The Trade Effects of Export Control Regulations in Japan

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***Abstract*:** Recent geopolitical tensions have generated various uncertainties in cross-border economic activities. A major concern is on how far export control regulations by the US and its allies would decouple supply chains. This study empirically investigates the trade effects of export control regulations by Japan initiated on July 23, 2023. The regulations restrict exports of 22 items of semiconductor manufacturing equipment (SME) and one item of semiconductor inspection equipment (SIE), implicitly focusing on Japan's exports to China. Our empirical analysis employs the monthly data of Japanese exports and Chinese imports. Our findings, perhaps counterintuitive, are as follows. The export restriction significantly increased exports of SME from Japan to China after not only at the timing of the announcement of the export restriction but also that of its enforcement. The export restriction also significantly increased the exports of SIE from Japan to China, though it significantly decreased exports to other restricted countries. A clear sign of trade reduction is not detected because export restrictions are imposed on a narrow range of products that cannot be precisely captured even by the most detailed trade statistics classification. At least we can say that the direct impact of the export control regulations on trade is quantitatively limited.

Keywords: Export control, China, integrated circuits, semiconductors
JEL Classification: F15; F53

1. Introduction

Since the latter half of the 2010s, export control regulations have become one of the frequently used trade policies under geopolitical tensions. The US government has step-by-step strengthened export control regulations from the national security perspective and regulated exports of key technologies and components to China. The main products in these regulations have been cutting-edge semiconductors, which are indispensable for producing all modern goods, including military goods. The equipment and devices to produce or develop such semiconductors were also restricted to export. On the other hand, the Chinese government strengthened export control regulations on rare-earth materials. It restricted exports of gallium and germanium products since August 2023. These products are used in

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semiconductor industries. Since December 2023, China has also started to restrict exports of graphite products, which are used to produce batteries in electronic vehicles. Export control regulations have taken a center stage in trade policy. The escalation of trade restrictions related to supply chains for high-tech products has generated a lot of uncertainties in cross-border private businesses. Particularly, a major concern is on how far such trade restrictions would decouple supply chains. Regulatory authorities, both in the US and Japan, do not disclose the detailed information on how far trade is actually restricted due to, they claim, national security reasons.

In this study, we empirically investigate the trade effects of export control regulations by the Japanese government in cooperation with the US. Since July 23, 2023, Japan has started to strengthen export control regulations on 23 items to maintain international peace and security. Those items include 22 items of semiconductor manufacturing equipment (SME) and one item of semiconductor inspection equipment (SIE). With this export control regulation, when exporting those items from Japan to approximately 160 countries including China, exporters must obtain an individual license, not a blanket license. Nevertheless, it is not necessarily subject to an embargo and may be approved if there is no risk of military use. The 42 countries participating in the Wassenaar Arrangement, excluding Russia and Japan, and including Taiwan and Singapore, are still subject to a blanket license. In particular, we shed light on the impacts on Japanese exports to China because the recent export restriction in the US mainly targets China. We investigate how this Japanese export restriction changes exports of SME and SIE from Japan to China.

In our empirical analysis, we employ the monthly data on Japanese exports and Chinese imports. With Japanese export data, we investigate how Japanese exports to China or other countries subject to an individual license change compared with those to the 42 countries subject to a blanket license. This analysis enables us to uncover the trade effects on individual-license countries relative to those in blanket-license countries. However, there is one limitation in Japanese data. In the harmonized system (HS) classification, the SME is included in code 848620. In Japanese trade classification, HS 848620 includes only one detailed code, which means that we cannot differentiate disaggregated items of SME and can examine only the aggregate exports of all kinds of SME. On the other hand, at a Chinese tariff-line level (HS eight-digit), it includes ten detailed codes for SME. Thus, by using Chinese import data, we also investigate how Chinese imports of each SME product from Japan changed after the Japanese government started its export restriction. Nevertheless, it is worth noting that not all items in each SME product are necessarily subject to Japanese export restrictions; strict restrictions are imposed only for more finely specified items than trade classifications.

More specifically, we investigate trade values defined at a country-product-time (year-month) level. We control for country-product, product-time, and country-time fixed effects. Products in the dataset include manufacturing equipment in HS 84 and inspection equipment in HS 90 (SIE is included in HS 903141). Our main explanatory variable is a

dummy variable that takes a value of one if observations are Japanese exports of SME/SIE to China since August 2023, which is just after tightening Japanese export control regulations. We also add some more explanatory variables. One is a dummy variable that takes a value of one if observations are Japanese exports of SME/SIE to China during the period of April to July 2023. At the end of March 2023, the Japanese government announced the initiation of this export restriction. We introduce this dummy to investigate its announcement effect. The other is these two dummy variables designed for exports to other individual-license countries. We also control for a possible effect of US export regulations on Japanese exports to China.

There are only a limited number of existing studies on the recent export control regulations. Almost all studies investigate the effects of US export control regulations. Those regulations by the US may control exports from not only the US but also other countries if export products in the latter countries fall into either the "re-exported products" or "direct products" of US-origin technology or software[1]. The studies on US regulations are the following. First, Ando et al. (2024a) found a significant decrease in US exports of SME to China. Second, Hayakawa et al. (2023) show a significant decrease in Japan's exports of HS8517 products (including telephones for cellular networks or for other wireless networks) to China. The third study, Ando et al. (2024b), also showed a significant decrease in Japan's exports of advanced technology products used in the production of smartphones to China. Last, Hayakawa (2024) conducted a more comprehensive study in terms of covering exports from not only the US and Japan but also Korea, the Netherlands, and Taiwan. As a result, he found a significant decrease in exports of semiconductor chips from the US and Korea but not from Taiwan. It was also shown that the US and the Netherlands decreased the exports of SME to China, but Japan did not. In any case, trade restricting effects of export control regulations on high-tech related products seem to be limited to the narrowly defined product level, rather than massive decoupling at the industry or macro level.

Unlike these existing studies on US export control regulations, this study investigates the regulations by the Japanese government. As mentioned above, Hayakawa (2024) found an insignificant effect of US export control regulations on Japanese exports of SME to China. This insignificant effect may be because the SME produced in Japan is not subject to the US export control regulations. However, the regulations by the Japanese government will have a direct impact on Japanese exports. In short, our study is the first one that examines the trade effect of the recent export control regulations specific to semiconductor-related products by a non-US government. Indeed, as the previous studies above found that US regulations decreased US exports to China, we may find the adverse consequences of

[1] "Re-exported products of US goods" refer to re-exports of a foreign-made commodity incorporating controlled US-origin commodities or bundled with US-origin software valued at more than 25% of the total value. "Direct products" are foreign-produced "direct products" of specified "technology" and "software." Exports outside the US may also be restricted if those fall into either one.

Japanese regulations on Japanese exports of SME and SIE to China.[2]

The rest of this study is organized as follows. The next section overviews the recent changes in export control regulations by the Japanese government. After explaining our empirical framework in Section 3, we will show the estimation results in Section 4. Last, Section 5 concludes this study.

2. Background

Japan has participated in international export control regimes[3], implementing security-related export controls as part of coordinated efforts to prevent the proliferation of weapons of mass destruction and the excessive accumulation of conventional weapons. Based on these treaties and international frameworks, the Japanese government controls the export of equipment and materials related to the development and manufacture of weapons of mass destruction and conventional weapons and related dual-use goods. The laws and regulations concerning trade control are stipulated by the Foreign Exchange and Foreign Trade Act. Exporting specific types of goods destined for specific countries is required to obtain permission (an export license) from the Ministry of Economy, Trade and Industry (METI), Japan. The "specific types of goods" are specified in the Export Trade Control Order, while the "specific technologies" are stipulated in the Foreign Exchange Order. These two orders are cabinet orders. More details of the control items are specified by a METI ministerial ordinance.

On March 31, 2023, the METI announced that the ministerial ordinance would be revised to add 23 items of SME and SIE to the scope of export control. This ordinance was enforced on July 23, 2023. When exporting those items from Japan to approximately 160 countries, exporters must obtain an individual license, not a blanket license. Only the 42 countries participating in the Wassenaar Arrangement, excluding Russia and Japan, and including Taiwan and Singapore, are subject to a blanket license. The 22 items of SME include three kinds of cleaning equipment[4], 11 kinds of deposition equipment[5], one kind of

[2] There are also several related studies. For example, Cerdeiro et al. (2021) and Funke and Wende (2022) conduct simulation analyses on the economic impacts of US export control regulations. More broadly, there are many studies on the trade effects of economic sanctions (e.g., Haidar, 2017; Crozet et al., 2020, 2021). Fuhrmann (2008) and Afesorgbor (2019) also studied the trade effect of export restrictions.

[3] Currently, there are four international export control regimes: the Wassenaar Arrangement for conventional weapons, the Nuclear Suppliers Group for nuclear weapons, the Australia Group for chemical and biological weapons, and the Missile Technology Control Regime.

[4] Those include the equipment that removes impurities under vacuum, surface impurities as a pretreatment for each manufacturing process, or impurities by changing the surface properties.

[5] Those include equipment that forms cobalt films using plating methods, equipment for depositing tungsten layers using chemical methods, equipment for selectively depositing tungsten or molybdenum, or equipment for forming a ruthenium wiring layer. They also include devices that use plasma to rotate a wafer and form films at the atomic level, deposit a layer of an insulator in a long and narrow groove,

annealing equipment[6], four kinds of lithography equipment[7], and three kinds of etching equipment[8]. The one item of SIE is the inspection equipment of an extreme ultraviolet (EUV) mask.

In the trade statistics, SME is included in HS 848620 "Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits," while SIE is in HS 903141 "Machines and apparatus for inspecting semiconductor wafers or devices (including integrated circuits) or for inspecting photomasks or reticles used in manufacturing semiconductor devices (including integrated circuits)." Out of 5,613 codes at an HS six-digit level in the HS 2022 version, HS 848620 has the second largest exports (19 billion USD) from Japan to the world in 2022, while HS 903141 has the 73rd largest exports (2 billion USD). These two codes account for 5% and 0.3% of total exports by Japan. The exports to China (and Hong Kong) in HS 848620 are 5.8 billion USD and account for 30% of total exports of this code. Indeed, China is a top destination in terms of export values. The corresponding figures for HS 903141 are 0.4 billion USD, 20%, and the third rank. In short, SME and SIE are important items for Japanese exports, and China has been one of the major export destinations.

Figure 1 shows Japan's monthly exports of SME and SIE by destination groups. The first group (WA) includes 42 countries participating in the Wassenaar Arrangement, excluding Russia and Japan, and including Taiwan and Singapore, which are subject to a blanket license. The second group (CHN) consists of China and Hong Kong. The last group (ROW) includes all the other countries. The latter two groups are subject to an individual license from July 2023. These export values are normalized to the value of one in March 2023. Changes in trade values do not seem to be easy to interpret. In SME, after March 2023, Japan's exports to the WA started to decrease, while those to individual-license countries (i.e., CHN and ROW) increased. Taking a closer look at these changes, we find that the decrease in the WA seems to be mainly driven by the decrease in exports to Taiwan. Also, the increase in exports to Malaysia seems to account for the increase in the ROW. In SIE, on the other hand, we can see a sharp rise in exports to the ROW during the announcement period. The temporary surge in exports to Israel accounts for this spike. While exports of SIE to China increased after the enforcement of export restrictions, those to the WA show a tentative drop.

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perform film deposition for extreme ultraviolet (EUV) masks, regularly grow silicon and silicon compounds to form films, or use plasma to form etching-resistant films, tungsten films at the atomic level, or insulator layers without gaps.

[6] More specifically, it is the equipment that removes gaps in thin films through heat treatment.

[7] Those include a protective cover for EUV mask, its manufacturing equipment, a coater/developer designed for EUV, and ArF-Wet lithography equipment.

[8] Those include etching equipment that realizes cutting-edge semiconductor structures (three-dimensional structures), etching equipment using chemical liquid, and equipment for fine and deep etching.

=== Figure 1 ===

3. Empirical Framework

This section explains our empirical framework to investigate the trade effects of Japanese export regulations. To this end, we first focus on Japanese exports by employing the monthly export data in Japan from January 2021 to December 2023, which are obtained from the Customs, Japan. Importing countries include 151 countries in the world. Products are defined at an HS nine-digit level in Japanese export statistics. Our interest lies in the effects on exports of SME (HS 848620) and SIE (HS 903141). At an HS nine-digit level, HS 848620 includes only 848620000, while HS 903141 does only 903141000. These products are so-called "treated" products. In the Broad Economic Categories (BEC), these products are categorized into BEC 612020 (specified gross fixed capital formation in ICT, media, computers, business, and financial services) and BEC 212 (gross fixed capital formation in mining, quarrying, refinery, fuels, chemicals, electricity, water, waste treatment), respectively.

In the empirical analysis, we have to carefully choose "control" products. We should not include all products other than treated products, e.g., agricultural goods, because trends in demand and production must be widely different across products and the trends of the control products must not be different from those of the treated products for our identification strategy. Therefore, we have to choose "similar" products to treated products but not subject to export control regulations. One example is "machines and apparatus for the manufacture of boules or wafers (HS848610)." This equipment is used in another production process for semiconductors but is not subject to export regulation.[9] As a result, we choose to use, as "control products," all products in HS 84 categorized in BEC 612020 for the analysis of SME and those in HS 90 categorized in BEC 212 for the analysis of SIE. Our sample comprises 27 and 8 control products for the analyses of SME and SIE, respectively.

With this dataset, we estimate the following equation for products in HS 84 and HS 90 separately.

$$\begin{aligned} Export_{ipt} = \exp\big(&\beta_1 ROW_i Treat_p Announce_t + \beta_2 ROW_i Treat_p Enforce_t \\ &+ \gamma_1 CN_i Treat_p Announce_t + \gamma_2 CN_i Treat_p Enforce_t \\ &+ \rho CN_i Treat_p US\ Regulation_t + \mathrm{u}_{ip} + \mathrm{u}_{pt} + \mathrm{u}_{it}\big) \cdot \epsilon_{ipt} \end{aligned} \quad (1)$$

[9] A potential concern is that the availability of SME/SIE may also change the demand for this equipment through the supply chain in semiconductor production, i.e., the violation of the stable unit treatment value assumption (SUTVA). However, we focus on the short-run effects of export control regulations, and it is important to note that the capital equipment, including the mentioned machinery, is durable. As a result, we can confidently assume that the SUTVA is satisfied in our case.

$Export_{ipt}$ refers to export values of product p (HS nine-digit) to country i in Japan at time t. $Treat_p$ takes a value of one if product p is SME (i.e., HS 848620000) in the HS 84 equation and SIE (i.e., HS 903141000) in the HS 90 equation. Export destination countries are classified into three groups defined in Figure 1. The control group includes countries in WA, which are subject to a blanket license. We set two treated groups. One is China and Hong Kong[10], where CN_i takes a value of one, while the other group includes all the other countries, where ROW_i does so. These treated groups are subject to an individual license. In terms of time, we consider two events. One is $Announce_t$, which takes a value of one from April to July 2023, i.e., from the announcement of export control until its enforcement. The other is $Enforce_t$, which takes a value of one since August 2023, which is the period when export control measures are effective.

We also control for a possible trade effect of export regulations by the US. Particularly in October 2022, the US government introduced tougher regulations. According to Part 744.23 in the Export Administration Regulation, firms are prohibited from exporting the items destined for the development and production of integrated circuits at a semiconductor fabrication facility located in China or Macau that fabricates "advanced integrated circuits[11]." This measure restricts firms' export of the SME for cutting-edge integrated circuits based on their end-use. Firms in Japan may not be allowed to export re-exported products to China if the items are destined for the above end-use[12]. To control this effect, we introduce the interaction term of CN_iTreat_p with $US\ Regulation_t$, which takes a value of one if time is after October 2022.

Three kinds of fixed effects (FEs) are included, i.e., country-product (u_{ip}), product-time (u_{pt}), and country-time (u_{it}) FEs. The country-product FEs control for time-invariant importing country-specific preference on each product. The product-time FEs include supply-side characteristics in Japan, especially technology and factor prices such as wages. This type of FE also controls for global demand trends for each product. The country-time FEs include country-level time-variant demand sizes. With these controls, we investigate the causal effects of export control regulations in Japan on exports to China and ROW countries, by examining γ_2 and β_2, respectively. We also investigate the effects of announcing these regulations by examining γ_1 and β_1. ϵ_{ipt} is a disturbance term. We estimate this equation by the Poisson Pseudo Maximum Likelihood (PPML) method.

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[10] Hereafter, we use China and "China and Hong Kong" interchangeably in the analysis using Japanese export statistics. The inclusion of Hong Kong is to take into account re-exports from Japan to China via Hong Kong.

[11] These integrated circuits include (A) logic integrated circuits using a nonplanar transistor architecture or with a production technology node of 16/14 nanometers or less; (B) NOT AND (NAND) memory integrated circuits with 128 layers or more; or (C) Dynamic random-access memory (DRAM) ICs using a production technology node of 18-nanometer half-pitch or less.

[12] According to Part 742.6(b)(10) in the EAR, license applications for semiconductor manufacturing items destined to end users in China that are headquartered in the U.S. or some developed countries (countries in Country Group A:5 or A:6 in Supplement No. 1 to Part 740 in the EAR) will be considered on a case-by-case basis, taking into account factors including technology level, customers, and compliance plans.

One empirical issue is worth discussing. Product codes in trade statistics in Japan are too broad to pinpoint regulated products, especially those in SME. Although exporting the 22 items of SME is restricted, HS 848620 in Japanese trade statistics includes only one nine-digit code, i.e., 848620000, which does not enable us to differentiate SME products. HS 848620000 includes many items that are not subject to the new Japanese export control regulations. Thus, it is inevitable that our dummy variables contain errors, which bias our estimates toward zero. To minimize this disadvantage, we also use Chinese import statistics.

In the analysis using Chinese import statistics defined at an HS eight-digit level, we focus on the effect on China's imports of SME[13]. Thus, the products include only HS eight-digit codes in HS 84 categorized into BEC 612020. In China's import statistics, HS 848620 includes ten eight-digit codes, including heat treatment (oxidation, diffusion, and annealing, HS 84862010), chemical vapor deposition (CVD, HS 84862021), physical vapor deposition (PVD, HS 84862022), other film deposition (HS 84862029), step and repeat aligners (HS 84862031), other projection (HS 84862039), dry plasma etching (HS 84862041), other etching and stripping (HS 84862049), ion implanters (HS 84862050), and other machines (HS 84862090). The study period is again from January 2021 to December 2023. The exporting countries include 97 countries in the world. The data on Chinese imports are obtained from the Global Trade Atlas.

Due to our examination of China's imports, we need to control for some other export regulations. One is the export control regulation by the US, as in equation (1). Specifically, tightening it in October 2022 may decrease imports of SME from not only the US but also Japan and the Netherlands. The other is the export restriction in the Netherlands, which was announced in March 2023 and started on September 1, 2023. This regulation restricts exports of not only advanced equipment (i.e., EUV) but also less advanced equipment (e.g., deep ultraviolet lithography equipment, DUV) from the Netherlands. Thus, this restriction may decrease imports of SME from the Netherlands in China.

The equation using Chinese import statistics is specified as follows.

$$Import_{ipt} = \exp\big(JP_i Announce_{it}\mathbf{Treat'}_{ip}\boldsymbol{\beta}_1 + JP_i Enforce_{it}\mathbf{Treat'}_{ip}\boldsymbol{\beta}_2 + \mathbf{X'}\boldsymbol{\gamma} + \mathrm{u}_{ip} + \mathrm{u}_{pt} + \mathrm{u}_{it}\big)\cdot\epsilon_{ipt}, \qquad (2)$$

where

$$\mathbf{X'}\boldsymbol{\gamma} = \alpha_1 US_i SME_p Oct22_t + \alpha_2 JP_i SME_p Oct22_t + \alpha_3 NL_i SME_p Oct22_t + NL_i Announce_{it}\mathbf{Treat'}_{ip}\boldsymbol{\delta}_1 + NL_i Enforce_{it}\mathbf{Treat'}_{ip}\boldsymbol{\delta}_2.$$

$Import_{ipt}$ refers to import values of product p (HS eight-digit) from country i in China[14] at time t. $\mathbf{Treat}_{ip}$ is a vector of dummy variables on the ten SME products, i.e., HS eight-digit codes in HS 848620. Furthermore, it differs by exporting countries. For imports from Japan,

[13] Like Japanese export statistics, HS 903141 in Chinese import statistics includes only one code.

[14] In the analysis using Chinese import statistics, "China" does not include Hong Kong.

all the ten SME products take a value of one.[15] For those from the Netherlands, it equals to one for only two SME products, i.e., HS 84862031 and HS 84862039, because the Dutch export controls mainly target lithography equipment.[16] All dummy variables in $\mathbf{Treat}_{ip}$ take a value of zero for imports from the other countries. Similarly, $Announce_{it}$ and $Enforce_{it}$ could take a value of one for only imports from Japan and the Netherlands. $Announce_{it}$ does so from April to July 2023 for imports from Japan and from April to August 2023 for imports from the Netherlands. $Enforce_{it}$ does so from August 2023 for imports from Japan and from September 2023 for imports from the Netherlands.

Other variables are as follows. US_i, JP_i, and NL_i take a value of one if country i is the US, Japan, and the Netherlands, respectively. The effects of export controls in Japan are examined by $JP_i Announce_{it}\mathbf{Treat}'_{ip}$ and $JP_i Enforce_{it}\mathbf{Treat}'_{ip}$, while we investigate those in the Netherlands by $NL_i Announce_{it}\mathbf{Treat}'_{ip}$ and $NL_i Enforce_{it}\mathbf{Treat}'_{ip}$. The effects of strengthening the US export controls in October 2022 are controlled by $US_i SME_p Oct22_t$, $JP_i SME_p Oct22_t$, and $NL_i SME_p Oct22_t$. SME_p takes a value of one if product p is SME (i.e., HS 848620), while $Oct22_t$ does so since October 2022. Namely, we do not differentiate SME products in this control.

Like equation (1), we control for three kinds of FEs, i.e., country-product (u_{ip}), product-time (u_{pt}), and country-time (u_{it}) FEs. However, the elements controlled by these FEs are slightly different. The country-product FEs control for time-invariant exporting country-specific supply capacity on each product, e.g., a short-run technology level. The product-time FEs include product-level demand sizes in China. This type of FEs also controls for global supply trends in each product. The country-time FEs include time-variant exporting country characteristics such as wages. ϵ_{ipt} is a disturbance term. We again estimate this equation by the PPML method. Last, although we use Chinese import statistics to differentiate the 10 SME products, those products are not still detailed enough to differentiate between restricted and unrestricted items in each product defined at an HS eight-digit level.

4. Empirical Results

This section reports our estimation results. In all estimations, we cluster standard errors by country-product. We first show the results using Japan's import statistics. Columns (I) and (IV) in Table 1 report our baseline results on the PPML estimation of

[15] Table A1 in the Appendix reports China's imports of the ten SME products from Japan, the Netherlands, and the US in 2022. For example, Japan's main export SME products to China are heat treatment (HS 84862010), other projections (HS 84862039), dry plasma etching (HS 84862041), and other machines (HS 84862090).

[16] Other machines to be restricted are, for example, equipment for atomic layer deposition. Indeed, the two SME products (HS 84862031 and HS 84862039) account for 99% of China's imports of SME from the Netherlands in 2022. See Table A1 in the Appendix.

equation (1) for SME and SIE, respectively. The results for SME are as follows. The announcement effect is significantly negative in exports to the ROW and significantly positive in exports to China, while the enforcement effect is significantly positive in both exports to the ROW and China. On the other hand, the results for SIE show insignificant announcement effects in both exports to the ROW and China. The enforcement effect in SIE is significantly negative in exports to the ROW and significantly positive in exports to China. Strengthening US export controls in October 2022 significantly increases Japan's exports of SME to China but does not change those of SIE. Overall, the results do not clearly show the adverse effect of Japan's export regulations.

=== Table 1 ===

We conduct two kinds of robustness checks. Specifically, we introduce control variables defined at a more detailed level. One is to control for country-product-month FEs instead of country-product FEs. This type of FE will eliminate seasonal changes at an importer-product level. The results are reported in column (II) for SME and column (V) for SIE. The noteworthy differences with the results in columns (I) and (IV) are that the announcement effect becomes insignificant in exports of SME to the ROW and significantly negative in exports of SIE to both the ROW and China. The effect of tightening the US export regulation turns out to be insignificant on exports of SME but is significantly positive on exports of SIE. The other is to introduce country-product-specific linear trend terms in addition to country-product FEs. Those terms will control for the time trend of demand at an importer-product level. The results are reported in column (III) for SME and column (VI) for SIE. The differences with our baseline results can be found in exports to SIE to the ROW. The announcement effect becomes significantly negative, while the enforcement effect turns out to be insignificant.

These results can be summarized as follows. The robust results in terms of obtaining significant results in all three specifications are significant increases in exports of SME to China after not only the announcement of export restriction but also its enforcement. In particular, the magnitude is larger in the effective period than in the announcement period. The results on exports of SME to the ROW are not robust but show at least that the initiation of export restriction does not decrease those exports to the ROW. In SIE, on the other hand, the robust results are that the initiation of export restriction decreases exports to the ROW but increases those to China. The SIE product subject to Japan's export restriction is the inspection equipment of an EUV mask. Since exports of EUV equipment from the Netherlands to China have been banned since 2019, China may not need to import the inspection equipment of an EUV mask. Thus, increased exports may occur in other types of inspection equipment. The results on exports of SIE during the announcement period are not robust but show at least that exports to the ROW and China do not increase.

Next, we examine the time-series changes of coefficients for $ROW_i Treat_p$ and

$CN_i Treat_p$ by estimating the following equation for SME and SIE separately.

$$Export_{ipt} = \exp\left(\sum_{\substack{k=Jan2021,\\ k\neq Mar2023}}^{Nov2023} \beta_k ROW_i Treat_p Time_k + \sum_{\substack{k=Jan2021,\\ k\neq Mar2023}}^{Nov2023} \gamma_k CN_i Treat_p Time_k + \mathrm{u}_{ip} + \mathrm{u}_{pt} + \mathrm{u}_{it}\right) \cdot \epsilon_{ipt} \qquad (3)$$

$Time_k$ takes a value of one if time t is k. In this dummy variable, we set March 2023 as a base time.[17] The results for SME are depicted in Figure 2, while those for SIE are shown in Figure 3. In SME, we can see a sharp drop in estimates for the ROW from January to March 2023. Their estimates gradually rise from the announcement to enforcement and then do not decrease much even after the enforcement. The estimates for China also show a gradual rise after the announcement. These rising trends yield significantly positive coefficients for enforcement in column (I) in Table 1. The trend of China is not statistically different from those of the countries in WA before March 2023, while the pre-trends are significantly different for ROW. In SIE, on the other hand, the estimates for the ROW and China remained at a low level from the announcement to enforcement. The pre-trends of both groups are similar to WA countries, though it is statistically different for China. However, from around July 2023, the estimates increase in exports to China and remain at a low level in exports to the ROW. This contrast yields an insignificant coefficient for enforcement in exports to the ROW and a significantly positive coefficient in those to China in column (IV).

=== Figures 2 and 3 ===

Last, to see the changes in Japan's exports of SME to China at a more detailed level, we estimate equation (2) using China's import statistics. The results are shown in Table 2. The robust results in imports from Japan are that the announcement effect is significantly negative in ion implanters and significantly positive in other projections, while the enforcement effect is significantly negative in PVD and significantly positive in step and repeat aligners and other machines. Namely, some SME products experienced an increase in imports from Japan, while imports of some SME products decreased. These mixed results would be the reason why we did not obtain significant adverse effects on Japan's exports of SME to China in Table 1. The increase in imports of step and repeat aligners may occur in the items not subject to Japan's export restriction, such as i-line or KrF semiconductor lithography equipment, which may be used to produce power semiconductors for electric vehicles in China. Another noteworthy result is the significant increase in imports of other projections from the Netherlands after the initiation of the Dutch export restriction. This increase would be because ASML, the world's largest lithography machine manufacturer,

[17] While the variables on the US regulations are not apparently included in this equation, the coefficients before the base time include the effects of the US regulations.

was allowed to continue shipping DUV lithography machines to China until the end of 2023.[18]

=== Table 2 ===

5. Concluding Remarks

In this study, we empirically investigated the trade effects of export control regulations on SME and SIE by the Japanese government initiated on July 23, 2023. To do that, we employed the monthly data of Japanese exports and Chinese imports. Our findings, perhaps different from popular belief, can be summarized as follows. First, the export restrictions significantly increased exports of SME from Japan to China after not only the announcement of the export restriction but also its enforcement. The positive effect of its enforcement is partly because some SME products (e.g., step and repeat aligners) experienced an increase in exports, though exports of some other SME products (e.g., PVD) decreased. The export restriction also significantly increased the exports of SIE from Japan to China, though it significantly decreased exports to the other individual-license countries. The increase in exports of SIE to China would be due to the increase of exports of SIE products not subject to Japan's export restrictions. Private companies certainly analyze possible effects of export control regulations and respond to them by modifying corporate strategies with considering substitutability/complementarity in supply chains, changes in demand, changes in corporate strategies of their business partners, and the timing of actions.

The recent policy debate, particularly in Tokyo, seems to be too far occupied by national security discussion. National security is certainly important, but policymakers need to keep a good balance between national security and economic matters. In this context, we believe that the empirical quantification of the effects of existing export control regulations is a meaningful effort. Our findings show that the trade-reducing effects are so far limited to the detailed product level, rather than the industry or macro level, which means that the "rest" of the economy is still alive and active. Of course, if technology decoupling policies were expanded further, the effects of such policies would become larger and might cause some permanent changes in investment patterns and the formation of supply chains. However, economic dynamism seems to be working as a countervailing force, and the decoupling is likely to stay partial. If so, we must take care of both a part of the economy under national security restrictions and the "rest" of the economy. Even the White House starts talking about "small-yard, high-fence" to seek a "political" equilibrium between the national security camp and the economy.

[18] See, for example, https://technode.com/2023/12/28/chinas-chip-making-equipment-imports-from-the-netherlands-surge-tenfold-in-value-in-november-report/.

The policy implication of our paper for middle powers such as Japan is profound. First, if the decoupling of supply chains is likely to be partial, how and to what extent to cooperate with the US for specific technology decoupling must be examined well. Will the effort of technology decoupling achieve the objective? Can the objective be justified in the logic of the prevention of the military use of technologies? Is it worth doing even if the most competitive firms in Japan bear the cost? There are many things that we need to discuss, even if the logic of national security may not easily allow the economic logic to come in.

Second, governments can mitigate redundant uncertainties generated by export control regulations to avoid excessive precaution in the private sector. The easiest is to expand the disclosure of information on the implemented export control regulations. Some revision of trade commodity classification below the six-digit level would also be effective for making effects of such policies more visible. More fundamentally, to retain active economic activities, the borderline between regulated trade and free trade must be set as clearly as possible.

Third, governments must implement policies to retain the rules-based trading regime, at least for the "rest" of the economy outside export control regulations. Some of the policies introduced in the context of geopolitical tensions do not seem to be consistent with the commitments under the World Trade Organization (WTO) or the conventional trade norm, which are weakening the rules-based trading regime. The rules-based trading regime is the basis for the vigorous world economy, particularly with global supply chains. The WTO is at risk with its impaired dispute settlement mechanism and its struggle as a rule-making organization. Middle-power governments, together with newly developed and developing countries, must strongly support the WTO. In addition, mega-regional trade agreements can also be utilized as initiatives for supporting the rules-based trading regime.

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Table 1. PPML Results: Japan's Export Statistics

	SME			SIE		
	(I)	(II)	(III)	(IV)	(V)	(VI)
Announce * ROW * Treat	-0.367**	-0.302	-0.422*	-0.101	-0.438*	-0.437*
	[0.151]	[0.211]	[0.229]	[0.214]	[0.242]	[0.240]
Enforce * ROW * Treat	0.500***	0.366**	0.292	-0.764***	-0.644***	-1.131***
	[0.188]	[0.183]	[0.243]	[0.246]	[0.179]	[0.338]
Announce * CN * Treat	0.191*	0.196*	0.240**	-0.121	-0.438**	-0.172
	[0.112]	[0.101]	[0.118]	[0.189]	[0.198]	[0.190]
Enforce * CN * Treat	0.562***	0.529**	0.579**	0.741***	0.582***	0.645***
	[0.161]	[0.207]	[0.226]	[0.104]	[0.139]	[0.139]
US Regulation * CN * Treat	0.262*	0.263	0.252	-0.016	0.220*	-0.154
	[0.139]	[0.189]	[0.157]	[0.096]	[0.121]	[0.131]
Country-time FE	X	X	X	X	X	X
Product-time FE	X	X	X	X	X	X
Country-product FE	X		X	X		X
Country-product-month FE		X			X	
Country-product specific trend			X			X
Number of observations	41,813	25,246	41,813	16,434	10,765	16,434
Pseudo R-squared	0.988	0.991	0.990	0.974	0.983	0.976

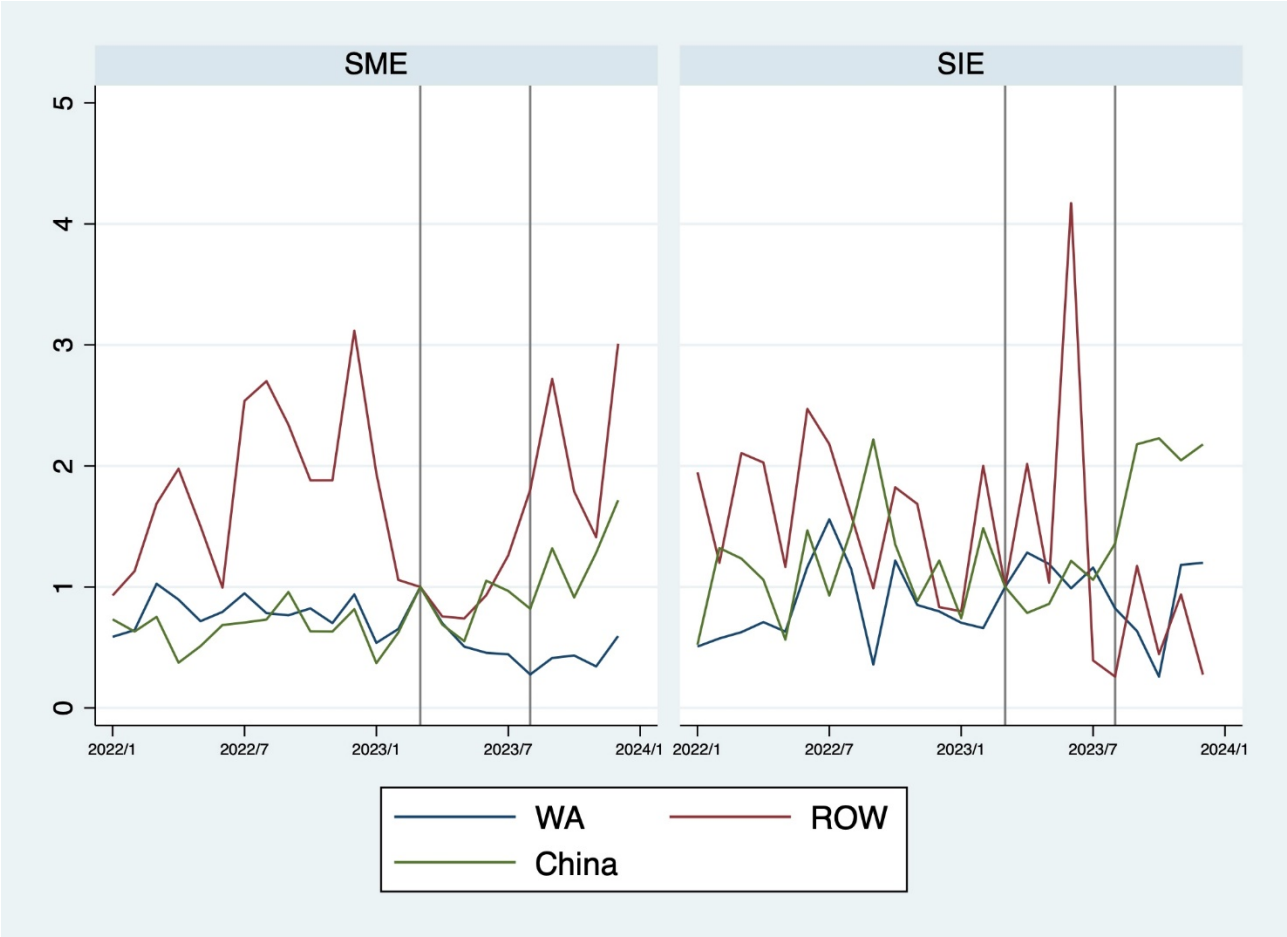
Notes: This table reports the estimation results using the PPML method. The dependent variable is Japan's monthly export values by destination countries and products (HS nine-digit codes). ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are clustered at a country-product level.

Table 2. PPML Results: China's Import Statistics

	(I)		(II)		(III)	
	Announce	Enforce	Announce	Enforce	Announce	Enforce
JP * HS84862010	-0.725***	-0.756**	-0.406*	-0.783**	-0.056	0.129
(Heat treatment)	[0.184]	[0.302]	[0.215]	[0.323]	[0.210]	[0.203]
JP * HS84862021	-0.379	-0.013	-0.201	0.083	0.019	0.525**
(CVD)	[0.235]	[0.218]	[0.277]	[0.234]	[0.175]	[0.252]
JP * HS84862022	-0.624***	-1.043***	-0.286	-1.065***	-0.774***	-1.212***
(PVD)	[0.179]	[0.275]	[0.244]	[0.342]	[0.137]	[0.237]
JP * HS84862029	-0.613**	-0.365	0.050	0.412	0.374**	0.958***
(Other film deposition)	[0.243]	[0.249]	[0.305]	[0.363]	[0.159]	[0.337]
JP * HS84862031	-0.770**	1.632***	-0.791*	2.071***	-0.835	1.557**
(Step and repeat aligners)	[0.359]	[0.439]	[0.461]	[0.550]	[0.597]	[0.628]
JP * HS84862039	0.886**	-0.152	0.772**	0.179	0.836***	-0.195
(Other projection)	[0.395]	[0.365]	[0.365]	[0.376]	[0.301]	[0.343]
JP * HS84862041	0.517*	-0.307	0.643**	-0.103	0.123	-0.713
(Dry plasma etching)	[0.273]	[0.402]	[0.286]	[0.385]	[0.154]	[0.438]
JP * HS84862049	0.539*	0.609	0.504*	0.765	0.190	0.186
(Other etching and stripping)	[0.291]	[0.401]	[0.305]	[0.469]	[0.284]	[0.655]
JP * HS84862050	-1.069***	-0.085	-1.036***	-0.179	-0.743***	0.354
(Ion implanters)	[0.196]	[0.267]	[0.214]	[0.289]	[0.204]	[0.292]
JP * HS84862090	0.344	0.550**	0.519**	0.734***	0.360*	0.622**
(Other machines)	[0.226]	[0.251]	[0.254]	[0.263]	[0.209]	[0.266]
NL * HS84862031	0.173	-0.134	0.122	0.626	0.085	-0.210
(Step and repeat aligners)	[0.380]	[0.409]	[0.506]	[0.524]	[0.591]	[0.614]
NL * HS84862039	0.632	1.826***	0.898**	2.260***	0.708**	1.975***
(Other projection)	[0.444]	[0.373]	[0.421]	[0.391]	[0.339]	[0.364]
US Regulation * US	-0.308		-0.252		0.360**	
	[0.226]		[0.231]		[0.162]	
US Regulation * JP	-0.053		-0.233		0.271	
	[0.191]		[0.222]		[0.169]	
US Regulation * NL	-0.607*		-0.846***		-0.057	
	[0.317]		[0.319]		[0.460]	
Country-time FE	X		X		X	
Product-time FE	X		X		X	
Country-product FE	X				X	
Country-product-month FE			X			
Country-product specific trend					X	
Number of observations	81,655		48,708		81,655	
Pseudo R-squared	0.974		0.980		0.980	

Notes: This table reports the estimation results using the PPML method. The dependent variable is China's monthly import values by source countries and products (HS nine-digit codes). ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors reported in parentheses are clustered at a country-product level.

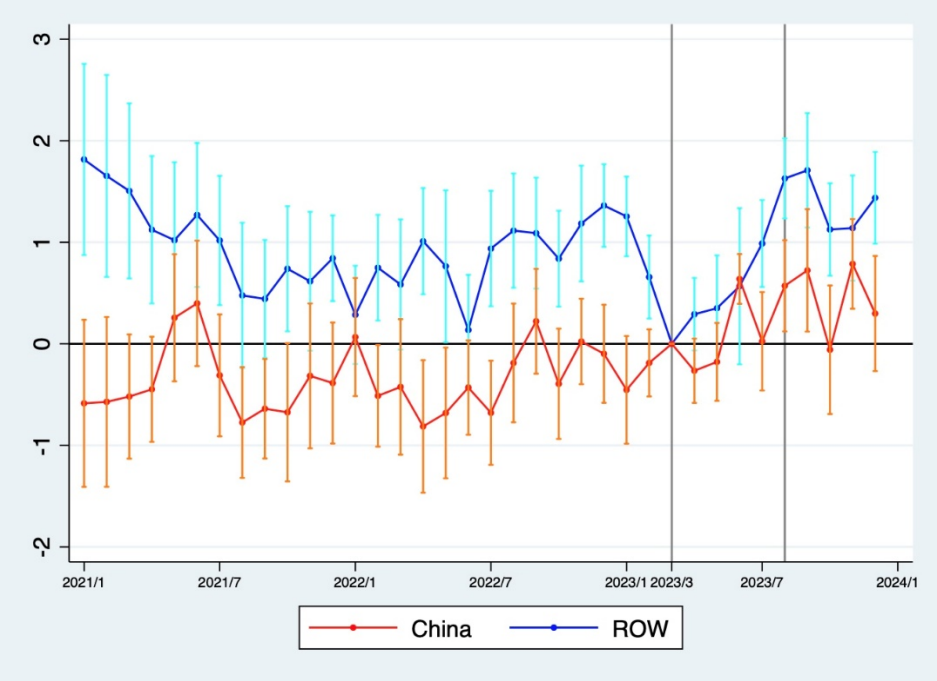
Figure 1. Japan's Exports of SME and SIE (1 for exports as of March 2023)



Source: Authors' computation using export statistics from the Customs, Japan.

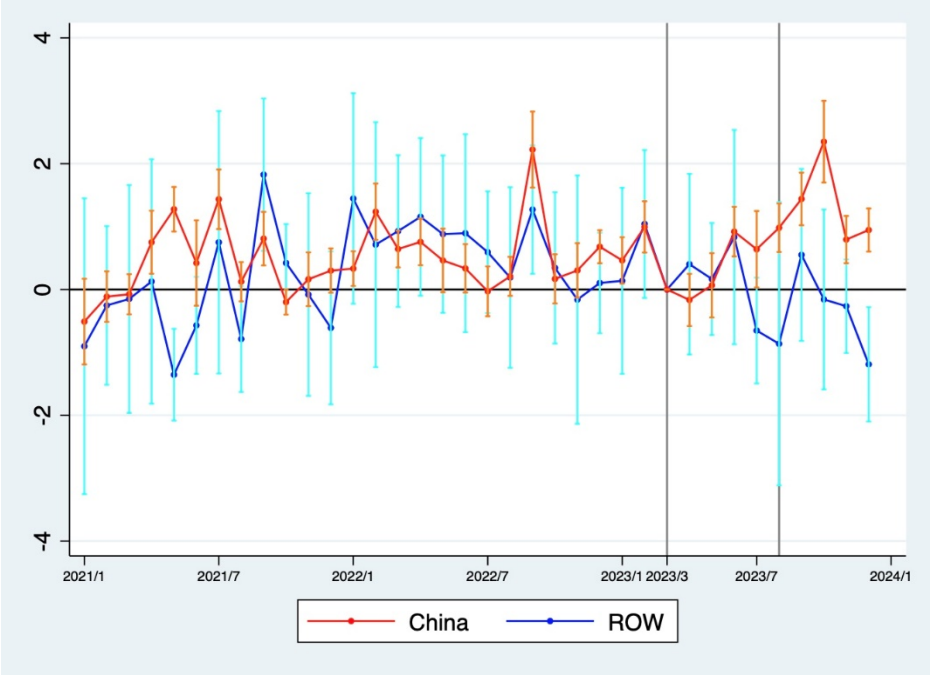
Notes: "WA" includes 42 countries participating in the Wassenaar Arrangement, excluding Russia and Japan, and including Taiwan and Singapore. "CHN" consists of China and Hong Kong. "ROW" includes all the other countries. Export values are normalized to the value of one in March 2023.

Figure 2. Changes of Estimates for SME over Time (0 for March 2023)



Source: Authors' estimation using export statistics from the Customs, Japan.

Figure 3. Changes of Estimates for SIE over Time (0 for March 2023)



Source: Authors' estimation using export statistics from the Customs, Japan.

Appendix. Other Tables

Table A1. China's Imports of SME from Japan, the Netherlands, and the US in 2022 (Million US dollars)

HS	Description	JP	NL	US
84862010	Heat treatment	1,012	6	361
84862021	CVD	396	0.5	503
84862022	PVD	77	0.3	308
84862029	Other film deposition	22	0.3	112
84862031	Step and repeat aligners	390	1,009	11
84862039	Other projection	902	1,539	6
84862041	Dry plasma etching	1,163	2	665
84862049	Other etching and stripping	516	6	78
84862050	Ion implanters	167	0	716
84862090	Other machines	1,234	3	204

Source: Global Trade Atlas