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Technological Decoupling Between the U.S. and China

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Abstract**:** In this paper, we address the ongoing debate on technological decoupling by examining the effect of US export controls and China's import tariffs on trade. By creating a detailed mapping between the products under the US export controls and 10-digit HS codes of US export products, we analyze the differences in US export reductions to China compared to other countries in 2017-2021. Contrary to expectations, we find no evidence that US export controls have led to a decrease in exports to China; in fact, these exports are either neutral or tend to increase relative to other countries. Additionally, our research indicates that China's imposition of additional import tariffs will likely diminish US exports to China.

Keywords: Export regulation; Trade; Tariffs, Technological decoupling; United States; China

JEL Classification: F15; F53

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1. Introduction

Since the 1990s, China has expanded its exports by leveraging cheap labor, becoming the world's largest exporter. As its economy grew, China aggressively invested in research and development to acquire advanced technologies, posing a challenge to the technological dominance of the U.S. Meanwhile, protectionist sentiments have emerged in the U.S., fueled by a significant trade deficit with China and concerns over Chinese technological advancements. This led to former U.S. President Trump imposing sanctions on China, citing intellectual property rights violations as unfair trade practices.

Invoking Section 301 of the Trade Act of 1974, the U.S. imposed a series of tariff measures against China in 2018 and 2019, to which China retaliated with countermeasures. To alleviate the resulting tension, the two governments signed the Economic and Trade Agreement, also known as the Phase One Agreement, which took effect in February 2020. Consequently, tariffs previously imposed on many products were suspended in both the U.S. and China throughout 2020. However, starting in 2021, the U.S. began to reimpose additional tariffs on these products, with the exception of some medical items.

In August 2018, the US government re-enacted the Export Controls Reform Act of 2018 (ECRA), strengthening export controls on dual-use goods for national security reasons. While these controls apply to all countries, the U.S. has specifically intensified controls on exports to China by adding a growing number of Chinese companies to the export control lists. In response, China revised its Catalogue of Technologies Prohibited or Restricted from Export, known as the Second Revision, in August 2020, marking its first update in twelve years since 2008. Subsequently, in October 2020, China enacted the Export Control Law, establishing a comprehensive legal framework to regulate exports from a national security standpoint.

Given these developments, there is growing concern that increasingly restrictive measures may have adverse effects on trade between the U.S. and China. The concern is particularly acute for high-tech goods and services, as many dual-use items fall into this category. Tighter U.S. export controls could lead to a technological split, or decoupling (decrease in trade in high-tech goods and services), between the U.S. and Chinese economies. Moreover, the global value chains over recent decades have fragmented the production process of high-tech products like computers and telecommunication equipment, with countries becoming specialized in specific stages of manufacturing. As a result, more stringent regulations in each country could exacerbate technological decoupling, impacting not just trade between the U.S. and China but potentially affecting other countries as well.

While numerous empirical studies have examined the impact of the U.S.-China tariff war[1], there is still a lack of quantitative analysis on the broader consequences of technological

[1] See for example, Fajgelbaum and Khandelwal (2022) for a review of this literature.

decoupling between the two nations, despite its significant implications for the global economy. A key reason for this gap is the absence of correspondence tables that align trade statistics codes, such as the Harmonized System (HS) codes, with the codes used in U.S. export control regulations, which reflects the differing objectives of these coding systems.

Against this backdrop, our study focuses on the U.S. initiative to strengthen trade controls and regulations on dual-use items for security purposes. We examine the impact of tightened export controls on U.S. exports to China by utilizing monthly U.S. exports data, disaggregated by partner country and detailed product category at the HS 10-digit level. This study spans from January 2017 to December 2021. We have developed correspondence tables between HS codes and U.S. export control regulation codes using various methods, including machine learning (ML) techniques. Additionally, for comparative analysis, we investigate the effects of China's additional tariffs on goods imported from the U.S. on the U.S. exports to China.

Our findings can be summarized as follows: First, our comprehensive mapping of U.S. export controls onto HS 10-digit level product categories indicates that the industries with a relatively high share of controlled products are chemicals, plastics, machinery, transport equipment, precision instruments, and arms. Second, our analysis reveals that the overall tightening of U.S. export control regulations has not led to a substantial reduction in exports to China. At the same time, China's import tariffs have had a negative impact on U.S. exports. Finally, the impact of export controls was not uniform across industries. For example, exports of transport equipment were negatively affected by export controls, while the stone, machinery, and precision sectors experienced an increase in exports of the controlled items. Overall, these findings align with the U.S. government's "small yard, high fence" strategy, which aims to safeguard key and sensitive technologies from being leaked to countries of concern, while keeping the economy opened to trade.

This paper contributes to the literature on the economic impacts of the recent U.S. export control regulations. As mentioned above, the existing literature on this topic is sparse.[2] The influence of export controls on exports was analyzed by Fuhrmann (2008) and Afesorgbor (2019). Fuhrmann's study utilized data on licensed U.S. dual-use exports and the total number of approved export licenses from 1991 to 2001, finding that democratic countries were more likely to receive dual-use exports from the U.S. Afesorgbor (2019) examined the global trade from 1962 to 2014 and found no significant effects of export restrictions on trade volumes. While these studies investigate the potential export-reducing effects of export controls, they rely on country-level aggregate export data and do not analyze detailed product categories. Furthermore, these studies do not address the intensification of U.S.

[2] There is a large literature on export restrictions in general. For instance, this is an important topic in agricultural trade (Abbott, 2012; He, 2021). The scope of these export restrictions which are focused on food security differs from the ones examined in our study that aim at protecting technological knowledge.

export controls during the recent U.S.-China trade tensions.[3]

Closely related to our paper, Hayakawa et al. (2023) examines the impact of recent export controls implemented by Japan and the U.S. on Japan's trade, utilizing detailed product-level trade data. Their research indicates that the U.S.'s tightening of the Foreign Direct Product Rule (FDPR) in August 2020 led to a marked decrease in Japan's exports of HS8517 products (including telephones for cellular networks or other wireless networks) to China. Another related study is Ando et al. (2023), which explored the impact of the FDPR on Japan's exports but broadened the scope to include additional products. Ando et al. (2023) found a significant decrease in Japan's export of advanced technology products, particularly those used in smartphone production (HS8517), to China. Nonetheless, both studies focus on the export of smartphone-related products and inputs from Japan, examining the consequences of Japanese and U.S. export controls on Japan's exports, rather than those from the U.S.

In summary, our paper contributes to the ongoing debate on U.S.-China technological decoupling. By conducting a detailed, product-level empirical analysis, we aim to present a concrete assessment of the impact of export control regulations. Additionally, we contrast this impact with the effects of China's import tariffs. Our empirical findings suggest that while export controls do not appear to reduce exports, the imposition of additional tariffs negatively affects exports. These results offer valuable insights for both scholars and policymakers amidst escalating geopolitical tensions.

The rest of the paper is organized as follows. The next section provides an overview of the additional tariff measures between the U.S. and China in 2018 and beyond, as well as developments in U.S. export control regulations. Section 3 then explains how to identify trade items and technologies that have been subject to export controls by the U.S. government. Section 4 examines quantitatively the impact of U.S. export controls on U.S. exports to China as well as the impact of additional tariffs imposed by the Chinese government on U.S. exports to China. Section 5 concludes.

2. Additional Tariffs and Export Control Regulations

2.1. U.S.-China Tariff War

The U.S. the trade war with China had four tariff escalation phases. The first phase started on July 6, 2018 and involved imposition of a 25% tariff on imports from China worth US$34 billion. On August 23, 2018, the second phase expanded the list of goods subject to tariffs by

[3] Cerdeiro et al. (2021) analyzes how much the technological decoupling between the U.S. and China would reduce the GDP of countries around the world. However, their study is a simulation analysis using a global dynamic macroeconomic model and does not examine the impact of export controls on actual trade.

another US$16 billion. The third phase, initiated on September 24, 2018, introduced a 10% tariff on US$200 billion of Chinese imports, which was subsequently increased to 25% on May 10, 2019. On September 1, 2019, the fourth phase brought about new tariffs of 15% on an additional US$101 billion of imports from China. In response, China imposed retaliatory tariffs corresponding to the phases of tariff increases on various products imported from the U.S.

The trade war between the U.S. and China, which peaked in 2019, began to wind down with the agreement on January 15, 2020, when the two countries postponed new additional tariffs in what became known as the "Phase One Agreement." On February 14, 2020, the U.S. reduced some of the previously imposed tariffs from 15% to 7.5% on approximately three thousand products, while China lowered tariffs from 5%-10% to 2.5%-5% on about two thousand products. Subsequently, both the U.S. and China completely removed some previously imposed tariffs on certain products.

However, in the U.S., the exemptions on all products except 87, which were in effect until September 2020, became ineffective on September 1, 2020. In 2021, even the exemptions on these 87 products expired. During 2021, the U.S. granted exemptions from additional tariffs to only 99 medical products, which were valid until the end of November 2021. Following that, the U.S. provided exemptions for 81 medical products until the end of May 2022.

2.2. U.S. Export Controls

The United States controls trade under the international export control regimes, i.e., 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. Many countries including the U.S. are 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. These four regimes control the export of weapons and the technologies and general-purpose items used in their development. Meanwhile, weapons themselves are regulated in treaties such as the Treaty on the Non-Proliferation of Nuclear Weapons, the Chemical Weapons Convention, and the Biological and Toxin Weapons Convention.

While imposing restrictions on imports through additional tariffs on China, the U.S. has also strengthened export controls. In August 2018, the Trump Administration enacted the Export Controls Reform Act (ECRA) to replace the Export Administration Act of 1979, which was enacted in 1979 but expired in 2001.[4] Within the ECRA legislative authority, dual-use items (plus less sensitive weapons items) are controlled under implementing regulations

[4] Since 2001 until 2018 the export control system was regulated by the U.S. president declarations and the International Emergency Economic Powers Act (IEEPA) of 1977 (Fergusson and Kerr, 2020).

called the Export Administration Regulations (EAR). In addition, the government added "emerging and foundational technologies", which were not previously subject to export controls, to the list of controlled items.[5]

The Bureau of Industry and Security (BIS) at the U.S. Department of Commerce is the supervising agency that maintains the Commerce Control List (CCL). The CCL assigns an Export Control Classification Number (ECCN) to each regulated item. Whether or not an export transaction is subject to the EAR is determined by the following criteria: 1) what is the ECCN of the item being exported; 2) what is the destination of the export; 3) who is the end-user; and 4) what is the end-use. When a firm exports, re-exports, or transfers items that fall into specified categories in these criteria, such a transaction is subject to the EAR and is required to obtain prior permission from the U.S. government.

Furthermore, the EAR includes the Denied Persons List (DPL), the Entity List (EL), and the Unverified List (UVL). The DPL includes individuals and companies whose export privileges are denied by written order of the Department of Commerce. The EL lists customers of concern about the proliferation of weapons of mass destruction (WMD) and customers who are in conflict with the U.S. national security and foreign policy interests.[6] The UVL lists parties that are not allowed to receive items listed in EAR under license exception.

In recent years, the U.S. government has added many Chinese companies to the EL. For example, in May 2019, Huawei Technologies Co. Ltd. (hereafter, Huawei) and its 68 affiliates were announced to be added to the EL. Huawei is a Chinese company that develops, manufactures, and sells information and communications technology (ICT) infrastructure and smart devices. In December 2020, the U.S. also added Semiconductor Manufacturing International Corporation (hereafter, SMIC) to the EL. SMIC is a partially state-owned publicly listed Chinese semiconductor foundry.

When transacting specified items subject to the EAR with customers on the Entity List, applications may be reviewed with a presumption of denial by the U.S. government. Therefore, although all the products or technologies on the CCL are potentially subject to export controls regardless of destination country, the increasing number of Chinese

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[5] For example, in May 2019, the list of controlled items was amended to include the following items: microwave transistors, electromagnetic countermeasure software, post-quantum cryptography technology, underwater transducers that function as underwater listening devices, and flight platforms for launching spaceflight vehicles. Subsequently, software for automatic analysis of geospatial imagery, items related to chemical substances and communication technology that are considered to be military-usable, and items related to the manufacture of high-density semiconductors were also added to the list.

[6] The difference in between DPL and EL is that entities in the former are not allowed to participate in export transaction of the U.S. goods or technology while entities in the latter may be allowed to trade under license and specified conditions.

companies on the EL suggests that export controls for China may be tightening.

In practice, an exporter must first identify whether its product is on the Commerce Control List and find the corresponding ECCN. If a product is on the CCL, then the exporter might need to obtain an export license from the U.S. government. The CCL is provided in Supplement No. 1 to Part 774 of the EAR and is divided into ten broad categories, with each category further subdivided into five product groups (See Appendix A). Examples of typical ECCNs are "3A001.b.2" and "3A001.b.3." Each ECCN has the leading explanatory five alpha-numerical characters. The first character of the ECCN identifies the broader category to which it belongs, and the second character identifies the product group. The third and fourth characters encode the reason for control.[7] The last digit is used for sequential numbering. The five-character ECCNs are further classified by detailed items. For example, some specific types of the "Monolithic Microwave Integrated Circuit" amplifiers are classified under the ECCN "3A001.b.2" while some specific types of discrete microwave transistors are classified under the ECCN "3A001.b.3."

Although ECCNs are assigned to a variety of products and technologies, only those items on the CCL that fall under a certain reason for control in a specific country require an export license. In addition, there are several license exceptions. For example, according to the BIS, in 2022, approximately 0.4% of U.S. exports to the world were exported under a BIS license. As for U.S. exports to China, out of the total US$153.8 billion in U.S. exports to China in 2022, US$1.1 billion, 0.72% were exported under a BIS license (Bureau of Industry and Security 2022). Although the share of licensed exports and the number of denied license applications for China seem to increase from 2020, the BIS statistics show that most of U.S. exports to China do not require a license, suggesting that the U.S. government is also concerned that excessive regulations will hinder the promotion of industry through free trade and does not want to expand the scope of regulation. As Jake Sullivan, the U.S. National Security Advisor to President Biden, stated "we are protecting our foundational technologies with a small yard and high fence,"[8] the U.S. government intends to strictly control exports involving sensitive technologies while focusing on a limited number of key areas of technology to be regulated.

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[7] There are the following reasons for control: 0: National Security reasons (including Dual Use and Wassenaar Arrangement Munitions List) and Items on the NSG Dual Use Annex and Trigger List; 1: Missile Technology reasons; 2: Nuclear Nonproliferation reasons; 3: Chemical & Biological Weapons reasons; 5: Items warranting national security or foreign policy controls at the determination of the Department of Commerce.; 6: "600 series" controls items because they are items on the Wassenaar Arrangement Munitions List (WAML) or formerly on the U.S. Munitions List (USML); 9: Anti-terrorism, Crime Control, Regional Stability, Short Supply, UN Sanctions, etc.).

[8] Jake Sullivan delivered his speech on Renewing American Economic Leadership at the Brookings Institution on April 27, 2023.

3. Mapping between US Export Controls and Trade Statistics

To examine the trade effects of US export control regulations, we need to have a mapping between the codes in trade statistics (i.e., HS codes) and ECCN codes. These two set of codes do not correspond to each other due to the difference in purposes, which makes construction of the mapping a nontrivial task. In this section, we first explain our information sources for ECCN and then present the procedure of creating a mapping between the ECCN and the US tariff lines at the 10-digit classification level.

3.1. Sources of the US Export Controls

We used two sources of information on the U.S. export controls that we could obtain. The first is the Alphabetical Index to the Commerce Control List (CCL).[9] We call it the *CCL index*. This alphabetical index lists various product names and the corresponding ECCNs. We call the product names ECCN names. The *CCL index* is reported by BIS on an irregular basis, and every edition reflects amendments of controlled products in the EAR that have been made recently. We were able to obtain ten editions of the CCL index for the period 2017-2021.[10] The total number of ECCN names in the lists for the entire period was 3,392.[11]

The second source of information on the U.S. export controls is the document published by BIS and called Supplement No. 1 to Part 774 - The Commerce Control List (description of categories). This document contains a more sophisticated description and examples of all ECCNs. It also specifies the reasons for exports control in each category.[12] We call the description provided in this document the *CCL categories*.[13] The various versions of this

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[9] The most recent version of the Alphabetical Index is available at the official BIS web-page following link: https://www.bis.doc.gov/index.php/regulations/commerce-control-list-ccl. We thank Export Compliance Training Institute for sharing with us earlier versions of CCL.

[10] The Alphabetical Index that we were able to access are of the following dates: 01-15-2017; 08-15-2017; 05-12-2018; 08-30-2018; 10-24-2018; 01-31-2019; 05-23-2019; 05-20-2021; 09-20-2021; 12-06-2021.

[11] Examples of ECCN names with the ECCN 8A002.o.3.a are: "Acoustic mounts, noise reduction equipment for vessels"; "Anti-vibration mounts (noise reduction), civil vessels"; "Noise reduction equipment for vessels, acoustic mounts".

[12] The reasons for exports control are: AT Anti-Terrorism; CB Chemical & Biological Weapons; CC Crime Control; CW Chemical Weapons Convention; EI Encryption Items; FC Firearms Convention; MT Missile Technology; NS National Security; NP Nuclear Nonproliferation; RS Regional Stability; SS Short Supply; UN United Nations Embargo; SI Significant Items; SL Surreptitious Listening.

[13] As an example, the CCL categories pertaining to ECCN 8A002.o.3.a consist of the following: "Marine systems, equipment, "parts" and "components," as follows (see List of Items Controlled). Propellers, power transmission systems, power generation systems and noise reduction systems, as follows: Noise

document are available at the webpage of the national archives of the Code of Federal Regulations.[14] We obtained 53 editions presenting a description of 6,611 CCL categories for the period 2017-2021.[15]

Both CCL index and CCL categories convey identical information. CCL index presents the classification of various products to ECCN codes. The purpose of CCL index is to facilitate the identification of an ECCN for exporter's products. CCL categories are detailed descriptions of each ECCN code. The purpose of CCL categories is to provide comprehensive information to the exporter, thereby assisting its decision about the need for a license application.

The documents provided by BIS are aimed at helping the US firms check whether products that they produce for exporting are under the export control regulation. Exporting firms must comply with the regulation. In fact, firms need to identify whether the product needs a license when exporting to particular destinations. First, the product should be checked against the CCL index list and the CCL categories detailed description of the products. Second, if the product can be classified under an ECCN, the exporter identifies the reason for control given in the product description and destination-specific regulation provided in the supplementary country chart. In addition, several license exceptions are provided in the product description. If, upon examination, the product is categorized under an ECCN and has security controls for a specific destination, then the exporter must apply for license prior to exporting. We expect that such a procedure affects firm's fixed cost of exporting. If it is too costly, firms may give up exporting.

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reduction systems designed for use on vessels of 1,000 tonnes displacement or more, as follows: Systems that attenuate underwater noise at frequencies below 500 Hz and consist of compound acoustic mounts for the acoustic isolation of diesel engines, diesel generator sets, gas turbines, gas turbine generator sets, propulsion motors or propulsion reduction gears, "specially designed" for sound or vibration isolation and having an intermediate mass exceeding 30% of the equipment to be mounted;"

[14] We accessed it via the following link: https://www.ecfr.gov/.

[15] They are of the following dates: 01-10-2017; 01-15-2017; 03-15-2017; 06-14-2017; 07-07-2017; 08-15-2017; 09-25-2017; 10-03-2017; 12-20-2017; 12-27-2017; 01-08-2018; 02-16-2018; 04-02-2018; 04-05-2018; 05-17-2018; 08-30-2018; 10-25-2018; 10-30-2018; 11-02-2018; 12-20-2018; 05-14-2019; 05-23-2019; 01-23-2020; 03-02-2020; 03-09-2020; 04-28-2020; 04-30-2020; 05-22-2020; 06-03-2020; 06-17-2020; 06-29-2020; 07-01-2020; 09-11-2020; 09-18-2020; 10-05-2020; 10-06-2020; 10-09-2020; 12-04-2020; 12-07-2020; 01-07-2021; 01-19-2021; 03-29-2021; 03-31-2021; 08-19-2021; 09-03-2021; 09-20-2021; 10-05-2021; 10-06-2021; 10-21-2021; 11-04-2021; 11-15-2021; 11-19-2021; 12-06-2021.

3.2. Mapping Procedures

We used three methods to create a mapping between the U.S. export controls and HS codes.[16] The first is a manual mapping. Two experts analyzed independently CCL index items and attempted to find the most appropriate HS codes. Several matches were identified. First was the perfect match when there was a perfect ECCN/HS mapping found. Second was a match found using external sources/documents/websites. Third was a custom match, based on common understanding what is a product in ECCN list and how it may correspond to HS-codes categories. Each match of ECCN could have several 10-digit HS codes correspondences. Based on this analysis we obtained a manual mapping between the CCL index and HS 10-digit level product tariff line.

The second mapping is based on a mapping between ECCNs and 8-digit HS codes created by the German authorities.[17] German authorities use the same ECCNs and the corresponding descriptions as the U.S. to classify dual-use items. We manually find the U.S. 10-digit HS codes that are the closest to the respective German 8-digit HS codes and then we use the German ECCN-HS mapping to construct the U.S. ECCN-HS mapping. One caveat to this procedure is that the number of ECCNs covered in the German mapping is smaller the one in the U.S. CCL index.[18]

The third method of mapping relies on machine learning techniques and is based on the idea of creating an embedding of a text, which is a vector of numbers that corresponds to the respective text.[19] We used three approaches to compute embeddings: two sentence transformers called mpnet and MiniLM; and the API provided by OpenAI company to create embeddings.[20] After creating a set of vectors of embeddings for export controls and 10-digit HS codes we calculated semantic distances between them using cosine distances as follows:[21]

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[16] We worked with 9,383 HS 10-digit level codes reported in the July 2021 Schedule B list which can be found at https://www.census.gov/foreign-trade/schedules/b/2021/index.html.

[17] This correspondence is available via The Federal Office for Economic Affairs and Export Control (BAFA) accessed at www.bafa.de/EN/Foreign_Trade/Export_Control/export_control_node.html. We thank Franz Ferdinand Willeit for pointing us to this list.

[18] There are 1,723 out of 3,392 ECCNs that corresponded to the U.S. ECCN in German mapping.

[19] The idea is inspired by the recent advancements in industrial organization research literature (Magnofi et. al., 2022).

[20] Additional documentation is available at https://huggingface.co/sentence-transformers/all-MiniLM-L6-v2 and https://huggingface.co/sentence-transformers/all-mpnet-base-v2. These Sentence-Transformers Models showed high efficiency in dense text embedding according to semantic textual similarity test. See https://medium.com/@nils_reimers/openai-gpt-3-text-embeddings-really-a-new-state-of-the-art-in-dense-text-embeddings-6571fe3ec9d9.

[21] Cosine distance is a widely used measure of textual similarity in natural language processing area of machine learning (Jurafsky and Martin, 2014, Chapter 6). As an alternative, we also used the Euclidean

$$d_{cosine} = 1 - \frac{x_{eccn} \cdot x_{hs}}{||x_{eccn}|| ||x_{hs}||}, \quad (1)$$

$$\widehat{d_{cosine}} = \frac{d_{cosine_i}}{\max\{d_{cosine}\}}, \quad (2)$$

where x_{eccn} is embedding of an ECCN name of CCL index or CCL category and x_{hs} is embedding of a product name that corresponds to a 10-digit HS code. $\widehat{d_{cosine}}$ is a normalized distance that we used for creating datasets. We use the calculated distances to identify pairs of 10-digit HS codes and ECCN names/CCL categories with close meanings according to the embedding.

To verify the validity of this procedure, we manually checked the random sample of 200 correspondences out of 21586. In this check we focused on first mapping of manually created correspondence in between ECCN name of CCL index and a 10-digit product name as described above. We examined the extent to which each machine learning method assessed the semantic relationship between ECCN name and a 10-digit HS code product name, or in other words, how accurately it predicted a 10-digit HS code for each ECCN name as compared to other methods. If ECCN name and 10-digit HS code are semantically similar or refer to about the same concept, then the most appropriate method chosen was the one with the minimum value of normalized cosine distance. If ECCN name and 10-digit HS code convey distinctly different meanings, then the most suitable method chosen was the one with the maximum value of normalized cosine distance, implying that it best discerned this semantic difference. Note, however, that the analysis of some products was challenging due to its short description and limited clarity.[22] Given the described above criteria we found that OpenAI method outperformed other methods in 66 cases out of 200, mpnet method in 74 cases, and MiniLM method in 77 cases. As the result obtained from the approach using MiniLM sentence transformer was slightly better than others, in what follows we present the analysis based on MiniLM sentence transformer embeddings.[23]

From the above-described mappings, we created the following sets of 10-digit HS codes.

- **Set 1** (Manual): Includes all 10-digit HS codes from both manual and German mappings.
- **Set 2** (Manual+German+ML): Includes German-mapping 10-digit HS codes combined with the manual-mapping 10-digit HS codes that have semantic distance to ECCN name listed in CCL index less than 0.7 based on MiniLM normalized cosine distance.

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distance. The results are identical to the results for cosine distances presented in the draft.

[22] Note that we did not check the accuracy of second-best or third-best prediction by semantic distance. This could affect the result of validity check as well.

[23] We did the analysis for datasets created using mpnet and OpenAI embeddings as well. The results are similar to the ones obtained using MiniLM embeddings.

- **Set 3** (German): Includes only 10-digit HS codes from the German mapping. Some of them coincide with manual mapping, but do not cover all ECCN names listed in the CCL index.
- **Set 4** (Manual+ML): Includes the 10-digit HS codes from Set 1, but only those that have the minimum normalized cosine distance to each ECCN name in the CCL index based on embeddings obtained by MiniLM sentence transformer.[24]
- **Set 5** (CCL index+ML): First, we created a cartesian product of semantic distances of export controls and HS codes, i.e., for each ECCN name we calculated distance to all 10-digit HS codes. Second, we chose 10-digit HS codes that correspond to the minimum normalized cosine distance to each ECCN name in CCL index from the cartesian product.[25]
- **Set 6** (CCL categories+ML): First, we created a cartesian product of distances of each CCL category name and 10-digit HS code name. Second, we chose 10-digit HS codes that correspond to two smallest normalized semantic distances to a CCL category.[26]

None of these sets is perfect and Table 1 summarizes the pros and cons of each of these sets. Nevertheless, given the complexity of ECCN products and their description we did the best job that we could to obtain the mapping and corresponding sets of 10-digit HS codes.

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[24] For example, ECCN 3A001.b.1.b Crossed-field amplifier tubes corresponds to HS codes 8540890040 Diode, triode, and tetrode type tubes (d_{cosine}=0.46), 8540890020 Gas and vapor electron tubes, nesoi (d_{cosine}=0.55), 8540890060 Light-sensing tubes (d_{cosine}=0.50), 8540890080 Thermionic, cold cathode or photocathode tubes, nesoi (d_{cosine}=0.51), 8540810000 Reciever or amplifier tubes (d_{cosine}=0.31). We choose only 8540810000 Reciever or amplifier tubes which has the minimum value of normalized cosine distance and can be considered to be the closest by semantic distance. Indeed, it indicates tubes used for amplification making it somewhat closer to the key function of ECCN 3A001.b.1.b Crossed-field amplifier tubes.

[25] We used all three methods of calculating embeddings: MiniLM, mpnet, and OpenAI. We report the results based on MiniLM embedding in the analysis part of the manuscript. For the analysis we also used two 10-digit HS codes that correspond to two smallest distances to an ECCN name. The results that we obtained were almost identical to the ones presented in the main text.

[26] We used all three methods of calculating embeddings: MiniLM, mpnet, and OpenAI. We also used one HS code that corresponds to smallest semantic distance to a CCL category. The results that we obtained were almost identical to the ones presented in the main text.

Table 1. Pros and cons of the sets of controlled products at HS 10-digit level.

Sets	Pros	Cons
Set 1 (Manual)	Created by careful review/analysis of ECCN names and HS codes.	Subject to human error due to high number of elements in the set.
Set 2 (Manual+German+ML)	Incorporates codes from the manual and German mappings. Most unlikely matches are removed using ML-based criteria.	Given that this mapping is based on the manual mapping, it can still be subject to human error due to high number of elements in the set.
Set 3 (German)	Created by German experts from The Federal Office for Economic Affairs and Export Control (BAFA).	Limited number of ECCN names covered in the German mapping.
Set 4 (Manual+ML)	Based on manual mapping. Keeps only most likely matches using ML-based criteria.	Remains to be subject to human error due to high number of elements in the set.
Set 5 (CCL index+ML)	Completely automatized using ML techniques. Recent advances in ML allow transformers to create embeddings that show good understanding of texts.	The ML transformers are not trained on relatively technical texts that are used in the descriptions of CCL index and HS codes. Therefore, not all of the resulting matches might be correct.
Set 6 (CCL categories+ML)	Completely automatized using ML techniques. Recent advances in ML allow transformers to create embeddings that show good understanding of texts.	The ML transformers are not trained on relatively technical texts that are used in the descriptions of CCL categories and HS codes. Therefore, not all of the resulting matches might be correct.

Source: Authors' compilation.

The coverage of 10-digit HS codes for each 2-digit HS code is presented in Table 2. Column 1 shows the number of 10-digit HS codes mapped to ECCN. Columns 2-7 show share of mapped 10-digit HS codes in total number of 10-digit codes of a respective 2-digit HS code category. The last row presents the coverage for all categories. As one can see, sets 1 and 2 contain the largest number of HS codes: close to one-third of all HS codes (29% out of total number of 10-digit HS codes). The reason for this is that in the manual mapping we included all possible codes that could potentially be associated with the respective ECCN name.

Table 2. Mapping Statistics

	Total	1(Manual)	2(Man+Ger+ML)	3(German)	4(Man+ML)	5(CCL ind.+ML)	6(CCL cat.+ML)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Chapter 01. Live Animals	521	0%	0%	0%	0%	3%	2%
Chapter 02. Vegetable Products	524	1%	1%	0%	0%	3%	1%
Chapter 03. Fats, Oils, and Waxes	69	0%	0%	0%	0%	3%	1%
Chapter 04. Food products and Tobacco	448	1%	1%	0%	0%	2%	0%
Chapter 05. Mineral products	237	21%	21%	1%	8%	13%	8%
Chapter 06. Chemical products	1295	30%	29%	17%	12%	19%	10%
Chapter 07. Plastics and Rubber	302	34%	34%	20%	14%	15%	12%
Chapter 08. Leather products	192	5%	5%	0%	2%	3%	2%
Chapter 09. Wood products	269	18%	18%	0%	1%	3%	1%
Chapter 10. Paper products	281	8%	6%	0%	1%	1%	4%
Chapter 11. Textiles	1219	7%	7%	4%	1%	2%	2%
Chapter 12. Footwear	89	12%	11%	0%	6%	3%	2%
Chapter 13. Stone/Ceramic products; Glassware	211	32%	31%	10%	10%	11%	10%
Chapter 14. Precision metals	68	15%	13%	7%	4%	10%	9%
Chapter 15. Base metals	834	33%	32%	16%	9%	10%	12%
Chapter 16. Machinery	1886	65%	64%	33%	22%	24%	21%
Chapter 17. Transport Equipment	336	48%	47%	19%	14%	15%	14%
Chapter 18. Precision machinery	346	61%	59%	32%	28%	42%	38%
Chapter 19. Arms	51	80%	78%	8%	37%	45%	57%
Chapter 20. Miscellaneous	188	19%	19%	0%	7%	9%	5%
Chapter 21. Works of Art	17	18%	18%	0%	6%	18%	12%
Total	9383	29%	29%	14%	10%	13%	10%

Source: Authors' estimation.

Notes: Share of mapped HS 10-digit level codes in the total number of HS 10-digit level codes for each HS2 level section. Based on embeddings method MiniLM.

We see that the top-3 HS categories that have the highest share of mapped codes across all sets are Chapter 16 Machinery; Electrical Equipment; Sound Recorders, Chapter 18 Optical, Medical, Musical Instruments; Clocks; Watches, and Chapter 19 Arms and Ammunition. This makes sense as these are the categories that include many high-tech products that could potentially have dual uses. For instance, semiconductors is one of the main products exports of which the U.S. aims to control. They fall under category HS84-85 of chapter 16 Machinery.

Tables 3 and 4 show the variation in the presence of mapped HS 10-digit level product codes over time in the source CCL index and CCL categories documents. We observe less time-variation of mapped codes. Only a small share enters/exits the mapped sets.

Table 3. Over-time Variation of HS 10-digit Level Codes Mapped to the U.S. Export Controls: Datasets 1-5

	Dataset 1(Manual)			Dataset 2 (Manual+Ger+ML)			Dataset 3 (German)			Dataset 4 (Manual+ML)			Dataset 5 (CCL index+ML)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Year	**Control**	**Entry**	**Exit**	**Control**	**Entry**	**Exit**	**Control**	**Entry**	**Exit**	**Control**	**Entry**	**Exit**	**Control**	**Entry**	**Exit**
20120109	2479			2383			1213			807			1041		
20160404	2615	240	104	2520	256	119	1233	47	27	875	116	48	1067	101	75
20160607	2613	3	5	2518	2	4	1233	0	0	875	1	1	1068	2	1
20160920	2611	2	4	2518	5	5	1232	0	1	875	6	6	1064	3	7
20161231	2613	5	3	2533	18	3	1235	4	1	885	13	3	1081	21	4
20170115	2613	0	0	2533	0	0	1235	0	0	886	1	0	1081	0	0
20170815	2622	9	0	2542	9	0	1235	0	0	890	4	0	1081	1	1
20180512	2620	0	2	2540	0	2	1234	0	1	889	1	2	1081	1	1
20180830	2618	0	2	2538	0	2	1234	0	0	885	0	4	1079	1	3
20181024	2618	0	0	2538	0	0	1234	0	0	883	0	2	1080	3	2
20190131	2620	2	0	2540	2	0	1234	0	0	887	5	1	1082	3	1
20190523	2620	0	0	2540	0	0	1236	2	0	887	0	0	1084	2	0
20210520	2626	8	2	2545	7	2	1242	6	0	889	11	9	1096	12	0
20210920	2623	0	3	2542	0	3	1242	0	0	892	3	0	1096	0	0
20211206	2623	0	0	2542	0	0	1242	0	0	893	1	0	1097	1	0

Notes: The table presents statistics for versions of CCL index that we obtained.

Table 4. Over-time Variation of HS 10-digit Level Codes Mapped to the U.S. Export Controls: Datasets 6

	Dataset 6(minilm)			Dataset 6 (mpnet)			Dataset 6 (openai)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	**Control**	**Entry**	**Exit**	**Control**	**Entry**	**Exit**	**Control**	**Entry**	**Exit**
20170115	560			499			502		
20170315	558	0	2	499	0	0	502	0	0
20170614	558	0	0	499	0	0	502	0	0
20170707	558	0	0	499	0	0	502	0	0
20170815	553	5	10	498	2	3	501	2	3
20170925	553	0	0	498	0	0	501	0	0
20171003	553	0	0	498	0	0	501	0	0
20171227	553	0	0	499	1	0	501	0	0
20180108	552	0	1	498	0	1	501	0	0
20180216	552	0	0	498	0	0	501	0	0
20180405	552	1	1	499	2	1	502	1	0
20180517	552	0	0	499	0	0	502	0	0
20180830	555	6	3	503	5	1	503	3	2
20181030	558	6	3	506	6	3	512	12	3
20181102	558	0	0	506	0	0	510	0	2
20181220	558	0	0	506	0	0	509	0	1
20190523	559	1	0	506	0	0	509	0	0
20200123	556	0	3	506	0	0	506	0	3
20200309	565	9	0	510	4	0	513	7	0
20200430	558	0	7	504	0	6	505	0	8
20200522	558	1	1	504	0	0	503	0	2
20200629	558	0	0	504	0	0	505	2	0
20200701	557	0	1	503	0	1	504	0	1
20200918	558	6	5	505	2	0	501	6	9
20201009	555	1	4	504	1	2	501	1	1
20201207	556	1	0	504	0	0	504	5	2
20210119	557	1	0	504	0	0	504	1	1
20210331	556	2	3	504	1	1	503	2	3
20210819	556	0	0	504	0	0	503	0	0
20210920	560	4	0	506	2	0	504	1	0
20211006	559	0	1	505	0	1	504	0	0
20211021	559	0	0	505	0	0	505	1	0
20211119	560	1	0	505	0	0	504	0	1
20211206	560	0	0	505	0	0	504	0	0
20220112	560	0	0	505	0	0	504	0	0
20220316	560	0	0	505	0	0	506	3	1
20220526	560	0	0	505	0	0	507	1	0
20220815	563	3	0	507	2	0	507	0	0
20221021	565	2	0	508	1	0	508	1	0
20230118	565	0	0	503	0	5	508	0	0
20230224	563	0	2	502	0	1	507	1	2
20230324	564	1	0	503	1	0	508	1	0

Notes: The table presents statistics for versions of CCL categories that we obtained.

Table 5 shows the share of exports of mapped to ECCN HS 10-digit level codes in total exports for the world and China. The table confirms that manual mapping covers a larger share of exports as compared to sets 3-6.

Table 5. Share of Exports of ECCN Products

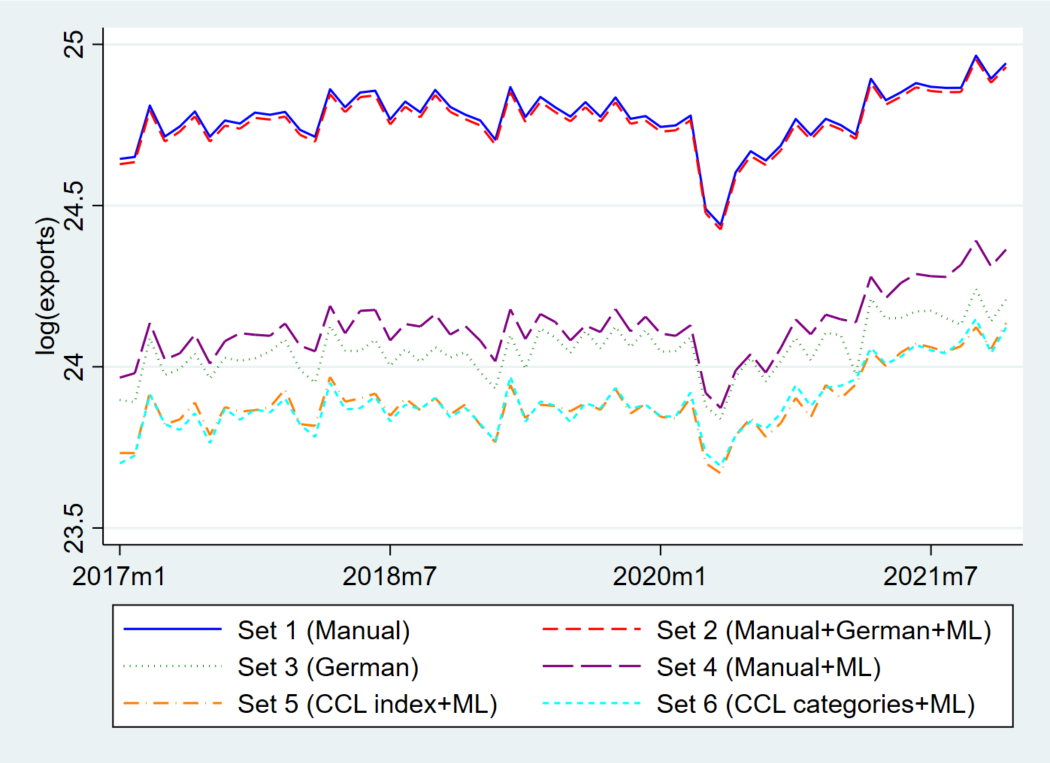
	Set 1 (Manual)	Set 2 (Manual+German+ML)	Set 3 (German)	Set 4 (Manual+ML)	Set 5 (CCL index+ML)	Set 6 (CCL categories+ML)
Share ECCN to world	0.43	0.42	0.21	0.23	0.18	0.18
Share non-ECCN to world	0.57	0.58	0.79	0.77	0.82	0.82
Share ECCN to China	0.40	0.40	0.26	0.25	0.22	0.23
Share non-ECCN to China	0.60	0.60	0.74	0.75	0.78	0.77

Notes: Table shows average share for the period 2017-2021 of the share mapped to ECCN HS 10-digit level codes exports in toral exports.

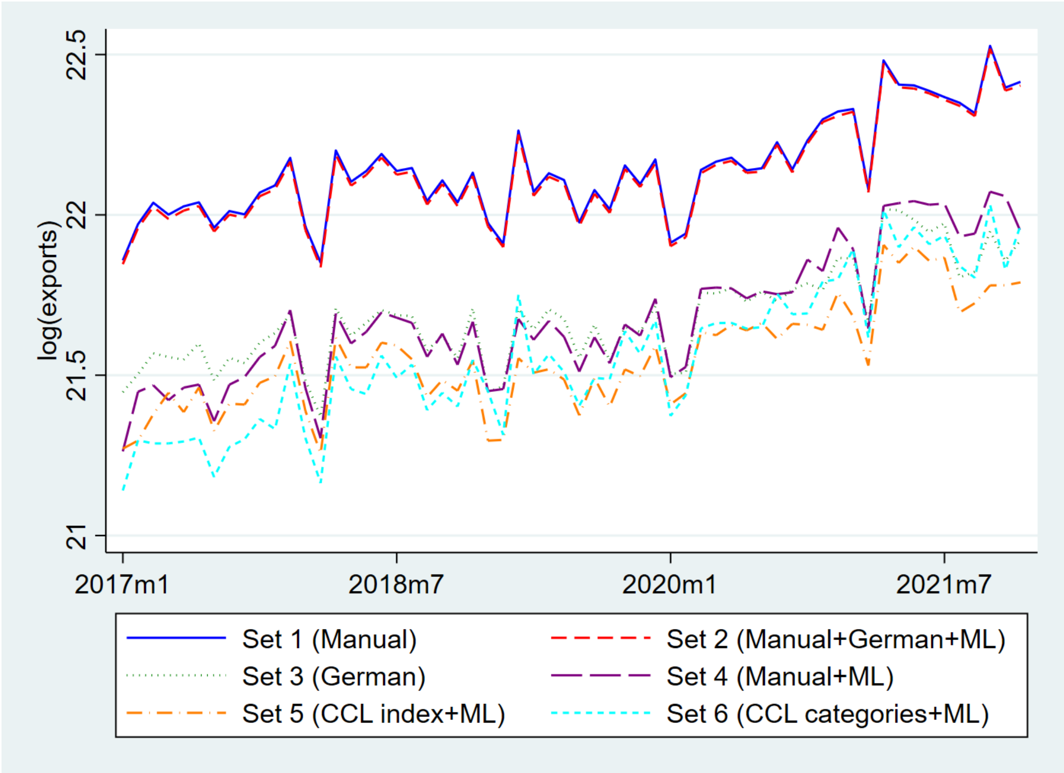
Figure 1 shows the evolution of exports of ECCN HS 10-digit level codes to the world and China, confirming this conclusion.

Figure 1. Exports of ECCN Products over Time

(i) Exports to the world



(ii) Exports to China



Source: Authors' compilation.

4. Empirical Strategy and Results

4.1. Benchmark Results

Our empirical analysis attempts to disentangle the effects of export controls and import tariffs on U.S. exports. As discussed in Section 2, the U.S. export controls target dual-use items. In addition, the U.S.-China trade war of 2018-2019 resulted in China imposing heightened import tariffs on a range of products originating from the U.S.

We examine monthly exports of 10-digit-level products from the U.S. to 231 countries for the period 2017-2021. Our baseline empirical specification is

$$Export_{ipt} = \exp\{\beta_1 China_i \times Control_{pt} + \beta_2 China_i \times \ln(1 + Tariff_{pt}) + \theta_{it} + \gamma_{pt}\} \cdot \epsilon_{ipt}, \quad (3)$$

where $Export_{ipt}$ represents a value of the U.S. exports of a 10-digit HS code p to country i at year-month t. $China_i$ is dummy variable equal to one if the country of the U.S. export destination is China, while $Control_{pt}$ is dummy variable equal to one if 10-digit HS code p was mapped to export control ECCN name in month-year t. $Tariff_{pt}$ is calculated as the average Chinese import tariff at the 6-digit HS code level. The tariff is only with respect to the U.S. and originally is reported at the 8-digit HS code level.

We also include the set of fixed effects (FE) θ_{it} and γ_{pt}, which are country-time FE and product-time FE, respectively. Country-time FE control for destination country time-variant characteristics such as GDP or exchange rates. Product-time FE control for the global trend of demand at a product level. For example, during 2020 and 2021, work-from-home styles were proliferated to avoid the COVID-19 infection. As a result, the demand for smartphones, laptop computers, and, as a consequence, integrated circuits dramatically increased worldwide. Also, this type of FE controls for technology or factor prices in the U.S. Importantly, we do not include country-product FE in our benchmark specification because $Control_{pt}$ has a limited time dimension variation.

The model is estimated using the Poisson Pseudo Maximum Likelihood (PPML) method. The key explanatory variable is an interaction of two dummies: $China_i \times Control_{pt}$. In case the U.S. export control policies adversely affect trade with China, we expect that coefficient β_1 is negative. Coefficient β_2 on interaction term $China_i \times \ln(1 + Tariff_{pt})$ shows the effect of China import tariffs on the products exported from the U.S., and we expect this coefficient to be negative as well. Our data source for U.S. exports is the Global Trade Atlas (IHS Markit). China's tariffs against the U.S. are computed using the data drawn from the World Integrated Trade Solution and the policy documents announced by the Office of the Customs Tariff Commission of the State Council, the People's Republic of China[27].

[27] https://gss.mof.gov.cn/gzdt/zhengcefabu/index.htm (Accessed on 11 September, 2023)

Table 6. Effect of the U.S. Export Controls and China Import Tariffs on the U.S. Export to China. Benchmark estimation.

	1(Manual)	2(Man+Ger+ML)	3(German)	4(Man+ML)	5(CCL index+ML)	6(CCL categ.+ML)
	(1)	(2)	(3)	(4)	(5)	(6)
China x Controls	-0.113	-0.105	0.260	0.195	0.282	0.324*
	[0.178]	[0.178]	[0.178]	[0.185]	[0.191]	[0.187]
China x Tariff	-2.954***	-2.956***	-2.819***	-2.871***	-2.756***	-2.736***
	[0.847]	[0.846]	[0.774]	[0.786]	[0.756]	[0.754]
Observations	37,716,109	37,716,109	37,716,109	37,716,109	37,716,109	37,716,109
Pseudo R^2	0.763	0.763	0.763	0.763	0.763	0.763
country-time FE	X	X	X	X	X	X
product-time FE	X	X	X	X	X	X
Destination	China	China	China	China	China	China

Source: Authors' estimation.

Notes: This table reports the estimation results using the PPML method. Dependent variable is export value. Each column shows estimation for a set of HS10-digit level codes that was obtained from various approaches to the export controls-HS mapping. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors clustered by products reported in brackets.

The estimation results of specification (3) are provided in Table 6. We estimate it for six sets of controls for 10-digit HS codes identified in our mapping exercise presented in Section 3. The coefficient β_1 is insignificant for all specifications except the specification in column (6), where it is positive and marginally significant at a 10% level. The result suggests that the U.S. export controls, which were made more stringent after 2017, do not appear to have a negative effect on the export of controlled products to China. Thus, although fixed export costs of the U.S. firms supposedly increased due to the tightening of export controls, these fixed costs did not considerably affect exports to China. Another interpretation is that US exporters of "controlled" items within an HS 10-digit code stopped their exports, but US exporters of "uncontrolled" items within the same 10-digit code increased their exports in preparation for possible future control. As a result, at an HS 10-digit level, export values did not change significantly. At the same time, coefficient β_2 is negative and significant in all specifications, suggesting that China import tariffs negatively affected U.S. exports to China. For instance, the results from column 1 of Table 6 suggest that a one-percentage-point rise in tariffs decreases U.S. exports to China by around 2.9%.

The obtained results lead us to the conclusion that imposing additional import tariffs by China decreases exports while export control regulations of the U.S. do not negatively affect exports of the related products. This result may represent some evidence of the “small yard, high fence” strategy of the U.S. government.

4.2. Restriction of Study Products

As discussed above, we cannot control for country-product FE due to the minimal variation over time of 10-digit HS codes mapped to the U.S. export controls. In an attempt to reduce the potential for endogeneity bias due to the absence of country-product fixed effects in our benchmark model given by equation (3), we conduct a robustness check. Specifically, we limit our study products to HS 6-digit level products that have at least one corresponding 10-digit HS code under U.S. export control according to our mapping. This restriction means that we included only those 6-digit HS codes that were affected by the control regulations at the more specific 10-digit level. Any 10-digit HS code belonging to HS 6-digit level products that did not have a corresponding controlled 10-digit product were excluded from the dataset used in the estimation.

Table 7. Effect of the U.S. Export Controls and China Import Tariffs on the U.S. Export to China. Affected HS6.

	1(Manual)	2(Man+Ger+ML)	3(German)	4(Man+ML)	5(CCL index+ML)	6(CCL categ.+ML)
	(1)	(2)	(3)	(4)	(5)	(6)
China x Controls	0.266	0.279*	0.419	0.487***	0.324*	0.556***
	[0.180]	[0.168]	[0.394]	[0.150]	[0.190]	[0.171]
China x Tariff	-5.774***	-5.769***	-6.175***	-6.046***	-4.498***	-6.053***
	[1.456]	[1.446]	[1.483]	[1.294]	[1.525]	[1.236]
Observations	15,915,163	15,863,318	6,771,440	10,211,036	11,296,031	10,141,848
Pseudo R^2	0.772	0.772	0.796	0.774	0.772	0.782
country-time FE	X	X	X	X	X	X
product-time FE	X	X	X	X	X	X
Destination	China	China	China	China	China	China

Source: Authors' estimation.

Notes: This table reports the estimation results using the PPML method for a subset of HS 10-digit level products that correspond to HS 6-digit level products containing at least one HS 10-digit level code mapped to export controls' list. Dependent variable is export value. Each column shows estimation for a set of HS10-digit level codes that was obtained from various approaches to the export controls-HS mapping. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors clustered by products reported in brackets.

We estimated equation (3) for this restricted dataset. The results are presented in Table 7. The effect of export controls on trade with China turns out to be positive and significant (columns 2, 4, 5, and 6), while the effect of China import tariffs becomes stronger in all specifications. We conclude that despite export controls and associated increases in fixed export costs, the US firms have a strong incentive to serve the Chinese market in order to exploit the profit opportunities. Therefore, they tolerate the increased costs and continue exporting. China's import tariffs, however, create a strong disincentive for U.S. firms to export the affected products due to increased variable cost of exporting.

4.3. Time Effects

Although the previous results suggest that export controls do not negatively affect U.S. exports to China, we suspected that there could have been changes in the effects over time. Therefore, we estimate the following model to obtain the time effects of the export controls to China.

$$Export_{ipt} = \exp\left\{\left(\sum_{k}\beta_k China_i \times Control_{pt} \times Quarter_k\right) + \beta_{k+1} China_i \times \ln\left(1 + Tariff_{pt}\right) + \theta_{it} + \gamma_{pt} + \delta_{ip}\right\} \cdot \epsilon_{ipt} \quad (4)$$

where $Quarter_k$ is a time effect dummy for quarters 2017Q2 to 2021Q4. In this estimation, we aggregate our data to the quarter level in order to reduce the computation burden. We sum year-month export values to obtain year-quarter totals. For export controls and tariffs, we aggregate to the quarter level by taking the maximum value from the corresponding year-months. The reference quarter is 2017Q1, which is before strengthening the US export control regulations. We investigate how the effect of export control regulations evolves over time compared with that in 2017Q1. In this estimation, furthermore, we include country-time, product-time, and country-product FE. Our control of country-product FE will reduce the risk of omitted-variable bias.

The results are presented in Table 8. Again, we document a positive and significant coefficient for a time trend in the period 2018Q3-2020Q1 in all specifications. The tariff effect remains negative but insignificant. These results support our previous finding that export controls do not seem to negatively affect the U.S. exports to China of the controlled products.

Table 8. Effect of the U.S. Export Controls and China Import Tariffs on the U.S. Export to China. Time effects.

	1(Manual)	2(Man+Ger+ML)	3(German)	4(Man+ML)	5(CCL index+ML)	6(CCL categ.+ML)
	(1)	(2)	(3)	(4)	(5)	(6)
China x Control x 2017Q2	0.134	0.131	0.051	0.088	0.046	0.013
	[0.098]	[0.097]	[0.079]	[0.088]	[0.076]	[0.082]
China x Control x 2017Q3	0.074	0.075	-0.018	0.066	-0.002	-0.049
	[0.066]	[0.066]	[0.071]	[0.076]	[0.073]	[0.073]
China x Control x 2017Q4	-0.092	-0.091	-0.161*	0.024	-0.097	-0.112
	[0.087]	[0.087]	[0.089]	[0.093]	[0.096]	[0.083]
China x Control x 2018Q1	-0.026	-0.029	-0.122	0.027	-0.047	-0.030
	[0.095]	[0.095]	[0.078]	[0.089]	[0.092]	[0.091]
China x Control x 2018Q2	0.270*	0.266*	0.126	0.285**	0.192	0.207*
	[0.149]	[0.148]	[0.122]	[0.127]	[0.131]	[0.123]
China x Control x 2018Q3	0.598***	0.592***	0.390***	0.552***	0.471***	0.463***
	[0.175]	[0.174]	[0.148]	[0.144]	[0.152]	[0.142]
China x Control x 2018Q4	0.754***	0.745***	0.526***	0.682***	0.625***	0.606***
	[0.240]	[0.238]	[0.199]	[0.192]	[0.198]	[0.189]
China x Control x 2019Q1	0.583***	0.578***	0.327**	0.483***	0.389**	0.614***
	[0.133]	[0.133]	[0.155]	[0.147]	[0.168]	[0.148]
China x Control x 2019Q2	0.512***	0.506***	0.364***	0.500***	0.425***	0.491***
	[0.102]	[0.103]	[0.125]	[0.122]	[0.141]	[0.122]
China x Control x 2019Q3	0.401***	0.395***	0.262***	0.412***	0.312***	0.398***
	[0.082]	[0.082]	[0.092]	[0.092]	[0.104]	[0.084]
China x Control x 2019Q4	0.498***	0.492***	0.250*	0.441***	0.352**	0.511***
	[0.167]	[0.166]	[0.149]	[0.140]	[0.137]	[0.126]
China x Control x 2020Q1	0.601***	0.593***	0.422***	0.610***	0.547***	0.543***
	[0.164]	[0.163]	[0.155]	[0.146]	[0.148]	[0.140]
China x Control x 2020Q2	0.229*	0.229*	0.116	0.313***	0.219	0.242**
	[0.137]	[0.137]	[0.123]	[0.117]	[0.134]	[0.121]
China x Control x 2020Q3	0.140	0.140	0.039	0.245**	0.154	0.231*
	[0.119]	[0.119]	[0.127]	[0.114]	[0.136]	[0.122]
China x Control x 2020Q4	-0.051	-0.053	-0.150	0.108	-0.045	0.024
	[0.145]	[0.144]	[0.142]	[0.130]	[0.142]	[0.130]
China x Control x 2021Q1	0.328**	0.324**	0.166	0.337**	0.231	0.401***
	[0.146]	[0.146]	[0.154]	[0.139]	[0.164]	[0.148]
China x Control x 2021Q2	0.343	0.340	0.220	0.457**	0.309	0.390**
	[0.229]	[0.228]	[0.211]	[0.191]	[0.205]	[0.186]
China x Control x 2021Q3	0.333	0.330	0.118	0.413**	0.227	0.379**
	[0.213]	[0.212]	[0.191]	[0.172]	[0.175]	[0.159]
China x Control x 2021Q4	0.197	0.193	-0.049	0.231	0.033	0.313*
	[0.182]	[0.181]	[0.159]	[0.148]	[0.151]	[0.167]
China x Tariff	-0.904	-0.907	-1.037	-1.055	-0.986	-0.982
	[0.641]	[0.641]	[0.655]	[0.659]	[0.652]	[0.650]
Observations	12,621,704	12,621,704	12,621,704	12,621,704	12,621,704	12,621,704
Pseudo R^2	0.965	0.965	0.965	0.965	0.965	0.965
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	X	X
Destination	China	China	China	China	China	China

Source: Authors' estimation.

Notes: This table reports the estimation results using the PPML method. Quarterly level analysis. Dependent variable is export value. Each column shows estimation for a set of HS10-digit level codes that was obtained from various approaches to the export controls-HS mapping. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors clustered by products reported in brackets.

4.4. Industry-level Analysis

As an additional exercise, we examine the effect of export controls by industries. We estimate equation (3) for the following industries: Chapter 05 Mineral Products, Chapter 06 Chemicals and Allied industries, Chapter 07 Plastics and Rubber, Chapter 13 Stone and Ceramic Products; Glassware, Chapter 15 Base Metals, and Articles Thereof, Chapter 16 Machinery; Electrical Equipment; Sound Recorders, Chapter 17 Vehicles; Aircraft; Vessels; Transport Equipment; Chapter 18 Optical, Medical, Musical Instr.; Clocks; Watches. The results for the case of set 4 (Manual+ML) are presented in Table 9.

Table 9. Effect of the U.S. Export Controls and China Import Tariffs on the U.S. Export to China. Industry level analysis.

	Mineral (1)	Chem. (2)	Plastic (3)	Stone (4)	Metals (5)	Machinery (6)	Transport (7)	Precision (8)
China x Controls	0.433	-0.004	0.113	0.449***	0.181	0.371**	-1.949***	0.506***
	[0.436]	[0.250]	[0.233]	[0.172]	[0.189]	[0.152]	[0.227]	[0.127]
China x Tariff	-6.547***	-1.217	1.893	-7.943***	-6.111***	-6.549***	-0.150	-2.978***
	[2.145]	[1.041]	[1.223]	[1.662]	[1.700]	[1.359]	[2.168]	[1.130]
Observations	632,827	4,141,942	1,799,614	919,339	3,748,439	10,890,647	1,444,441	2,242,289
Pseudo R^2	0.783	0.713	0.838	0.767	0.766	0.804	0.844	0.824
country-time FE	X	X	X	X	X	X	X	X
product-time FE	X	X	X	X	X	X	X	X
Destination	China	China	China	China	China	China	China	China

Source: Authors' estimation.

Notes: This table reports the estimation results using the PPML method. Industry level analysis. Dependent variable is export value. Set 4 (Manual+ML) of HS 10-digit level product codes is used for estimation. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. The standard errors clustered by products reported in brackets.

We observe the following. The effect of export controls on US exports to China tends to be negative and significant for the transport equipment industry only. The effect of China tariffs is insignificant. This industry seems to stand as an outlier. The effect of export controls for stone, machinery and precision industries is positive and significant. The effect of Chinese tariffs on US exports to China tends to be negative and significant for almost all industries except the chemicals, plastic, and transport equipment industry.

5. Concluding Remarks

The dynamics of trade disputes between the US and China have seen a considerable shift over the past few years, leading to the dispute of so-called technological decoupling. This study aimed to empirically investigate the implication of export control regulations on U.S.

exports for a period from January 2017 to December 2021, along with China imposing import tariffs.

To achieve our goals, we mapped the U.S. ECCN from CCL index and CCL categories to 10-digit HS codes using manual and machine learning procedures. We used the obtained sets of 10-digit HS codes for empirical analysis of export controls and tariffs effect of the U.S. exports to China.

We document a few important points. First, contrary to general perception, the export controls did not exhibit a broad negative impact on U.S. exports of controlled products to China. This finding challenges the conventional wisdom and suggests that the effects of export controls are more nuanced and may be specific to a small number of product categories that are exported. It implies that the U.S. government indeed adopted the "small yard high fence" strategy. Second, the transport equipment industry seems to be an outlier, with export controls having a negative effect. On the contrary, industries such as stone, machinery, and precision have seen a positive impact from these controls. Such industry-specific variations show that export controls exhibit heterogeneous impacts across sectors.

While this study provides important insights into the US-China technological decoupling process, the recent tightening of controls on advanced computer and semiconductor-related exports to China in late 2022, for instance, might have implications beyond the scope of this study and needs further investigation. In sum, while regulatory measures serve national security and strategic interests, their implications for trade and industry are complex. Our detailed product-level approach to the analysis brings important insights for policymakers and scholars who need a deeper understanding of the U.S.-China technological decoupling process.

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APPENDIX A: Structure of ECCN

The first character of the ECCN indicates to which of the following 10 Commerce Control List Categories it belongs:
0 = Nuclear materials, facilities and equipment (and miscellaneous items)
1 = Materials, Chemicals, Microorganisms and Toxins
2 = Materials Processing
3 = Electronics
4 = Computers
5 = Part 1 -- Telecommunications and Part 2 -- Information Security
6 = Sensors and Lasers
7 = Navigation and Avionics
8 = Marine
9 = Aerospace and Propulsion

The second character of the ECCN indicates to which of the following Five Product Groups it belongs:
A. End Items, Equipment, Accessories, Attachments, Parts, Components, and Systems
B. Test, Inspection and Production Equipment
C. Materials
D. Software
E. Technology