SMEs in the semiconductor ecosystem, ceding a competitive edge is not an option. Developing SMEs with marketable offerings that can outperform their Chinese counterparts is essential. Recognizing the rapid advancements made by Chinese competitors, often facilitated by substantial subsidies, underscores the urgency of bolstering Korean SMEs. Addressing sectors heavily affected by export controls and engaged in fierce competition with China, such as etching, cleaning, and deposition equipment, requires the Korean government to strategically utilize all available tools outlined in the "Special Act on Materials, Components, and Equipment." This comprehensive approach is essential to support the growth and competitiveness of Korean SMEs in the semiconductor industry. KIEP

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