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# Investigating the Effect of the U.S. Semiconductor Export Controls on China

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## I. Introduction

In October 2022, the Biden administration introduced semiconductor export controls on China at an unprecedented scale. Traditionally, U.S. policies toward China were centered around the Department of Commerce's Entity List (EL), which prohibited certain transactions with entities on the list. While the Obama and Trump administrations also implemented semiconductor export controls, their measures were targeted at specific companies. In contrast, the Biden administration's new regulations broadly control all semiconductor manufacturing facilities and AI chips that meet certain criteria.

For semiconductor manufacturing facilities, those capable of producing logic chips at 16/14nm or below, DRAM at 18nm or below, or NAND with 128 layers or more were subjected to export controls. The technology governing these facilities was not new; for example, SMIC had already produced 7nm logic chips – well below the 16/14nm threshold – just before the October 2022 measures were introduced. The 18nm DRAM corresponds to the "1x generation" DRAM, which was introduced in 2016, and YMTC had produced a prototype of a 232-layer 3D NAND flash in 2022. As a result, the three major semiconductor manufacturing companies in China – SMIC (foundry), YMTC (NAND), and CXMT (DRAM) – were all affected by the decision. Although not directly related, Apple reversed its plan to use YMTC's NAND chips shortly after the export control measures were announced.

Another major component of the export controls focused on AI chips. In the initial measure introduced in October 2022, chips were subject to control if they had a performance power – calculated as the product of tera operations per second (TOPS) and bit length per operation – of 4,800 or more, and a bidirectional transfer rate of 600 Gb/s or higher. Most high-end datacenter chips had high bidirectional transfer rates, while consumer-grade chips rarely featured this capability. As a result, the bidirectional transfer rate condition effectively excluded chips that were not highly sensitive or useful for developing AI models. Chips like the Nvidia A100 and AMD MI250 were among those impacted.

However, shortly after the October 2022 measure was introduced, Nvidia developed a modified version of the A100 specifically for the Chinese market. A year later, in October 2023, the U.S. introduced an updated version of the export control, which removed the bidirectional transfer rate condition, thereby expanding the range of AI chips subject to regulation. Additionally, the threshold for performance power was lowered, further broadening the scope of AI chips under control.

A significant aspect of the Biden administration's approach is the strategic alignment with allies to enforce semiconductor export controls on China. Japan and the Netherlands have joined in these efforts, although they did not explicitly identify China as the primary target. Nevertheless, the list of items controlled by Japan and the Netherlands aligns with the U.S. measures introduced in October 2023, which expanded the list of semiconductor manufacturing equipment under control. Since Chinese chipmakers could potentially circumvent U.S. export controls by purchasing equipment from other countries, it was a logical step for the U.S. to encourage its allies to participate in these restrictions.

Even if allies do not fully align with U.S. policies, the U.S. has a powerful tool to enforce its export controls globally: the Foreign-Direct Product Rule (FDPR). Under the FDPR, companies using certain U.S. technologies or software must obtain an export license from the U.S. for transactions involving specific products and entities. Leveraging this tool, the Biden administration introduced a new "advanced computing FDPR," which specifically applies to AI chips being exported to China.

## II. Impact of Semiconductor Export Controls

Based on the background information provided, this report presents a preliminary assessment of the impact of U.S. semiconductor export controls on China. The export controls encompass various areas, including semiconductor manufacturing facilities, AI chips, supercomputers, and more. However, this report will focus on two key elements that are particularly relevant to the Korean semiconductor industry: China's imports of semiconductor manufacturing equipment and AI chips.

## 1. Imports of China's Semiconductor Manufacturing Equipment

We estimate the decrease in China's semiconductor manufacturing equipment imports by analyzing monthly trade data from China, Korea, and Taiwan from January 2018 to June 2023. Korea and Taiwan were not targeted by the export controls and therefore serve as control groups in our analysis. Data from after June 2023 is included to reflect the participation of Japan and the Netherlands in the semiconductor export controls. The primary model specification we used is as follows:

$$\ln IMP_{i,j,t} = \rho \ln IMP_{i,j,t-1} + \beta EC_{j,t} + CONTROLS_{j,t} + \epsilon_{i,j,t}.$$

$\ln IMP_{i,j,t}$ is the log of imports of product $i$, country $j$, at time $t$. $EC_{j,t}$ is an indicator variable which is one after October 2022, when the U.S. imposed the sweeping semiconductor export control, and zero, otherwise. $CONTROLS_{j,t}$ include various control variables, such as, year fixed effect, DRAM and NAND price indexes to represent semiconductor industry business environment, and indicators for COVID-19 lockdowns. Additionally, we used 12-month difference terms to control for seasonality in imports. To address potential endogeneity issues when employing a dynamic panel data model, we applied the Anderson & Hsiao (1981) estimator.

Based on our estimation results, China's semiconductor equipment imports decreased by 32.5% overall. We also investigated whether China attempted to stockpile semiconductor equipment starting in January 2022, prior to the introduction of the export control measures, but we found no significant evidence of such an effect. Additionally, we examined the impact of adding YMTC and SMIC to the Entity List, but the results were also insignificant. This may suggest that the Entity List alone was not sufficient to produce a substantial impact on China's semiconductor equipment imports, or that these two firms do not fully represent the overall Chinese semiconductor industry.

We can further break down the results by the type of semiconductor manufacturing equipment. For lithography equipment, we did not observe a significant decrease in imports, likely due to the Netherlands' dominant role in this market. However, for other types of equipment, such as those used in silicon wafer production, thermal processing, chemical mechanical planarization (CMP), etching, deposition, and ion implantation, we observed a significant decrease in import levels following the October 2022 export controls.

Another perspective in our investigation involves analyzing three types of regions in China: regions where Chinese firms manufacture advanced semiconductors, regions with foreign firms, and regions that focus more on legacy semiconductors. We observed a 43.7% decrease in imports in regions where Chinese firms lead the fabrication of advanced semiconductors and a 51.6% decrease in regions dominated by foreign firms after the export

**Table 1. Impact of Semiconductor Export Controls on Chinese Semiconductor Manufacturing Equipment Imports**

| Dependent variable: Chinese imports of semiconductor manufacturing equipment | | Models | | |
|---|---|---|---|---|
| | | (A) Benchmark Model | (B) Entity List Effect | (C)Pre-stockpiling Effect |
| Impact of Export Controls | | -0.325*** | -0.366*** | -0.346*** |
| | | (0.111) | (0.0847) | (0.116) |
| Entity List Effect | YMTC | | 0.0597 | |
| | | | (0.0901) | |
| | SMIC | | 0.00515 | |
| | | | (0.0328) | |
| Stockpiling Effect (From January 2022) | | | | -0.0718 |
| | | | | (0.0656) |
| Sample Size | | 1,661 | 1,661 | 1,661 |

Note: ***, **, * represents that the estimates were significant at 1%, 5%, and 10% level.
Source: Author's estimation.

controls were implemented. However, in regions focused on legacy semiconductors, the effect of the export controls was insignificant.

When estimating by country, we observed the most dramatic decrease in Chinese imports of semiconductor manufacturing equipment from Korea, with a 49.1% decline following the export controls. Imports from both the U.S. and Japan also significantly decreased. However, the Netherlands was an exception, showing a 27.5% increase in their exports to China during the same period.

When focusing on Korean semiconductor manufacturing equipment exports by the types of regions described earlier, the decrease in exports was primarily driven by regions with a significant presence of foreign companies, such as Samsung Electronics in Shaanxi Province and SK hynix in Jiangsu Province, as well as regions focused on legacy semiconductors. In regions dominated by foreign companies, exports decreased by about 44.6%, while in regions focused on legacy semiconductors, we observed a 44.7% decrease following the export controls. This suggests that foreign companies in China were sensitive to the uncertainty in the business environment due to U.S.-led export controls and consequently reduced their capital investments in China. Additionally, domestic Chinese companies may be shifting from using foreign manufacturing equipment to relying more on domestic alternatives.

A word of caution is necessary. Our analysis only covers the period before July 2023. Starting in July 2023, the U.S. successfully persuaded Japan and the Netherlands to impose export controls, and the U.S. itself expanded its export controls in October 2023. These changes have prompted idiosyncratic responses from Chinese semiconductor manufacturers, including stockpiling essential equipment. As a result,

the response of Chinese semiconductor manufacturers is evolving over time, influenced by the shifting circumstances surrounding semiconductor export controls.

Additionally, the results may be influenced by the guardrail provision in the CHIPS and Science Act of 2022, which prohibits material expansions of more than 5% for entities receiving subsidies from the U.S. government. This provision could also discourage foreign firms operating in China from maintaining or increasing their capital investments, further complicating the analysis of the export controls' impact. However, it is unlikely that the objectives of the semiconductor export controls and the guardrail provision are distinct from each other. Both regulations aim to constrain the capabilities of the Chinese semiconductor industry, and the analysis above may deliver the combined effect of these U.S. regulations.

### 2. AI Chips

The AI chip industry is currently experiencing rapid growth. Following the introduction of several prominent AI models, the scope of AI applications has broadened significantly, leading to a surge in demand for AI chips. Given the industry's ongoing expansion, accurately assessing the full impact of AI chip export controls is a challenging task. However, it is clear that the overall performance of AI chips will continue to improve, and as time goes on, an increasing number of AI chips will likely fall under export control.

Nvidia, the market leader in the AI chip sector, held approximately 97% of the market share in Q4 2022, based on unit sales. Consequently, the short-term impact of semiconductor export controls on Korea would primarily stem from a decrease in Chinese demand for AI chips. Due to the Foreign-Direct Product Rule (FDPR), China may struggle to find foundry services or memory providers, although these challenges are relatively small compared to the dominance of global giants like Nvidia and AMD.

As a result, the decline in demand may lead China to import downgraded AI chips that incorporate less valuable memory components, other than High Bandwidth Memory (HBM). This could, in turn, lead to an increase in China's DRAM imports, but the overall value of these DRAM imports would decrease due to the substitution with less advanced memory.

We conclude that the overall impact on Korean memory makers, such as Samsung Electronics and SK hynix, will likely be offset by the benefits of the broader AI market expansion. However, when comparing the current situation to a counterfactual scenario in which China was not affected by AI chip export controls, the loss of demand could be significant – and may grow even larger in the future.

## III. Policy Implications

From a policy perspective, Korea should prepare for the dynamic evolution of export con-

trols. The U.S. presidential election is scheduled for the end of 2024, but regardless of whether a Democratic or Republican candidate wins, it is likely that the current U.S. policy of "small yard, high fence" will continue. Even if the current export control regime remains, it is inevitable that the "small yard" will naturally expand into a "large yard" in the future as technology advances.

To safeguard economic security and mitigate negative external economic influences, Korea should prioritize strengthening its competitiveness in the upstream semiconductor industry, particularly in semiconductor manufacturing equipment. The cooperation between the South Korean and U.S. governments, which allowed Samsung Electronics and SK hynix to obtain VEU status, addressed the immediate issue of semiconductor manufacturing equipment supply. However, in the long term, as market demands for higher levels of DRAM technology increase, it may become necessary to introduce EUV equipment into production facilities in China. If the U.S. government's stance does not change, DRAM plants located in China are likely to gradually lose their significance. To respond to this situation, it seems necessary to support the reshoring of semiconductor production bases back to the domestic market.

In October 2023, the U.S. Bureau of Industry and Security (BIS) announced expanded export control measures, highlighting the need for caution when exporting integrated circuits, computers, electronic devices, and components that contain High Bandwidth Memory (HBM) and have over 50 billion transistors. Although meeting these criteria does not necessarily mean a product will be subject to export controls, the BIS interprets that if such products are exported to countries under export control, they are likely to require an export license under U.S. regulations. In light of this warning, it may be necessary to carefully assess whether future collaborations with Chinese companies could potentially violate U.S. export control regulations.

Export controls are expected to accelerate the fragmentation of the logic semiconductor market. However, since the areas that South Korean AI semiconductor designers focus on are likely not closely related to export controls, it is important to support these designers in taking advantage of the reduced capacity of major semiconductor design firms to respond to this fragmentation. Traditional financial and funding support may be necessary, but ultimately, measures that help these designers adapt to the evolving logic semiconductor market will be more critical. For example, providing pilot lines that allow small semiconductor design companies to develop and test various types of semiconductors, thereby improving their access to advanced processes offered by foundries, would be a key support method.

U.S. regulatory authorities have been engaging in ongoing consultations with the South Korean government and other relevant governments, but they have not disclosed any pre-

impact assessment data related to these measures, and it is unclear whether such assessments were conducted. For instance, during the feedback process related to the previous export controls (October 7, 2022), SEMI demanded that when regulations such as export controls are proposed, the industry should be given ample opportunity to participate in evaluating the impact. Similarly, the Semiconductor Industry Association (SIA) suggested that considering the economic impact on companies within the U.S. and its allied countries, it is necessary to estimate the scope of potential uncertainties and effects these companies may face due to the controls.

Based on these positions from various industry associations, it seems likely that the U.S. government may not have conducted a comprehensive process of seeking industry-wide input or performing pre-impact assessments. However, the more significant and far-reaching a policy is, the more cautiously it should be implemented, and it is crucial to evaluate its execution and outcomes. In this context, if possible, a joint study between the countries negotiating with the U.S. on export controls could be conducted to carry out pre-impact assessments before the implementation of such controls and to reconcile differing perspectives. KIEP

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