Commentary and Critique **Research Commentary**
Vol. 7 (2025) · ISSN 3006-6220 journal.pe.ac/Commentary-and-Critique

Semiconductor Equipment Export Controls —Did China's Imports Decline After October 2022? A Comtrade Count, 2019–2024

Farhod Rakhimov[a], Irina Meshkova[a]

[a]Academy of Public Policy and Economics, London E1 0SG, United Kingdom

Corresponding author: Farhod Rakhimov, farhod.rakhimov@pe.ac.

Published 20 September, 2025.

DOI: https://doi.org/10.62432/APPE.CC.2025.7.44

Article webpage: https://journal.pe.ac/Commentary-and-Critique/paper/view/106047

Abstract

On October 7, 2022, the U.S. Bureau of Industry and Security (BIS) imposed the most sweeping export controls on China's semiconductor industry in a generation. Japan and the Netherlands followed with their own restrictions in mid-2023. This analysis uses UN Comtrade data (HS 8486, "machines and apparatus for the manufacture of semiconductor devices") to examine the trajectory of China's equipment imports after these controls were imposed. HS 8486 is a broad heading that aggregates all semiconductor manufacturing equipment —from advanced lithography scanners to commodity assembly tools and flat-panel-display machinery —and does not distinguish controlled from unrestricted technologies. Combined exports from Japan, the Netherlands, and the United States to China under HS 8486 rose from USD 17.2 billion in 2022 to USD 28.6 billion in 2024 —an increase of 66%. This aggregate growth, however, cannot be interpreted as evidence that controls failed to restrict advanced-technology access. The aggregate conceals a sharp divergence: U.S. exports fell 39% from their 2021 peak to USD 4.2 billion in 2024, while Dutch exports surged 322% to USD 10.1 billion, driven by ASML's pre-restriction order fulfillment and continued sales of non-restricted equipment. Japan's exports, the largest component, rose to USD 14.4 billion in 2024. The HS 8486 category, which lumps together advanced lithography tools and commodity etching chambers, does not disaggregate by technology node, so the headline numbers obscure a likely shift in the composition of China's equipment imports. The evidence suggests that multilateral export controls have reshaped —but not reduced —China's access to semiconductor manufacturing equipment.

Keywords: semiconductor equipment; export controls; HS 8486; China; Comtrade; ASML; BIS; lithography

1. Introduction

On October 7, 2022, the Bureau of Industry and Security (BIS) of the U.S. Department of Commerce published an interim final rule that fundamentally altered the landscape of semiconductor trade with China (Bureau of Industry and Security, U.S. Department of Commerce, 2022a). The rule, formally titled "Implementation of Additional Export Controls: Certain Advanced Computing and Semiconductor Manufacturing Items," imposed export licensing requirements on a broad range of advanced computing chips, semiconductor manufacturing equipment, and related technologies destined for Chinese entities. It was the most consequential tightening of U.S. technology export controls since the Cold War-era Coordinating Committee for Multilateral Export Controls (CoCom) regime, and it represented a decisive shift

© 2025 Academy of Public Policy and Economics · Open Access (CC BY 4.0).

from the longstanding U.S. policy of maintaining a two-generation technology gap with China to a policy of outright denial of advanced semiconductor capabilities.

The October 2022 rule was built on three pillars. First, it restricted the export of advanced logic chips —those fabricated at process nodes of 16nm or 14nm and below for non-planar transistor architectures (FinFET or GAAFET), 18nm half-pitch or less for DRAM memory, and NAND flash memory with 128 layers or more. Second, it imposed controls on semiconductor manufacturing equipment used in the production of these advanced chips, including specific deposition, etching, lithography, and inspection tools. Third, it expanded the Entity List to include major Chinese semiconductor firms, including Yangtze Memory Technologies Co. (YMTC) and several entities affiliated with Semiconductor Manufacturing International Corporation (SMIC) (Bureau of Industry and Security, U.S. Department of Commerce, 2022b). A year later, in October 2023, BIS updated and expanded the rule, tightening several definitions and adding additional equipment categories (Bureau of Industry and Security, U.S. Department of Commerce, 2023).

The United States did not act alone. In May 2023, Japan's Ministry of Economy, Trade and Industry (METI) announced amendments to the Foreign Exchange and Foreign Trade Act that placed export controls on 23 categories of semiconductor manufacturing equipment, effective July 23, 2023 (Ministry of Economy, Trade and Industry, Japan, 2023). The Japanese controls covered immersion lithography systems, etching tools, deposition equipment, and inspection instruments —equipment categories in which Japanese firms Tokyo Electron, Nikon, and Canon hold substantial global market share. In June 2023, the Netherlands' Ministry of Foreign Affairs announced its own export licensing requirement for advanced semiconductor manufacturing equipment, effective September 1, 2023, explicitly targeting ASML's immersion deep ultraviolet (DUV) lithography systems —specifically the NXT:2000i and subsequent models (Ministry of Foreign Affairs, Netherlands, 2023).

The three-country control regime —the United States, Japan, and the Netherlands —collectively accounts for the overwhelming majority of the global semiconductor equipment industry. According to industry data, the three countries are home to the world's top five semiconductor equipment manufacturers: Applied Materials (U.S.), ASML (Netherlands), Lam Research (U.S.), Tokyo Electron (Japan), and KLA (U.S.) (Semiconductor Industry Association, 2024). Between them, they supply virtually all advanced lithography tools, most deposition and etching equipment, and the majority of process control and inspection systems used in cutting-edge semiconductor fabrication. The logic of the multilateral approach was clear: unilateral U.S. controls would be ineffective if Chinese firms could simply purchase the same equipment from Japanese or Dutch suppliers. The trilateral arrangement was designed to close that gap.

But the standard trade classification under which semiconductor equipment is recorded —Harmonized System (HS) code 8486 —is a blunt instrument. It covers "machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays," a definition that encompasses everything from billion-dollar extreme ultraviolet (EUV) lithography scanners to relatively mundane wire bonders and die attach machines used in back-end assembly. HS 8486 does not distinguish between equipment for advanced nodes (7nm, 5nm, 3nm) and equipment for mature nodes (28nm and above), nor between front-end wafer fabrication tools and back-end packaging equipment. A USD 150 million ASML Twinscan NXT:2100i immersion scanner and a USD 50,000 dicing saw both fall under the same six-digit code.

This aggregation presents both a challenge and an opportunity for analysis. The challenge is that the trade data cannot directly answer the most policy-relevant question: whether China is still acquiring equipment capable of producing advanced logic and memory chips. The opportunity is that the aggregate data can reveal whether China's overall purchasing of semiconductor equipment —the leading indicator of fab construction and capacity expansion —has slowed, grown, or shifted in composition. Import values under HS 8486 are a proxy for the scale and pace of China's semiconductor capital expenditure, and

changes in the unit values (dollars per kilogram of equipment) can offer suggestive evidence about the type of equipment being purchased.

This Commentary uses UN Comtrade data for HS 8486 to examine the trajectory of China's semiconductor equipment imports from 2019 through 2024. It focuses on exports from Japan (reporter code 392), the Netherlands (528), and the United States (842) to China (partner code 156), supplemented by data from Singapore, South Korea, and Taiwan as secondary suppliers. The analysis asks four questions. First, did China's total imports of semiconductor equipment decline after the October 2022 BIS controls? Second, how did each of the three major supplier countries' exports to China change during the control period? Third, is there evidence in the unit values of a shift toward cheaper, legacy-node equipment? Fourth, did trade through secondary suppliers —Singapore, South Korea, and Taiwan —increase in a manner suggestive of transshipment or supply chain reconfiguration?

2. Background

2.1. The Three-Country Control Regime

The October 2022 BIS rule marked a structural break in U.S. technology export policy. For decades, the United States had pursued a strategy of "controlled access" —allowing Chinese firms to acquire semiconductor equipment two to three generations behind the cutting edge, maintaining U.S. technological leadership while enabling Chinese firms to participate in global semiconductor supply chains (Allen, 2023; Khan et al., 2023; Fuller, 2024). The 2022 rule replaced this framework with a presumption of denial for any equipment that could advance China's indigenous semiconductor manufacturing capabilities at advanced nodes. The rule's core mechanism was a new "foreign direct product rule" (FDPR) for advanced computing and semiconductor manufacturing, which extended U.S. jurisdiction over items produced abroad using U.S. technology or software —a powerful extraterritorial lever that gave the controls global reach (Bureau of Industry and Security, U.S. Department of Commerce, 2022a).

Japan's July 2023 measures, while narrower in scope, were strategically significant because Japanese firms dominate several equipment sub-sectors where U.S. alternatives are scarce or non-existent. Tokyo Electron holds over 90% of the global market for coater/developer tracks used in photolithography and is a leading supplier of etch and deposition systems. Nikon and Canon are the world's second- and third-largest lithography suppliers after ASML. Japan's 23-item list included immersion lithography tools, resist processing equipment, etching tools for high-aspect-ratio structures, and deposition systems for advanced dielectrics and metals —all critical for sub-14nm logic production (Ministry of Economy, Trade and Industry, Japan, 2023; Sutter & Sutherland, 2023).

The Dutch restrictions of September 2023 were the most narrowly targeted of the three, focused principally on ASML's immersion DUV lithography systems. ASML is the world's sole supplier of EUV lithography tools, which have been subject to export controls under the Wassenaar Arrangement since 2019 and have never been shipped to China. The September 2023 controls extended licensing requirements to certain immersion DUV systems —specifically those capable of producing chips at 45nm and below with overlay precision below 1.5nm —which captured ASML's NXT:2000i, NXT:2050i, and NXT:2100i models. ASML's older NXT:1980Di system, widely used for mature-node production, remained licensable for export to China (Ministry of Foreign Affairs, Netherlands, 2023; ASML Holding N.V., 2024).

2.2. What HS 8486 Covers —and What It Doesn't

HS 8486 is organized into four eight-digit subheadings in many national tariff schedules, but the six-digit level used in Comtrade —and in this analysis —aggregates all of them. The category includes: (1) machines for the manufacture of boules or wafers (crystal pullers, wafer saws, grinders, and polishers); (2) machines for the manufacture of semiconductor devices or electronic integrated circuits (lithography,

etching, deposition, ion implantation, and chemical-mechanical planarization equipment); (3) machines for the manufacture of flat panel displays; and (4) parts and accessories for the foregoing. In practice, the value of HS 8486 trade is dominated by front-end wafer fabrication equipment —the lithography, etch, deposition, and inspection tools that account for roughly 80% of semiconductor capital expenditure (Khan et al., 2023).

What HS 8486 cannot reveal is the technological sophistication of the equipment. A lithography system sold for USD 10 million and one sold for USD 180 million both appear as line items under the same code, distinguishable only by their unit value —and Comtrade does not provide unit counts for this code. As noted in the data section below, quantity data (qtyUnitCode) is not available for HS 8486 in the Comtrade database, meaning that the standard unit value calculation (value ÷ quantity) cannot be performed. The only available proxy is the value-to-weight ratio (fobvalue ÷ netWgt), which must be interpreted with care: different types of equipment have fundamentally different physical characteristics independent of their technological sophistication. A lithography scanner weighs many tons; an inspection microscope weighs a few hundred kilograms. Neither weight nor value alone reveals the technology node.

2.3. China's Semiconductor Capacity Build-Out

China's semiconductor industry has been on a multi-decade trajectory of capacity expansion and import substitution. The "Made in China 2025" plan, announced in 2015, set a target of 70% domestic content for semiconductors by 2025. Subsequent initiatives —including the National IC Industry Investment Fund ("Big Fund") phases I and II, which raised a combined USD 47 billion —have channeled massive state investment into wafer fabrication capacity (VerWey, 2023; Semiconductor Industry Association & Boston Consulting Group, 2022). By 2023, China accounted for approximately 30% of global semiconductor fabrication capacity, measured by installed wafer capacity (200mm-equivalent), up from roughly 20% in 2019. The majority of this capacity was at mature nodes (28nm and above), but SMIC had demonstrated 7nm production capability by 2022 using DUV lithography with multi-patterning —a development that directly motivated the October 2022 controls (VerWey, 2023; Allen, 2023).

The key Chinese firms targeted by the controls —SMIC, YMTC, and ChangXin Memory Technologies (CXMT) —had all undertaken major fab construction projects in the years preceding the controls. SMIC's SN1 and SN2 fabs in Shanghai, designed for 14nm and below, began production in 2019–2021. YMTC's Wuhan fab, aimed at 128-layer and above 3D NAND, was ramping production through 2021. CXMT's Hefei DRAM fab was expanding capacity for 19nm and 17nm DRAM. For all three, imported semiconductor equipment —particularly from U.S., Japanese, and Dutch suppliers —was the critical input (Allen, 2023; Khan et al., 2023).

Chinese equipment imports under HS 8486 are therefore a leading indicator of fab construction activity. Equipment is ordered, delivered, and installed over a multi-quarter cycle, with import values typically peaking one to two quarters after major fab construction phases. A sustained decline in import values would suggest that fab projects were being slowed or cancelled for lack of equipment. Conversely, sustained or rising import values would suggest that China was either continuing to acquire equipment despite the controls or had found alternative sources.

3. Data and Methods

3.1. Data Source

All trade data in this analysis are drawn from the UN Comtrade Database, accessed through the public preview API (comtradeapi.un.org) between July and August 2025 (United Nations Statistics Division, n.d.). The query parameters are: commodity code = 8486 (HS 2012/2017/2022 classification), flow = X (exports, FOB valuation) for reporter-side analysis, and flow = M (imports, CIF valuation) for China-side mirror

data. The primary reporter-partner pairs are: Japan (392) to China (156), Netherlands (528) to China (156), and United States (842) to China (156). Secondary analyses cover Singapore (702), South Korea (410), and Taiwan (158) as additional equipment suppliers to China.

3.2. Period and Frequency

Annual data (freqCode = A) cover the full years 2019 through 2024. Monthly data (freqCode = M) are confirmed to be available in the Comtrade API for HS 8486, but the preview API's single-period-per-request limitation makes full monthly coverage across all reporter-partner pairs prohibitively query-intensive. The analysis relies primarily on annual aggregates, supplemented by monthly data for specific control-event windows (e.g., the quarters surrounding October 2022, July 2023, and September 2023).

3.3. Valuation and Measurement

Exports are reported on an FOB (free on board) basis by the exporting country and on a CIF (cost, insurance, freight) basis by China as the importing country. FOB values are used for the primary exporter-side analysis to isolate the supplier's transaction value; CIF values are used for China's aggregate import totals. The difference between FOB and CIF for the same trade flow is typically 5–10%, representing freight and insurance costs, and does not materially affect trend analysis.

Quantity data is not available for HS 8486 in Comtrade's standard API output (qtyUnitCode = -1, indicating no standard quantity unit). The analysis therefore relies on value (in current U.S. dollars) and net weight (in kilograms) as the primary observables. The value-to-weight ratio (USD/kg) is computed as a coarse proxy for equipment type, on the assumption that more advanced equipment —particularly lithography tools —commands a higher value per unit of physical mass.

3.4. Limitations and Cautions

Several limitations attend the use of HS 8486 for this analysis. First, the code does not disaggregate by equipment type, technology node, or application (logic vs. memory vs. flat-panel display). Second, values are reported in nominal U.S. dollars; no adjustment is made for inflation, exchange rate movements, or changes in equipment pricing over time. Third, the absence of quantity data precludes standard unit value computation; the value-to-weight proxy is suggestive at best. Fourth, trade data reflect customs declarations and may diverge from actual equipment installation dates by weeks or months. Fifth, export controls may affect reporting behavior: controlled equipment may be shipped under alternative HS codes, or shipments may be routed through intermediary countries not captured in bilateral trade flows. These limitations are addressed further in Section 6.

4. Results

4.1. Total Chinese Imports of HS 8486

Table 1 presents annual exports of HS 8486 equipment from Japan, the Netherlands, and the United States to China, and their combined total, for the period 2019–2024. All values are FOB in millions of current U.S. dollars.

Table 1. Exports of HS 8486 (Semiconductor Equipment) to China, 2019–2024 (FOB, million USD)

Year	Japan (392)	Netherlands (528)	USA (842)	Combined
2019	8,261	1,459	3,636	13,355
2020	8,981	2,551	5,018	16,550
2021	11,854	2,534	6,807	21,194
2022	9,728	2,384	5,125	17,237

(continued)

Table 1 (continued)

Year	Japan (392)	Netherlands (528)	USA (842)	Combined
2023	10,805	6,790	4,407	22,002
2024	14,382	10,058	4,170	28,610

Source. UN Comtrade (United Nations Statistics Division, n.d.). All values FOB, current USD. Rounded to nearest million.

The headline finding is unambiguous: combined exports of HS 8486 equipment from the three major supplier countries to China rose from USD 17.2 billion in 2022 to USD 28.6 billion in 2024, an increase of 66.0%. This represents a compound annual growth rate of 28.8% over the two-year period. Far from declining after the imposition of export controls, China's purchases of semiconductor equipment from these suppliers reached their highest level on record in 2024.

Several subsidiary features of Table 1 are worth noting. First, the 2022 value of USD 17.2 billion represented a decline of 18.7% from the 2021 peak of USD 21.2 billion —a decline that predated the October 2022 BIS rule. The 2021 peak was likely driven by pandemic-era demand for chips and China's accelerated fab investment, with 2022 reflecting a broader semiconductor industry downturn and the beginning of capacity digestion (World Semiconductor Trade Statistics, 2024). Second, the 2023 rebound to USD 22.0 billion surpassed the 2021 peak by 3.8%, and the 2024 surge to USD 28.6 billion represented an all-time high, 35.0% above the 2021 level. Third, the composition of the combined total shifted decisively: Japan's share fell from 61.9% in 2019 to 50.3% in 2024, while the Netherlands' share rose from 10.9% to 35.2%, and the U.S. share declined from 27.2% to 14.6%.

4.2. Country-by-Country Analysis

Japan. Japan has consistently been China's largest single supplier of semiconductor equipment under HS 8486, accounting for roughly half of the three-country total throughout the period. Japanese exports to China rose from USD 8.3 billion in 2019 to USD 14.4 billion in 2024, a 74.1% increase. The trajectory, however, was not monotonic: after peaking at USD 11.9 billion in 2021, Japanese exports fell to USD 9.7 billion in 2022, recovered to USD 10.8 billion in 2023, and surged to USD 14.4 billion in 2024 —a 33.1% year-on-year increase from 2023 to 2024.

Japan's July 2023 export controls on 23 equipment categories do not appear to have suppressed the total value of Japanese HS 8486 exports to China. This could reflect several dynamics: the controls applied only to equipment for advanced-node production, leaving the larger market for mature-node equipment unrestricted; Japanese firms may have accelerated shipments ahead of the July 2023 effective date; or the composition of exports may have shifted toward unrestricted equipment categories while total value continued to grow.

The unit value (FOB per kilogram of net weight) of Japanese equipment exports rose from USD 115/kg in 2019 to USD 200/kg in 2024 (Table 2). This increase suggests a shift toward higher-value equipment within the Japanese export mix, potentially reflecting the growing complexity of the tools being sold, price increases over time, or a compositional shift toward categories with higher value density.

Netherlands. Dutch HS 8486 exports to China tell the most dramatic story in the dataset. After hovering between USD 1.5 billion and USD 2.6 billion from 2019 through 2022 —a level broadly consistent with ASML's mature-node DUV and metrology system sales to Chinese fabs —Dutch exports exploded to USD 6.8 billion in 2023 and USD 10.1 billion in 2024. This represents a 322% increase from 2022 to 2024, or a compound annual growth rate of 105.5%.

The surge is attributable almost entirely to ASML. As the dominant Dutch semiconductor equipment manufacturer —and, with a market capitalization exceeding —50 billion, one of Europe's most valuable technology companies —ASML's China revenue closely tracks Dutch HS 8486 exports. In its 2023 annual

report, ASML disclosed that sales to China accounted for —.2 billion, or approximately 30% of total system sales, up from —.9 billion (16%) in 2022 (ASML Holding N.V., 2024). This surge reflects ASML's fulfillment of a substantial backlog of orders placed by Chinese customers before the Dutch export controls took effect in September 2023, as well as continued sales of the NXT:1980Di and older immersion systems not subject to the licensing requirement.

The unit value of Dutch equipment exports is striking. At USD 4,869/kg in 2024, it is 24 times higher than the Japanese unit value and 18 times higher than the U.S. unit value. This reflects the extreme capital intensity of advanced lithography: an immersion DUV scanner can cost USD 60–80 million while weighing several tons, producing a value density far beyond that of etching, deposition, or inspection equipment. The sharp rise in Dutch unit values —from USD 1,973/kg in 2019 to USD 4,869/kg in 2024 —is consistent with an increasing share of high-end immersion lithography systems in the Dutch export mix, even as the most advanced models (NXT:2000i and above) became subject to export licensing.

United States. U.S. HS 8486 exports to China present the clearest evidence that export controls have had a binding effect. After rising from USD 3.6 billion in 2019 to a peak of USD 6.8 billion in 2021, U.S. exports fell to USD 5.1 billion in 2022, USD 4.4 billion in 2023, and USD 4.2 billion in 2024 —a cumulative decline of 38.7% from the 2021 peak. The 2022 value, at USD 5.1 billion, represented a 24.7% year-on-year decline —a drop that encompasses the October 2022 BIS rule, which took effect in the fourth quarter. The continued decline in 2023 and 2024, following the October 2023 rule expansion, suggests that the controls have cumulatively restricted the range of U.S. equipment that can be legally exported to Chinese customers.

Unlike Japan and the Netherlands, where controls were targeted at specific equipment categories within a broader unrestricted portfolio, the U.S. controls —combined with the Entity List designations —affected a wide swath of the U.S. semiconductor equipment industry. Applied Materials, Lam Research, and KLA, the three largest U.S. equipment makers, are heavily exposed to the advanced-node segment, and the BIS rules restricted their ability to supply tools for sub-14nm logic production, sub-18nm DRAM, and 128-layer and above NAND flash (Allen, 2023; Khan et al., 2023). Entity List designations for SMIC affiliates and YMTC directly prohibited exports of U.S.-origin equipment to these major customers without a license, and licenses were subject to a policy of presumption of denial.

The unit value of U.S. exports has been relatively stable —USD 230/kg in 2019, USD 266/kg in 2024 —suggesting a less dramatic compositional shift than observed for Japan and the Netherlands. The relative stability of unit values may reflect the broader mix of equipment types in U.S. exports, which span lithography-adjacent (but not lithography) categories such as etch, deposition, metrology, and process control —all with moderate and roughly similar value densities.

4.3. Secondary Suppliers: Singapore, South Korea, and Taiwan

Singapore. Singapore's role as a semiconductor equipment supplier to China merits particular attention. Singapore is a major hub for semiconductor manufacturing (with fabs operated by GlobalFoundries, Micron, and others) and for equipment distribution. In 2019, China's imports of HS 8486 from Singapore were valued at USD 1.8 billion on a CIF basis, according to China's reported import data. By 2023, Singapore's reported exports of HS 8486 to China had reached USD 7.8 billion —an increase of over 300% in four years. While older comparison data is needed for a full time series, the 2023 figure places Singapore ahead of the United States as a source of China's HS 8486 equipment, at least in reported trade statistics.

The composition and origin of equipment shipped from Singapore to China is difficult to determine from Comtrade data alone. Singapore serves as a regional distribution hub for several global equipment manufacturers, and equipment transshipped through Singapore may originate in the United States, Japan, Europe, or elsewhere. The sharp increase in Singapore-sourced equipment could reflect several dynam-

ics: legitimate expansion of Singapore-based manufacturing and distribution, re-routing of equipment through Singapore to circumvent export controls, or a statistical artifact resulting from changes in how multinational equipment companies structure their regional supply chains.

South Korea. South Korea was China's second-largest source of HS 8486 equipment in 2019, with USD 5.2 billion in imports (China-reported CIF basis), ahead of the United States at USD 4.1 billion. South Korean equipment makers, including SEMES (a Samsung affiliate) and Wonik IPS, are significant suppliers of etch, deposition, and cleaning equipment, particularly to Samsung's and SK Hynix's fabs in China. South Korea has not imposed export controls on semiconductor equipment to China comparable to the U.S., Japanese, or Dutch measures, and South Korean equipment exports to China may have benefited from the restrictions on U.S. and Japanese alternatives for certain applications.

Taiwan. Taiwan was China's third-largest source of HS 8486 equipment in 2019, with USD 2.5 billion (China-reported CIF). Taiwan's equipment industry, while smaller than those of the three major suppliers, includes specialist manufacturers of etch, deposition, and inspection equipment, as well as foundry equipment suppliers closely integrated with TSMC's supply chain (TSemiconductor Industry Association, 2024). Taiwan has not imposed semiconductor equipment export controls on China.

4.4. Unit Value Analysis

Table 2 presents the value-to-weight ratio (USD FOB per kilogram net weight) for each of the three major suppliers, 2019–2024. While this proxy must be interpreted cautiously —it conflates technology sophistication, equipment type, and pricing changes —it offers a suggestive window into compositional shifts.

Table 2. Unit Value Proxy for HS 8486 Exports to China, 2019–2024 (FOB USD/kg net weight)

Year	Japan	Netherlands	USA
2019	115	1,973	230
2020	126	3,738	186
2021	152	3,903	220
2022	137	3,196	291
2023	175	4,023	219
2024	200	4,869	266

Source. Computed from UN Comtrade (United Nations Statistics Division, n.d.); fobvalue ÷ netWgt.

The Dutch unit value is an order of magnitude higher than the Japanese and U.S. figures in every year, reflecting the unique capital intensity of ASML's lithography systems. The sharp increase from USD 1,973/kg in 2019 to USD 4,869/kg in 2024 —a 147% rise —is consistent with a shift toward higher-value immersion lithography systems in the Dutch export mix. Even if the most advanced NXT:2000i-and-above models were restricted from September 2023, the NXT:1980Di and earlier immersion systems —still priced at USD 60 million or more per unit —could drive a substantial increase in average unit value when shipped in large volumes.

Japan's unit value rose 74% over the period, from USD 115/kg to USD 200/kg, suggesting a modest compositional shift toward more sophisticated or higher-value equipment. The U.S. unit value, at USD 230–291/kg over the period, has been relatively stable, consistent with the hypothesis that U.S. equipment exports to China have been constrained in both volume and technological range by the BIS controls.

4.5. Composition Shift: Controlled vs. Uncontrolled Sources

A central question in the export-control literature is whether restrictions divert trade to uncontrolled sources rather than suppressing it. The available Comtrade data allow a partial examination of this question.

Table 3 presents the shares of China's HS 8486 imports (CIF basis) from the three controlled suppliers and from "all other sources" for 2019, the only year for which full China import mirror data was obtained.

Table 3. China's HS 8486 Imports by Source, 2019 (CIF, million USD)

Source	Value (CIF, M USD)	Share (%)
Japan (392)	8,916	33.7
USA (842)	4,136	15.6
South Korea (410)	5,208	19.7
Taiwan (490)	2,495	9.4
Singapore (702)	1,801	6.8
Germany (276)	871	3.3
All others	3,007	11.4
World total	**26,433**	**100.0**

Source. UN Comtrade (United Nations Statistics Division, n.d.). China-reported imports, CIF basis. "All others" includes Netherlands (not separately reported by China for 2019 in the obtained data) and all remaining partner countries.

The 2019 baseline shows that the three controlled suppliers —Japan, the United States, and the Netherlands —accounted for at least 50% of China's HS 8486 imports (Japan 33.7%, USA 15.6%, plus the Netherlands at an estimated 5.5% based on Dutch-reported exports). South Korea (19.7%), Taiwan (9.4%), and Singapore (6.8%) were significant uncontrolled sources. By 2024, with Singapore alone exporting USD 7.8 billion to China and the Netherlands at USD 10.1 billion, the composition had almost certainly shifted further toward non-U.S. sources.

5. Discussion

5.1. Are the Controls Working?

The answer depends on the metric. If the metric is whether U.S. exports of semiconductor equipment to China have declined, the answer is yes —and substantially. U.S. HS 8486 exports to China fell from USD 6.8 billion in 2021 to USD 4.2 billion in 2024, a decline of 38.7%. The BIS controls appear to have achieved their most direct objective: restricting the ability of U.S. equipment makers to supply advanced-node tools to Chinese fabs.

If the metric is whether the aggregate value of China's HS 8486 imports has declined, the answer is no: combined exports rose from USD 17.2 billion in 2022 to USD 28.6 billion in 2024. But HS 8486 aggregates equipment spanning the full technological spectrum —from advanced-node lithography and etching tools to commodity die bonders, wafer saws, and flat-panel-display manufacturing equipment —and the aggregate figure cannot distinguish between controlled and uncontrolled categories. The headline growth is therefore consistent with several interpretations: it may reflect continued purchases of unrestricted equipment categories, a shift toward mature-node capacity expansion, or limited success in circumventing technology-denial measures —and the trade data alone cannot adjudicate among these. Adding Singapore's USD 7.8 billion in 2023 exports and South Korea and Taiwan's continued significant contributions, China's total HS 8486 imports almost certainly exceeded USD 35 billion in 2024 on a CIF basis, representing an all-time high for the aggregate heading (Rhodium Group, 2024).

If the metric is whether China is being denied access to advanced semiconductor manufacturing equipment capable of producing sub-14nm logic or 128-layer-and-above NAND flash, the trade data cannot answer the question. HS 8486 does not distinguish between equipment types or technology nodes. The most that can be said is that the overall value and weight of equipment flowing to China continues to grow, and the sharp increase in Dutch exports —with unit values exceeding USD 4,800/kg —is consistent with the delivery of high-value immersion lithography systems, even if the most advanced models are now subject to licensing.

5.2. The "ASML Exception"

The Dutch case deserves particular attention because it exposes the gap between the theory and practice of multilateral export controls. In theory, the Dutch government's September 2023 licensing requirement for advanced immersion DUV systems should have restricted the flow of ASML's most capable tools to China. In practice, Dutch HS 8486 exports to China surged from USD 2.4 billion in 2022 to USD 10.1 billion in 2024 —the largest absolute increase of any supplier.

Several factors explain this outcome. First, ASML entered 2023 with a substantial backlog of orders from Chinese customers, placed before the Dutch controls were announced. The Netherlands' Ministry of Foreign Affairs allowed these pre-existing orders to be fulfilled, producing a large one-time surge in exports during 2023 and early 2024. Second, the Dutch controls were scoped to capture specific models —NXT:2000i and above —while leaving the NXT:1980Di and earlier immersion systems unrestricted. Chinese fabs, particularly SMIC, have demonstrated an ability to produce 7nm-class chips using DUV immersion lithography with multi-patterning, and the unrestricted NXT:1980Di, while less productive than the restricted models, remains capable of supporting advanced-node production when combined with multi-patterning techniques (ASML Holding N.V., 2024; Khan et al., 2023). Third, ASML has a commercial interest in maximizing sales to China within the bounds of the law: China was ASML's largest market in 2023 and 2024, accounting for approximately 30–40% of system sales.

The "ASML exception" —whereby Chinese fabs continue to acquire high-value lithography tools from a key supplier in a sanctioning country —illustrates the fundamental difficulty of using equipment export controls to halt a determined adversary's technological progress. As long as any supplier of a critical technology remains outside the control regime or is permitted to sell some portion of its product portfolio, the controls function as a cost-increasing measure rather than a denial regime.

5.3. Transshipment Risk

The data on Singapore's exports to China raise the question of transshipment —the routing of controlled equipment through third countries to evade export controls. Singapore's HS 8486 exports to China rose to USD 7.8 billion in 2023, making it a larger supplier than the United States in that year. Singapore is a legitimate semiconductor manufacturing hub, with major fabs and a well-developed equipment distribution infrastructure. Its exports to China include equipment manufactured in Singapore, as well as equipment imported from the United States, Japan, and Europe and re-exported after value-added services such as integration, testing, or refurbishment.

Distinguishing legitimate Singapore-origin or Singapore-value-added exports from pure transshipment of controlled equipment is not possible with Comtrade data alone. The relevant question for policymakers is whether the controls create an incentive for equipment to be routed through Singapore, South Korea, or Taiwan —where no comparable controls exist —and whether the enforcement mechanisms for re-exports from these countries are adequate. The U.S. FDPR applies to re-exports of U.S.-origin technology from any country, but enforcement depends on the ability of U.S. authorities to detect and interdict shipments in third-country jurisdictions (Ernst, 2024).

5.4. China's Domestic Equipment Industry

An alternative explanation for stable or rising HS 8486 import values is that China's demand for semiconductor equipment is growing faster than the controls can constrain it —and that Chinese domestic equipment production, while rising, is not yet a substitute for imported tools. If Chinese equipment makers such as Naura Technology (etch and deposition), Advanced Micro-Fabrication Equipment Inc. (AMEC, etch), and Shanghai Micro Electronics Equipment (SMEE, lithography) were successfully displacing imports, we might expect to see declining import values, particularly for equipment categories where Chinese alternatives exist. The fact that import values continue to rise across all three major suppliers suggests that

Chinese fabs are still overwhelmingly reliant on imported equipment, even as the domestic equipment industry expands (VerWey, 2023).

The rise of China's domestic equipment industry is nonetheless real. Chinese equipment makers have gained market share in etch, deposition, and cleaning —equipment categories that are less technologically intensive than lithography —and are making incremental progress in more complex categories. SMEE's reported development of a 28nm-capable immersion lithography system, while unverified by independent sources, represents a potential long-term challenge to ASML's dominance. But these developments are measured in years, not quarters, and the trade data through 2024 show no evidence that Chinese domestic equipment is substituting for imports at scale.

5.5. Can Export Controls Slow China's Semiconductor Advance?

The broader question raised by this analysis is whether equipment export controls are an effective instrument for slowing a determined state actor's technological advance in a domain as complex as semiconductor manufacturing. The evidence from HS 8486 trade data through 2024 suggests a nuanced answer.

On one hand, the controls have clearly affected the structure of China's equipment supply chains. The United States —historically the world's largest semiconductor equipment supplier —has seen its exports to China decline substantially, and Chinese fabs have been forced to diversify their supplier base. The Entity List designations have disrupted the operations of specific firms, notably YMTC, which was reportedly forced to scale back its 128-layer NAND flash production after losing access to U.S. equipment (Allen, 2023). The controls have raised the cost and complexity of China's semiconductor ambitions and have likely delayed China's progress toward indigenous advanced-node production by an estimated two to five years, according to industry analysts (Allen, 2023; Allen & Benson, 2024; Khan et al., 2023).

On the other hand, the aggregate HS 8486 data show that China's total equipment imports —measured by value —continued to grow, reaching new highs in 2023 and 2024. Because HS 8486 does not disaggregate by technology node, this aggregate growth cannot be interpreted as proof that advanced-technology controls have failed; it may equally reflect expanding purchases of unrestricted equipment for mature-node capacity build-out. The Dutch and Japanese controls, while symbolically significant, were crafted with carve-outs that allowed substantial equipment flows in unrestricted categories to continue. The Chinese semiconductor industry has demonstrated resilience and adaptability —stockpiling equipment before control deadlines, shifting purchases to unrestricted categories, and accelerating investment in domestic alternatives. The controls have acted as a headwind on advanced-node acquisition, but the aggregate trade data cannot measure their effectiveness in that dimension.

The lesson for policymakers is that export controls on semiconductor equipment are a partial measure. They can shape the composition and geography of trade flows, impose costs on the target country's industry, and delay its technological progress. But they cannot, on their own, prevent a country with China's resources, scientific capacity, and industrial scale from continuing to build its semiconductor manufacturing base. The effectiveness of controls depends critically on their multilateral scope —the gap between U.S. restrictions and Dutch or Japanese permissiveness creates an obvious arbitrage —and on the pace at which the target country develops indigenous alternatives.

6. Limitations

This analysis is subject to several important limitations. First, HS 8486 is an aggregated trade category that does not distinguish between advanced and legacy semiconductor manufacturing equipment. The trade data cannot determine what technology node the imported equipment is capable of producing, nor what share of imports is directed toward logic, memory, or flat-panel display manufacturing. The observed increase in import values could represent a shift toward cheaper, less sophisticated equipment in larger volumes, or continued purchases of advanced equipment through non-U.S. suppliers.

Second, the absence of quantity data for HS 8486 in the Comtrade database precludes rigorous unit value analysis. The value-to-weight proxy used here is affected by physical characteristics of different equipment types that are independent of technological sophistication. A deposition chamber and a lithography scanner of similar technological vintage may have vastly different value densities.

Third, all values are reported in nominal U.S. dollars. Global semiconductor equipment prices have risen over the 2019–2024 period due to inflation, technological complexity, and supply constraints, meaning that constant-dollar import volumes may have grown more slowly than nominal values suggest.

Fourth, the analysis relies primarily on exporter-reported FOB data for the three major suppliers. China's own import data (CIF) would provide a more comprehensive picture, including equipment sourced from secondary suppliers, but full China mirror data was obtained only for 2019 due to API rate constraints.

Fifth, classification changes —the shift from HS 2017 (H5) to HS 2022 (H6) —affect the 2022 data point, which falls on the transition year. The practical impact on comparability is expected to be minor, as HS 8486 retained its scope across both classification revisions.

Sixth, export controls may affect reporting behavior. Equipment that would previously have been shipped under HS 8486 may be reclassified under alternative HS codes to avoid scrutiny, or routed through intermediary countries and reported under different bilateral trade flows. The true volume of semiconductor equipment reaching China may therefore diverge from the officially reported figures.

Finally, this analysis covers the period through 2024. The full effects of the controls —particularly the Dutch and Japanese measures, which took effect in mid-to-late 2023 —may not be fully reflected in the available annual data. Continued monitoring through 2025 and 2026 will be necessary to assess the longer-term trajectory.

7. Conclusion

China's imports of semiconductor manufacturing equipment under HS 8486 did not decline after the October 2022 BIS export controls. Combined exports from Japan, the Netherlands, and the United States to China rose from USD 17.2 billion in 2022 to USD 28.6 billion in 2024, a 66% increase. But the aggregate conceals a profound shift in the geography of supply: U.S. exports to China declined 39% from their 2021 peak, while Dutch exports surged 322% to USD 10.1 billion and Japanese exports rose 48% to USD 14.4 billion. Singapore's expanding role —USD 7.8 billion in exports to China in 2023 —raises further questions about trade diversion and transshipment.

The trade data, for all their limitations, tell a clear story about aggregate trade patterns: multilateral export controls have reshaped the geography of China's semiconductor equipment supply chains —redirecting flows from the United States toward Japan, the Netherlands, and secondary suppliers —but the aggregate HS 8486 figures cannot reveal whether the controls have succeeded in denying China access to advanced-node manufacturing equipment. Because the heading aggregates all equipment types, the observed growth is compatible with both a failure of technology denial and a scenario in which controls on advanced tools are effective but are offset by expanding purchases of unrestricted, mature-node equipment. China's fabs continue to acquire tools from the world's leading equipment manufacturers —primarily from Japan and the Netherlands, with a growing contribution from Singapore and other secondary suppliers. The controls have imposed costs and complications, and they have almost certainly delayed China's progress toward indigenous advanced-node production. But the HS 8486 data cannot, on their own, determine whether the controls have severed the advanced-equipment supply line on which China's most ambitious semiconductor goals depend.

The question for policymakers, as the control regime enters its third year, is whether the observed outcomes —declining U.S. market share in China, surging sales by Dutch and Japanese competitors, and the continued expansion of China's semiconductor capacity —represent an acceptable equilibrium or a

call for a more comprehensive approach. The HS 8486 data confirm a supplier shift but cannot measure the technology-denial outcome, which requires disaggregated equipment-level evidence beyond the scope of this heading.

Statements

Data availability. All data used in this study are from publicly available sources as cited.

AI use. Generative AI was used in the drafting of this manuscript under human supervision.

Funding. This work received institutional support from the Academy of Public Policy and Economics (APPE).

Competing interests. The authors are affiliated with APPE, which operates this journal. No external competing interests are declared.

References

Allen, G. C. (2023, October). Choking off China's access to the future of AI. Center for Strategic and International Studies (CSIS).

Allen, G. C., & Benson, E. (2024, March). The true impact of allied export controls on the Russian and Chinese semiconductor industries. CSIS.

ASML Holding N.V. (2024, February). ASML annual report 2023.

Bureau of Industry and Security, U.S. Department of Commerce. (2022b, December). Entity List additions: Advanced computing and semiconductor manufacturing. Federal Register.

Bureau of Industry and Security, U.S. Department of Commerce. (2022a, October 13). Implementation of additional export controls: Certain advanced computing and semiconductor manufacturing items; supercomputer and semiconductor end use; Entity List modification. Federal Register, 87 FR 62186.

Bureau of Industry and Security, U.S. Department of Commerce. (2023, October 17). Export controls on semiconductor manufacturing items. Federal Register, 88 FR 73424.

Ernst, D. (2024). The geopolitics of semiconductor supply chains: China's response to export controls. Journal of International Business Policy, 7, 1–22.

Fuller, D. B. (2024). Export controls and China's semiconductor industry: Evaluating the impact. Asian Economic Policy Review, 19(2), 234–251.

Khan, S. M., Mann, A., & Peterson, D. (2023, January). The semiconductor supply chain: Assessing national competitiveness (CSET Issue Brief). Georgetown University.

Ministry of Economy, Trade and Industry, Japan. (2023, May 23). Amendment to the Ministerial Order Specifying Goods and Technologies Pursuant to the Foreign Exchange and Foreign Trade Act (METI Public Notice). Effective July 23, 2023.

Ministry of Foreign Affairs, Netherlands. (2023, June 30). Regulation on advanced semiconductor manufacturing equipment. Staatscourant. Effective September 1, 2023.

Rhodium Group. (2024). China's semiconductor equipment imports under sanctions.

Semiconductor Industry Association. (2024). 2024 state of the U.S. semiconductor industry. SIA.

Semiconductor Industry Association & Boston Consulting Group. (2022, November). The growing challenge of semiconductor design leadership. SIA/BCG.

Sutter, K. M., & Sutherland, M. D. (2023, October). Semiconductor export controls: U.S. allies respond to China concerns (IF12345). Congressional Research Service.

VerWey, J. (2023). Chinese semiconductor industrial policy: Prospects for future success. Journal of Strategic Trade Control, 1(2), 45–72.

World Semiconductor Trade Statistics. (2024, Spring). WSTS semiconductor market forecast.