Export Costs of National (In)security*

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We examine the structure, rationale, and economic impacts of export controls and their growing use worldwide for national security reasons. U.S. export controls primarily target dual-use goods—technologies with both civilian and military applications—through licensing requirements and multilateral agreements such as the Wassenaar Arrangement. Recent policy changes, particularly in high-tech sectors like semiconductors and aerospace, have increased trade frictions, causing delays, higher costs, and regulatory uncertainty. About 44% of U.S. exports fall under some form of export control, though only a fraction require a formal license. We show that export controls, even those requiring minimal licensing, reduce exports and that the effects are mitigated for members of multilateral export control regimes (MECRs). We quantify the economic impact of unilateral versus multilateral control measures, assessing their effects on trade.

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1 Introduction

Export controls have long been central tools in international economic policy, typically motivated by national security concerns broadly defined to encompass military capabilities, strategic technologies, and geopolitical objectives. As far back as Hirschman (1945), economists have attempted to measure the trade offs and balance of power among allies and adversaries flowing through trade relationships.[1] Geopolitical tensions, particularly involving strategic competition with China and conflicts such as Russia's invasion of Ukraine, have increased the scope and use of export controls by the U.S. and other countries.

Export controls are often justified by the need to prevent sensitive goods and technologies from falling into adversarial hands, thereby safeguarding national and global security. However, export controls present economic trade-offs because the parts, components and final goods subject to controls for nuclear and chemical weapons, missile guidance systems, and information technology are "dual-use" goods that have both civilian and military applications. Although widely recognized in policy debates (Lord, 2002) and international relations scholarship (Grinberg, 2021; Miller, 2022; Farell and Newman, 2023) rigorous economic analysis of export controls is sparse, largely due to data limitations (Sundaram and Richardson, 2013), and with an emphasis on trade sanctions (Eaton and Enger, 1992; Itskhoki and Ribakova, 2024). We provide a theoretical and empirical foundation for evaluating whether "dual-use" export controls achieve their strategic aims by combining new data with empirical and quantitative analysis. Thus illuminating the scope, effectiveness, and the trade-offs of export controls and, more broadly, trade policies with national security objectives.

Recent events underscore the growing national security motives behind a variety of strategic trade policies and export controls. However, it is difficult to measure and evaluate the effects of many of these policies, and their national security trade-offs, due to the piecemeal approach of multiple policymakers and the conflating of economic and national security definitions that justify the restrictive measures.[2] For example, the Section 232 *import* tariffs on steel and aluminum implemented by the first and second Trump administrations were justified using the national security provisions of the Trade Expansion Act of 1962. The Biden administration largely maintained these policies for national security reasons and expanded the scope of export controls and protectionism under a "small yards, high fences" approach to restrict both imports and exports in strategic sectors (Sullivan, 2023).

While there may be genuine doubts about the national security rationale for some trade policies, export control regimes are both important to international economic policy cooperation and provide a useful context to study the trade-offs with national security issues. First, the topic is salient

[1] Hirschman was credited for developing the Herfindahl-Hirschman Index of concentration, which he used as a measure of interdependencies across countries in key sectors with military importance.

[2] A 2009 report by the OECD on "Security-Related Terms in International Investment Law and in National Security Strategies" has a 30 page appendix of examples of national security references in international agreements on trade and investment (OECD, 2009).

now because the U.S. and other countries have recently begun to more intensively employ export controls. However, these control regimes have been in place for many years and were formed in part to balance economic and security issues. Second, data are available that measure the degree of control imposed on different countries and products. We can theoretically model the potential effects of controls and quantify their impact when combined with data on export values or trade participation.

To expand on the first point, we note that the mission statement of the agency handling export controls for the U.S., the Bureau of Industry and Security (BIS) explicitly recognizes these tensions (bold italics added):

> "Advance U.S. ***national security, foreign policy, and economic objectives*** by ensuring an effective export control and ***treaty compliance*** system and promoting continued U.S. ***strategic technology leadership***."[3]

But compliance with export controls and the licensing regime is both costly and can be shaped by events outside the exporting firm's control. In Figure 1, we show that rejection rates and waiting times for licenses increase for Russia after the annexation of Crimea in 2014 and for China around the onset of the US-China trade war in 2018. In contrast, the same measures for Ukraine and Taiwan remain stable or even decrease. In an extensive 2007 survey of aerospace firms, described in detail in section 2, 58% of firms classified export controls as the single largest barrier to foreign market entry and estimated compliance costs were 1 to 8 percent of sales, conditional on receiving a license (AFRL & DOC, 2007). They reported lost sales from non-licensing of at least 15% of their exports. More recently, firms such as NVIDIA have had to design and produce special varieties of GPU chips only for the Chinese market to comply with controls.[4]

Our empirical analysis overcomes some of the difficulties in systematic measurement and impacts of trade policies driven by national security. We employ detailed data on export values by country and type of control obtained from the U.S. Bureau of Industry and Security (BIS). We then leverage comprehensive data we digitized from the U.S. Export Administration Regulations at the product control code level and on the U.S. treatment of different countries and thus their differential export control exposure, e.g. due to their membership in multilateral export control regimes (MECRs).

We use data and theory to address three central questions related to the breadth, effectiveness, and multilateral implications of export controls:

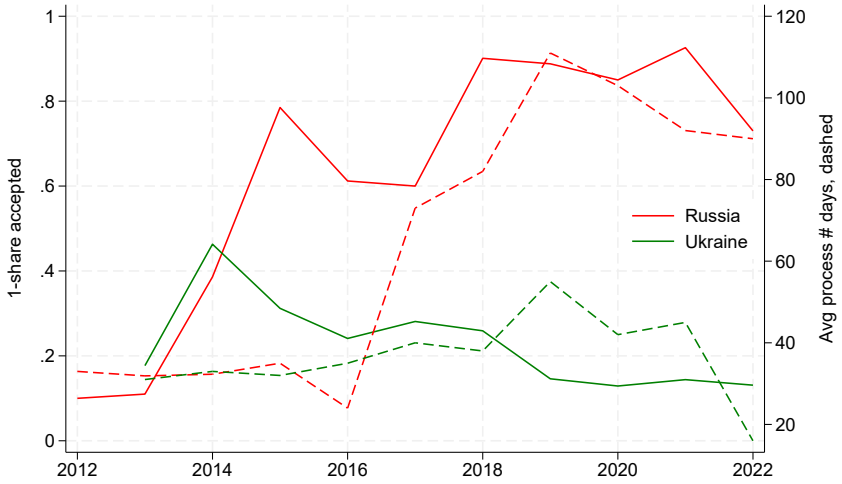
First, we ask how broad U.S. export controls are; both in terms of the range of products and targeted countries. Contrary to the perception that export controls target a narrow set of high-tech or strictly military goods, our findings reveal a significantly broader scope. Using detailed BIS data, we document that over 40% of U.S. exports in 2015 faced some form of export control. These

[3] BIS website https://www.bis.doc.gov/index.php/about-bis/mission-statement (accessed March 19, 2025)

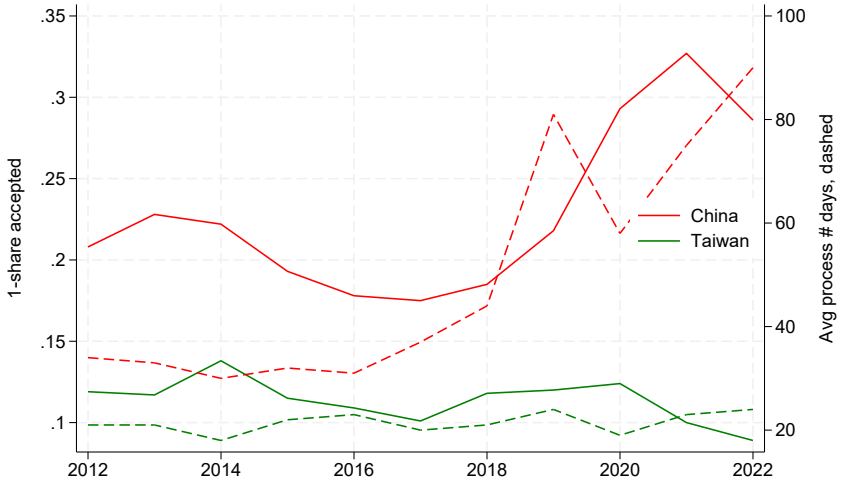
[4] See *Reuters*, "Nvidia preparing version of new flagship AI chip for Chinese market, sources say," July 22, 2024. https://www.reuters.com/technology/nvidia-preparing-version-new-flaghip-ai-chip-chinese-market-sources-say-2024-07-22/.(accessed March 19, 2025).

Figure 1: Divergence in US Export License Outcomes for Allies and Adversaries

(a) Russia vs. Ukraine



(a) China vs. Taiwan



Notes: Left-axis is the rejection rate for license applications represented by solid lines for each country. Right-axis is the average processing time in days for a license application represented by a dashed line. Authors' calculations on digitized, annual BIS country reports.

controls cover not only strategic geopolitical adversaries, such as China and Russia, but also allies. For example, over 60% of exports to France are covered by some form of export control and 35% under the most stringent controls.[5]

[5]The breadth of country targets and systematic list of controlled products is not novel. U.S. export control policy dates back to the 1917 Trading with the Enemy Act. Its modern structure was formalized in the Export Control Act

Second, we address a central and first order question: do export controls significantly restrict exports to targeted countries? While previous literature primarily offers evidence from sanctions targeting specific sectors such as arms, oil, and financial assets (Besedeš, Goldbach, and Volker, 2021;2024) our analysis highlights the broader implications for dual-use products, which are in many cases also dual-inputs; as such they are key components of global value chains (GVCs). Employing novel detailed data and a gravity model, we find a substantial reduction of U.S. exports of controlled products to countries subject to higher scrutiny. Importantly, this reduction is not limited to the specific dual-use goods described in detail on the Commerce Classification List (CCL). Even exports under a miscellaneous catch-all code for goods the U.S. government seeks to monitors and potentially control in some cases have relatively lower exports.

Third, we investigate the role and impact of multilateral agreements that address national security externalities using trade policy. Modern multilateral export control regimes (MECRs) date back to the Coordinating Committee on Multilateral Export Controls (COCOM) established in 1949. Its successor, the Wassenaar Arrangement, and other regimes described in section 2 aim to coordinate export policies and mitigate adverse trade impacts among allied member countries. Our empirical analysis provides novel empirical evidence that MECR membership significantly moderates the trade-reducing effects of export controls. This underscores the importance of multilateral coordination not only for strategic effectiveness, but also in reducing the economic distortions inherent in unilateral export restrictions.
In section 2 we start with the relevant historical background on export control regimes and estimates of their trade implications. We expand a standard dataset on bilateral country aggregate exports from 1965-2010 to include membership in MECRs and estimate their impact is very similar to those of PTAs: both increase trade between members relative to non-members by a similar amount. We then report specific pieces of evidence that link the cost of U.S. controls on its exporters to high costs of compliance with licensing rules, as well as delays and rejections. These facts and characteristics of the system inform our theoretical modeling and empirical approach.

In section 3 we examine the effects of the U.S. regime at a granular level. We use data on U.S. export values in 2015 by country, product, and type of export license applicable to dual-use. We combine this data with information on the nature of the controlled products (computers, electronics, chemicals, etc.) and country-level membership in MECRs or placement on U.S. lists that group countries into higher degrees of licensing scrutiny: case-by-case (B list) or presumed denial (D list). We first extract basic facts on the country and sector coverage of different controls.

Our empirical approach is a difference-in-difference gravity model. This allows us to estimate the effect on exports of MECR members relative to non-members in controlled exports. The difference in exports of controlled vs non-controlled products within each country removes any country specific effect. The difference in exports of controlled products in MECR members relative to the non-members, removes any control-specific effect. In aggregated non-parametric tests and

of 1949, which applied even outside explicit wartime scenarios. Understanding the evolution and expansion of the regime across products and over time is important to assessing their contemporary impact.

using fixed effects OLS, we find there is a positive effect on trade in MECR members. Even for exports subject to the least stringent control, known as EAR99 and subject to limited to no licensing requirements, the effect is about 47 log points relative to non-members in our baseline. Exports of products subject to the more stringent Commerce Control List that receive an Export Control Classification Number (ECCN) are almost twice as high, 94 log points, in members relative to non-members.

The effects are positive but heterogeneous across different product technology categories. The largest effects are in higher technology sectors such as computers, electronics, aerospace and sensors, whereas they are lowest for materials processing, chemicals, and nuclear materials. This heterogeneity and the different sector composition of exports imply that two countries can face differential trade weighted aggregate restrictions, even if both are in the same restriction list. We use this to compute the partial equilibrium export increase if a country joined a MECR. For countries such as Ethiopia, with a very high share of controlled exports, the effect is over 100 log points. For countries such as China and Vietnam the effect on U.S. exports is 30-40 log points.

To assess the trade-off associated with dual-use controls and the value of MECRs, we build and quantify a general equilibrium trade model. We add two novel ingredients to a multi-sector model with input-output linkages (Caliendo and Parro, 2015). First, within each sector, there are two types of production technologies, dual-use and civilian. Goods produced with dual-use technology use upstream dual-use goods more intensively than upstream civilian goods; conversely, goods produced with civilian technology are relatively more intensive in upstream civilian goods. This feature allows the model to speak to the asymmetric impacts of controls on critical inputs on civilian and dual-use downstream industries. Second, we incorporate export control restrictions that generate an implicit export tax on dual-use goods. The restrictions can differ by sector and destination, but not by whether the downstream user has a civilian or dual-use technology, capturing the difficulty in enforcing exports controls based on how the importer uses the good.

Crucial to quantification of the model are two inputs. The first is the standard global trade and input-output linkages data, which we construct from the World Input-Ouput Datbase (WIOD). The second is information on the intensity at which dual-use/civilian technologies use upstream dual-use/civilian goods. We construct this share using granular U.S. BEA make-use table, together with a novel classification of 6-digit NAICS industries into civilian versus dual-use based on descriptions of ECCN categories.

Motivated by recent events, our initial quantitative exploration considers the following scenario: what would happen to U.S. exports if the U.S. withdraws from MECRs and places the same restrictions it now has on non-MECR countries. We discipline the size of these implicit taxes using our empirical estimate in section 3, allowing them to be heterogeneous across sectors. We also do a similar exercise where we allow the MECR countries to retaliate and impose similar restrictions on the U.S.

These counterfactuals have major trade impacts. The unilateral U.S. increase in restriction on

MECR partners reduces its total exports to those countries by 6%, and even more, 33%, in dual-use goods. Linkages and general equilibrium play a role: they not only amplify the export effects but also lead to a modest decrease in imports from other agreement countries. In the second counterfactual where we also allow other MECR countries to 'retaliate' then their exports to the U.S. also decrease substantially; moreover, this leads to a decrease in U.S. industry competitiveness, which further pushes down the U.S. exports. The withdrawal of the U.S. from the MECRs leads to a 8.63% decrease in exports a 9.23% decrease in imports to other agreement countries.

In sum, we find U.S. export controls have large effects on international trade patterns and through global supply chains. In an era with more intense strategic competition where trade policy increasingly intersects with government national security objectives, understanding the design and consequences of export controls is important. Our analysis reveals there are economic costs to export controls and licensing regimes, but they can be mitigated by MECRs that facilitate cooperation and coordination among allies. More broadly, we provide a framework for evaluating how countries can balance trade and security goals in an era of rising of geopolitical conflict and uncertainty.

The rest of the paper is organized as follows. In section 2 we provide background on the global and U.S. export regimes and novel estimates of the aggregate trade effect of MECRs. In section 3 we describe our data and reduced form estimates. Section 4 develops a quantitative, general equilibrium model of supply chain linkages and export controls. We use the model to quantify unilateral or multilateral changes to the U.S. regime in Section 5.

2 Export Control Regimes: Background and Trade Implications

In this section, we provide a broad overview of export control regimes (ECRs), including their goals, recent evolution and policy tools. We also offer novel evidence of the trade effects of multilateral export control arrangements (MECRs) using a standard gravity approach. We then focus on a specific country that has been an active participant in MECRs and plays a dominant role in innovation and production of dual-use inputs, the United States. We lay out the guiding principles, processes, and specific examples of its potential economic costs.

2.1 Definitions and Examples

Export control regimes are the body of laws and regulations that governments—unilaterally or multilaterally—establish with the goal of preventing "sensitive" goods and technologies from reaching specific foreign entities.

The essential component of ECRs is a set of *export licensing requirements*. These require firms to undergo an approval process that ensures their export product-buyer transaction is permitted under the ECR, as we describe in more detail in the context of the US ECR below. Non-compliance results in steep fines and in the US potentially exclusion from any exporting activity.

ECRs focus on a broad range of goods and technologies that is evolving and uncertain. The potentially *export controlled products* fall under two broad categories: military and dual-use. Examples of controlled military exports include missiles, guns, etc., and possibly maintenance services and technological specifications. *Dual-use products*–are those with a potential for civilian and military application, and are thus harder to define and not globally harmonized. The closest to a broadly accepted definition and product list comes from a MECR and is used by its 42 members. The Wassenar Agreement (WA) defines dual-use products as those that, "*are major or key elements for the indigenous development, production, use or enhancement of military capabilities.*"[6] The nine broad categories in its list range from fairly specific: e.g. lasers and sensors, to vague, e.g. materials processing. Examples include both old technologies and the latest, such as biotechnology that can be used for cancer treatment or weaponized.[7]

2.2 Multilateral Export Control Regimes (MECRs)

MCERs represent voluntary arrangements among states to regulate exports of dual-use and military-sensitive technologies. Some arrangements are informal, confidential discussions between countries, and others are formal agreements with commitments and requirements for participating governments. We describe the five principal MCERs related to dual-use technology and weapons-related trade and estimate their bilateral trade impact.

The Coordinating Committee for Multilateral Export Controls (COCOM)

Following World War II, the United States and its European allies agreed to coordinate trade restrictions towards the Soviet Union and its allies. They created COCOM, which began operating in 1950 and included the US, and six European countries,[8] growing to 17 members across 4 continents. COCOM became obsolete after the fall of the USSR and its members agreed to terminate it in November 1993, and establish a new MECR.[9]

The negotiations between COCOM members were informal and private, creating a sense of secrecy. However, the Committee's operations were clear: the development of lists of products subject to export controls, their implementation and enforcement, as well as exceptions. Each country had veto power on the other members' exports of sensitive controlled products to target countries. These COCOM operations should increase exports between its members, and reduce their exports to the restricted countries. We estimate if those restrictions played a significant role in overall trade patterns of COCOM members, which could arise if they affected a broad set of goods or a limited set but still generated uncertainty about broader trade restrictions.

[6] "Criteria for the Selection of Dual-Use Items," 1.
[7] The complete lists are available at https://www.wassenaar.org/control-lists/
[8] *Technology and East-West Trade*, 153.
[9] https://www.govinfo.gov/content/pkg/GPO-CRPT-105hrpt851/html/ch9bod.html#anchor5563742

Wassenaar Arrangement

In 1994 COCOM ceased to operate and the 23 former members and cooperating states established working groups to develop the Wassenaar Arrangement (WA). They were joined by the Russian Federation, other Eastern European countries, Argentina and South Korea, for a total of 33 founding members when WA was established in November 1996. Another nine countries joined between 2004 and 2018 and the arrangement accepts new members on a non-discriminatory basis upon fulfillment of specific criteria.

The WA aims to promote global stability and cooperation by

1. establishing two control lists—one for dual-use products and one for military goods,
2. creating information exchanges regarding the trade of items on the two control lists,
3. conducting outreach practices to non-member states to, "encourage broad adoption of the Arrangement's standards and promote effective national export control systems in line with non-proliferation norms."

The annual plenary sessions, which are the WA principal decision-making mechanism, revise the dual-use and munition lists. The arrangement does not harmonize but it does coordinate the control lists of the members, including the US, so we provide details below in that context.

Unlike COCOM, the WA explicitly states that it "is not targeted at any region or group of states, but rather at 'states of concern' to members" , moreover its "members also lack veto authority over other member's proposed exports, a power that COCOM members exercised."[10] Nonetheless, WA members must report any licenses they deny to non-members, so others may do the same if they decide. Therefore we expect WA to increase exports between members *relative* to non-members.

Other MCERs

Three other *MECRs* are narrower in scope than the WA and concerned with Weapons of Mass Destruction. First, the Australia Group, which was formed in 1985 is, "an informal arrangement that aims to minimize the risk of assisting chemical and biological weapons (CBW) proliferation through the harmonization of export control measures,"[11] among its participants. In their annual meeting, the participants discuss the effectiveness of their export controls on a non-binding, voluntary basis. Its control lists and guidelines for export control policy address, "certain chemicals, pathogens, toxins, dual-use chemical and biological facilities and equipment, and related technologies,"[12] to ensure these products, when exported, are used for civilian applications. This group was founded by 17 countries and the European Union, and has slowly expanded to 42.

[10] https://www.wassenaar.org/genesis-of-the-wassenaar-arrangement/
[11] "Australia Group Common Control List Handbook Volume I," 7.
[12] "Australia Group Common Control List Handbook Volume I," 8.

Second, the Missile Technology Control Regime focuses on export controls of inputs to weapons of mass destruction and missile technology. It currently has 35 participants[13] and operates as a, "voluntary association of countries which share the goals of non-proliferation of systems capable of delivering weapons of mass destruction (other than manned aircraft), and which seek to coordinate national export licensing efforts aimed at preventing their proliferation."[14]

Third, the Nuclear Suppliers Group includes 48 governments and meets on a regular basis to discuss the trade of inputs to nuclear technology and related export controls to support the goal non-proliferation.[15] It brings together potential nuclear suppliers of reactor equipment, fuel for civilian reactors, and nuclear material. The group maintains two sets of guidelines that serve as, "conditions of supply that are applied to nuclear transfers for peaceful purposes to help ensure that such transfers will not be diverted to unsafeguarded nuclear fuel cycle or nuclear explosive activities."[16] The guidelines are not legally binding, but the members commit to apply them through national legislation.[17] Under these guidelines, exports and transfers are only permitted "when the exporting country has been satisfied that the transfer would not contribute to the proliferation of nuclear weapons."[18]

2.3 Aggregate trade impacts of MECRs

Data and approach

Despite the importance and potentially broad impacts of MECRs that focus on dual-use, WA, COCOM and AUS, we have not found any estimates of their trade effects, thus we provide them here. We employ a standard structural gravity approach on a panel dataset that extends Limão (2016) to reflect the evolving membership of MECRs. This involves estimating the following equation.

$$ln\ T_{xmt} \ = \ \widehat{\delta} MECR_{xmt} \ + \widehat{\beta} WTO_{xmt} \ + \ \widehat{\gamma} PTA_{xmt} \ + \alpha_{xt} + \alpha_{mt} + \alpha_{xm} \ + \ \varepsilon_{xmt}$$

where T represents the log of bilateral trade flows, PTA is a joint membership dummy for various preferential trade agreements, similarly for WTO. Consistent with Limão (2016), we control for bilateral as well as time effects by importer and exporter. So the identification of MECRs relies on accessions, which is exactly the same approach used in the extensive literature on the WTO and PTAs. The data contains bilateral export flows between country pairs from 1965 to 2010 at 5-year

[13] "Missile Technology Control Regime Annex Handbook," 2.
[14] "Missile Technology Control Regime Annex Handbook," 2.
[15] The NSG emerged out of a set of meetings between 1975 and 1978 following a nuclear explosion in 1974 located in India, which was deemed a non-nuclear-weapon state at the time of the explosion.
[16] "The Nuclear Suppliers Group: Its Guidelines, Origins, Structure, and Role," 3.
[17] The first set of guidelines concerns items designed specifically for nuclear use, whereas the second set of guidelines govern, "the export of nuclear-related dual-use items and technologies." "The Nuclear Suppliers Group: Its Guidelines, Origins, Structure, and Role," 1.
[18] "The Nuclear Suppliers Group: Its Guidelines, Origins, Structure, and Role," 2.

intervals.

The results are summarized in Table 1. Column 1 replicates Limão (2016) for PTAs and WTO and column 2 adds the effect of the broadest MECR, the Wassenaar Agreement. We find a positive and significant effect, with a magnitude of 0.33, which is very similar to the PTA effect. The coefficient implies that when both the exporter and importer become members of this export control regime, trade flows between them increase by 33 log points. The results are unchanged if we also include COCOM, which has an insignificant effect.[19]

There is significant membership overlap between WA and nonproliferation and security agreements, so we examine if these have independent impacts.[20] In column 4 we find that NATO membership is associated with an almost 50 lp increase in bilateral trade. The independent effect from WA is now lower, 24 lp. In column 6 we add AUS, which has an impact of 24 lp and find that WA has a smaller independent effect, which is now about 10 lp, and NATO's effect is also smaller, 43 log points.

Given the overlap in membership we examine the interactions between the agreements to estimate the incremental effect of an export control agreement in the presence of others. In column 7 we find that in the absence of other agreements WA has a small positive effect as do the interactions. Each of the coefficients is individually statistically insignificant. The overall impact of WA conditional on membership in other agreements is 12 lp. We also calculate that, for non-NATO countries, the accession to either WA or AUS is associated with a 32 lp increase in trade, which is almost the same impact as entering a PTA in the same specification.

The effects of dual-use MECRs, WA and AUS, are comparable to those of PTAs in increasing exports between members relative to non-members. These agreements thus warrant similar attention to PTAs, which have been examined extensively using this identification approach. These aggregate estimates may be sensitive given that WA is only active in the last three periods, the correlation with NATO membership and type of exports[21]. Moreover, they do not pin down specific mechanisms. For this we turn to a detailed analysis of one of the members of WA—the US.

[19] This is identified by the only two accessions after 1950, Spain in 1985 and Australia in 1990. We may obtain a better estimate if we account for the narrower scope of restricted countries, which one could test by collecting yearly target data.

[20] By the end of our 2010 sample both AUS and WA have 40 members with 38 in common (SA not in AUS and Iceland not in WA). Only 4 of those 38 entered WA before AUS (Bulgaria, Croatia, Turkey and Ukraine). NATO membership is 27 by 2010, with 25 in common with WA; 6 entered WA before NATO (but only 3 far enough apart to have different status in our 5-year data) and 19 after or in same year (15 with different status in a given year in our data). So there is potentially more identifying variation from switchers across WA with respect to NATO then with AUS.

[21] A 2007 BIS survey (DOC 2007) of aerospace firms found that US allies accounted for 73% of US aerospace firm exports and 80% of their imported inputs.

Table 1: Bilateral trade effects of MECRs 1965-2010

	1	2	3	4	5	6	7
WTO	0.0860	0.106	0.107	0.0990	0.102	0.105	0.105
	(0.0491)	(0.0492)	(0.0492)	(0.0492)	(0.0492)	(0.0492)	(0.0492)
PTA	0.369	0.354	0.354	0.344	0.345	0.338	0.339
	(0.0308)	(0.0305)	(0.0305)	(0.0304)	(0.0304)	(0.0304)	(0.0305)
WA		0.335	0.327	0.243	0.215	0.0926	0.0395
		(0.0466)	(0.0483)	(0.0474)	(0.0494)	(0.0461)	(0.0989)
COCOM			-0.0460		-0.149		
			(0.0726)		(0.0734)		
NATO				0.492	0.519	0.430	0.456
				(0.0721)	(0.0728)	(0.0747)	(0.101)
AUS						0.239	0.247
						(0.0450)	(0.0513)
c.WA#c.AUS							0.0281
							(0.0732)
c.WA#c.NATO							0.0542
							(0.105)
c.NATO#c.AUS							-0.0637
							(0.0797)
Observations	158,713	158,713	158,713	158,713	158,713	158,713	158,713
R-squared	0.815	0.815	0.815	0.815	0.815	0.815	0.815

Robust standard errors in parentheses. All specifications include importer-year, exporter-year and importer-exporter fixed effects. The triple interaction WA#AUS#NATO is collinear and thus dropped.

2.4 US ECR

The US regime is central to understanding the impact of export controls more broadly, both because it shaped agreements such as COCOM and WA, and because it restricts exports of some of the most advanced technologies. We briefly describe its evolution and relationship to MECRs. Our focus is on the goals of the US ECR, its instruments and potential economic impacts via dual-use products in the last decade. This institutional detail is relevant for the empirical analysis.

The evolution of the current US regime can be divided into three periods. First, 1949-1994, the COCOM era; which the US largely led. Second, 1994-2018, the post-cold war era marked by relative liberalization in the context of WA, and regulatory reform in the US. Third, 2018 to the present is, so far, the technology competition era , which expanded restrictions on emerging technologies; and lead to restrictions on advanced semiconductors and AI hardware to China.

The Export Control Act of 1949 laid the foundation for modern US export controls that apply even in the absence of wars; and these regulations were formalized under COCOM. The 1949 Act was repeatedly renewed until, in 1969, it was replaced by a more liberal regime, the Export Authorization Act (EEA). The latter was updated by the more comprehensive 1979 EEA that addressed dual-use goods, and is the basis for the current EAR, administered by Bureau of Industry and Security (BIS) in the Department of Commerce. The 1979 EEA lapsed twice in the 1990's

and between 2000-2018—during these periods the regulations remained in force by invoking the International Emergency Economic Powers Act of 1977.[22]

The current legal framework is the Export Control Reform Act (ECRA) of 2018. Among other things, it granted the President expanded authority to regulate emerging and foundational technologies. Furthermore, it attempted to improve coordination and efficiency across departments with important responsibilities in administering the three primary export control regulations, namely,

1. The Export Administration Regulations (EAR, 15 CFR chapter VII, subchapter C, which are administered by the department of Commerce via the Bureau of Industry and Security (BIS).

2. The International Traffic in Arms Regulations (ITAR) []22 CFR 120-130, under the State Department's Directorate of Defense Trade Controls.

3. The Foreign Assets Control Regulations (FACR, 31 CFR 500-598), under the Treasury Department.

The 2018 reform was a response to long-standing concerns with the US ECR. In 2002, the Government Accounting Office found that the US ECR is, *"unclear and inconsistent leading to uncertainty among U.S. industry officials about the rationale for U.S. government licensing decisions,"*[23] and recommended that the federal government work to, *"reevaluate, clarify, and document export policy on semiconductor manufacturing equipment and materials."*[24] In 2009 the Obama administration launched an extensive review, which culminated in the 2018 reform. The role of BIS was reinforced as it gained control over thousands of military products now reclassified as dual-use.

2.5 BIS guiding principles

We focus on dual-use exports, which are regulated by the EAR.[25] The stated guiding principles of the BIS that administers the EAR are important in understanding our subsequent modeling choices. So we summarize the key parts here[26]

1. "The Bureau's paramount concern is the security of the United States (...) which includes its national security, economic security, cyber security, and homeland security.

2. Protecting U.S. security includes not only supporting U.S. national defense, but also ensuring the health of the U.S. economy and the competitiveness of U.S. industry.

[22] For additional details see Casey and Kerr (2021), which this section draws on.
[23] Lord, "GAO-02-620," 2.
[24] Lord, 29.
[25] ITAR regulates military technology, FACR regulates sanctions on individuals and countries, which can include export controls.
[26] https://www.bis.gov/guiding-principles

(...) The Bureau must take great care to ensure that its regulations do not impose unreasonable restrictions on legitimate international commercial activity that is necessary for the health of U.S. industry

3. The Bureau's rules, policies, and decisions should be stated clearly, applied consistently, and followed faithfully.
   (...) Uncertainty, and the delay it engenders, constitute a needless transaction cost on U.S. companies and citizens, hampering their ability to compete effectively

4. International cooperation is critical to the Bureau's activities.
   (...) With regard to export control laws in particular, effective enforcement is greatly enhanced by both international cooperation and an effort to harmonize the substance of U.S. laws with those of our principal trading partners."

Our model will capture the potential trade-off between national security and economic costs in (1) and (2). We will consider specific costs reflected in (3) including licensing delays and rejections. The model and estimation will capture the multilateral cooperation in (4).

2.6 BIS activity and licensing process

The main instrument used by the BIS to implement the EAR is the Commerce Control List (CCL). The CCL, described in 15 C.F.R. part 774, is divided into nine categories, including, for example, electronics, aerospace, information security, and sensors. Each item is assigned an Export Control Classification Number (ECCN), which determines the export restriction based on technical characteristics, end-user, and intended use. BIS jurisdiction extends beyond explicitly listed items, meaning even unlisted goods may require licenses or face export denials depending on their potential risks. The CCL is continuously updated based on executive decisions and discussions within MECRs.

Export restrictions rely on a licensing process. BIS requires licenses for certain transactions and reviews applications on a case-by-case basis. Licensing decisions must be made within 30 days of receiving a completed application, and if denied, then an appeal process is available. The process with an appeal can take up to 90 days; after this period a decision must be reached or appealed to the US president (with no deadline). Using BIS report data we find the average times across all countries is below 30, but the maximum is higher, e.g. it was 90 days for China in 2022.[27]

The restrictions for any ECCN product also vary depending on the end-user. We explore the ECCN-country variation that arises from the country lists (Supplement No. 1 to Part 740 of the EAR). In any given year the US classifies countries in roughly increasing order of restrictive controls

[27] https://www.bis.doc.gov/index.php/country-papers/3420-2022-statistical-analysis-of-us-trade-with-china/file

into the A-list—mainly members of MECRs, the B–list——those countries more restricted than A but not facing the presumed denial of the countries in the D-list, nor the embargo-like restrictions of the E-list countries. We provide additional details on these in the data section.

In addition to these the BIS maintains various lists of parties of concern, "including businesses, research institutions, government and private organizations, individuals, and other types of legal persons."[28] These entities face supplemental licensing and export denials regardless of the destination country list status, they are also regularly updated by the BIS. [29]

2.7 Firms costs and benefits of complying with the US EARs

Benefits of compliance

The main incentive for a firm to comply with EARs is to avoid steep costs, both legal and reputational, associated with violations. According to BIS these costs may include
"civil penalties, denial of export privileges, and placement of individuals and entities on lists that restrict or prohibit their involvement in export and reexport transactions. Under ECRA, criminal penalties can reach 20 years imprisonment and $1 million per violation. Administrative monetary penalties can reach $364,992 per violation (...) or twice the value of the transaction, whichever is greater."[30]

BIS emphasizes its enforcement efforts and publishes the outcomes of disputes, which creates reputational risk for those involved. In 2024 the BIS reported "the highest number ever of convictions, months of imprisonment, temporary denial orders, and post-conviction denial orders, as well as the largest standalone administrative penalty in BIS history."[31] This was a 300 million settlement with Seagate due to its shipments of hard drives to Huawei. Once an individual or firm is named in an investigation or found guilty the risk of transacting with them is higher, so the reputational costs can go beyond any fines or temporary loss of export privileges. Moreover, the liability extends to agents all along the transaction chain, so the cost of non-compliance on a particular shipment can have large costs if an agent loses the ability to export *any* controlled product.

Costs of compliance, delays and rejections

In order to avoid these costs, firms incur substantial and ongoing compliance costs. The application process requires that the firm determine if the product in any given transaction is subject to EAR via a complicated decision tree (see the Appendix). That determination is not obvious for several reasons, including changing country and product lists. Moreover, the ECCN descriptions bear no

[28] BIS *Entity List* 2024

[29] Our current data does not include the identity of the end-user or the reasons for denial, so we are unable to use entity information.

[30] https://www.bis.gov/media/documents/dlthty-nov-2024-1-7-25

[31] https://www.bis.gov/media/documents/dlthty-nov-2024-1-7-25

relationship to Harmonized Standard codes. So firms must invest in internal or external compliance services. If they apply for a license, they must then wait and possibly be denied. The license is valid for up to two years for the particular product, end-user and amount requested. After licensing there may be audits at the destination to verify the end-user and use.

The guiding principles of BIS, particularly (2) and (3) listed above are a response to U.S. firm and industries complaints that the ECR imposes significant costs, There is little direct and systematic evidence for the magnitude and source of those costs. But in 2007 BIS conducted an in-depth study for the Aerospace industry (AFRL & DOC, 2007). It surveyed over 200 firms and found:

1. 58% of firms classified US export controls as the single largest barrier to entry in foreign markets.
2. Compliance costs ranged from 1 to 8% of firms' foreign sales under licensing and was mainly driven by salaries and outside legal expenses.
3. Firms lost at least export value in 2016 was equal to 16% of their actual licensed exports, which was caused by decision delays, rejections, and restrictive conditions on licenses obtained.[32]

The costs above are a lower bound since they only take into account sales for which licenses were requested but sales did not materialize. So it does not account for reduced demand due to higher costs and avoidance of US suppliers due to regulatory uncertainty.

Our analysis will provide a broader measure of lost sales for a variety of sectors. Moreover, our quantification will account for input-output linkages that propagate the effects of export restrictions on dual-use inputs within the US and export markets. We will also be able to examine the role of substitution across countries on the effectiveness of unilateral restrictions and the value of coordinating them multilaterally with MECR partners.

3 Trade Effects of U.S. Export Controls

3.1 Aggregate effects of export controls

3.1.1 Data

We obtained data from the the BIS only for the year 2015. After excluding countries subject to embargo (Iran and North Korea), we have data on 194 countries. It excludes Canada because U.S. export data to that country is compiled from Canadian imports, which do not include details about export restrictions. We augmented this data on controlled exports with U.S. Census aggregate exports to obtain the value of exports not subject to any export controls or licensing as a residual.

[32] In 2006, most of these products were subject to the ITAR regime that was more restrictive. But since 2014 many were moved to CCL and will be reflected in our data.

Table 2: Exports by License & Control Group

	Exports($bil)	Share
No Controls	698.37	56%
EAR99	355.59	29%
CCL		
NLR	156.49	13%
Lic. Exc.	20.87	2%
BIS Licensed	4.58	0.3%
Lic. Exc. Other	1.40	0.00%
Total (ex_CAN)	**1237.30**	

Notes: 2015 export data obtained from BIS.

The standard set of gravity controls are from the USITC Dynamic Gravity Dataset and include distance, GDP, PTA and WTO membership. Where GDP was missing (e.g. Taiwan), we filled it with alternative sources such as the IMF World Economic Outlook tables.

A large share of US exports must go through the licensing process, even if a small value is actually licensed. In 2015, the set of countries included in the BIS data, which excludes Canada, represented 82% of total US exports. From those, 56% had no controls, and 44% had some, as listed in Table 2. Within the controlled export sample, 66% is under EAR99, 29% are listed on the CCL with a specific ECCN, the largest share of these requires no license (NLR), followed by license exceptions. The smallest CCL category is BIS licensed.

There is considerable variation in these shares across countries. In 2015, the average share of U.S. exports by country listed on the CCL is 11% with the highest share to Ethiopia (85%) and the lowest for Benin (0.1%). But among the top 15 US export destinations that account for two-thirds of all US exports (excluding Canada), the lowest share is only 7.5% for Mexico and the highest is 35% for France. China (21%), the Netherlands (16%) and Australia (11%), among others, lie in between.

There is also high variation across product categories in the amount of exports that are listed in the CCL. Table 3 shows the amount of exports in billions for each of the broad BIS product categories. The highest by value are aerospace and propulsion, followed by telecommunications, electronics, and computers. Categories with more obvious security externalities, such as nuclear materials and equipment, account for a small share of the trade. Whereas the CCL listed "Dual use" items such as chemicals and microorganisms, totaling $3 billion, can be used to make pharmaceuticals or industrial solvents, as well as chemical and biological weapons.

The degree of export control is reflected in the ECCN number, country characteristics, and also their interaction. The lowest level of export control at the ECCN level reported in the data is EAR99. These are described by BIS as lower technology goods without significant military or strategic value and thus require no license.[33]

[33]There are exceptions to NLR for a product otherwise classified as EAR99; namely if the buyer is an embargoed

Table 3: 2015 Total Exports (bils) by Technology Category and License Type

Product Tech Category	BIS Licensed	Lic. Exception	NLR
Aerospace & Propulsion	2.51	1.66	99.07
Security	0.13	16.52	20.66
Electronics	0.72	2.13	14.84
Computers	0	0.02	11.79
Materials, Chemicals, Microorganisms, and Toxins	0.36	0.06	2.74
Navigation & Avionics	0.19	0.14	2.62
Materials Processing	0.25	0.05	2.53
Lasers and Sensors	0.08	0.18	1.02
Marine	0.04	0.02	1.02
Nuclear Materials, Equip. & Misc	0.3	0.1	0.2
Total	4.58	20.87	156.49

Notes: 2015 billions of USD, from BIS.

In the EAR, each export destination appears on one or more sets of country group lists, which we designate as EAR-x, where x=A, B, or D.[34] List EAR-A is subdivided into A1-A6 where A1-A4 include the MECR agreements, A5 is a list of countries in multiple agreements, and A6 is a list of countries with a strategic trade authorization (STA). Country groups in EAR-D1-D5 cover specific security concerns (e.g. national security, missile technology, arms embargoes, etc.) where an export license is much more likely to be denied. List EAR-B is not subdivided and licensing is determined on the case-by-case basis that is more strict than the EAR-A list countries but less than the EAR-D list (i.e., more license exceptions are available for EAR-B vs. EAR-D destinations).

We classify countries from the EAR-x lists into mutually exclusive groups. We define our A list group as members of an MECR that are not on EAR-D. Our A6 are the STA countries not part of an MECR and not on EAR-D. Group B is the subset on EAR-B that do not appear on any EAR-A or EAR-D list. Group D is the same as those on any EAR-D (e.g. China, Russia, Taiwan). Table 4 shows the aggregate trade by control type: CCL, EAR99 and None, for each mutually exclusive group. Aggregate trade for each group increases from left to right, as the strictness of the controls decreases. Similarly, within any column there are more exports to A list countries relative D list countries, but B list countries occupy a gray area. It's notable that U.S. still exports $50 billion of items on the CCL to D list countries, highlighting again the dual-use nature of the controls and that exports are allowed in many products.

country, an entity of concern, or the use of the product is prohibited, in which case a license is required. In our data they account for less than 0.08% of the value. https://www.bis.doc.gov/index.php/documents/pdfs/286-licensing-faq/file

[34] There is also an E list for countries that are state sponsors of terrorism or embargoed. These include Iran and North Korea in our data, which we drop from the analysis sample.

Table 4: Export Value and Share by Country Control Lists

	Control Type (value and share)		
Country Groups	**CCL**	**EAR99**	**None**
A List (1 or more MECR agreements)	100.14 0.13	217.95 0.28	449.36 0.59
A6 List (strategic trade authorization)	13.70 0.21	20.10 0.31	31.86 0.49
B Group List (no agreements, case-by-case	18.34 0.12	53.47 0.35	82.30 0.53
D Group List (presumption of denial)	49.76 0.20	64.05 0.26	135.98 0.54

Note: Values in billions ($) and shares. Share computed over the total

3.1.2 Approach

To estimate the impact of export controls we first use a difference-in-difference approach, which relies on differential country exposure. We define $r_{e,i}$ as the log of aggregate exports to each destination i by export control type, e. We rank $e = 0, ...E$ in increasing degree of restrictiveness, respectively none, EAR99 and CCL. We classify countries into sets of $l = 0, ..., L$ mutually exclusive categories, increasing in their exposure to export controls. Standard trade models generate a log-linear export value that is fully described by exporter and importer specific characteristics, and a bilateral friction. Our starting point is any model that generates a similar relationship but where the flow is defined at the US-control category to different destinations i and has an export control friction, ε. More generally, let's consider any model that generates a sales equation with those properties so conditional on exporting, we have :

$$r_{ie} = a_i + a_e - \varepsilon(\tau_i, \tau_e). \tag{1}$$

The a_i capture any importer specific characteristics common across e that are not included in ε, but may be correlated with it, e.g. income, population, distance from U.S., etc. The a_e term is the analogous for a flow of type e to any destination, e.g. share of all production classified under a particular control, and any characteristics associated with it.

The export control friction can be any function that satisfies the following properties. First, it varies with the destination's exposure to control, denoted τ_i, and the restrictiveness of the control τ_e. Second, $\varepsilon(\tau_i, \tau_e = 0) = 0$ for all i, i.e. the lowest level of export control in a product, $\tau_e = 0$, denoted by the set "no controls" or "none", does not affect export levels in that product, regardless of the country status. Third, $\varepsilon(\tau_i, \tau_e)$ is supermodular in the vector (τ_i, τ_e), i.e. it captures a

model where an increase in the restrictiveness placed on a country, $\tilde{\imath} > i$, when the control is higher, $\tilde{e} > e$, is more restrictive than a similar increase when the control is lower. Therefore, $\Delta_i \varepsilon\left(\tilde{e} > e\right) \equiv \varepsilon\left(\tau_{\tilde{\imath}>i}, \tau_{\tilde{e}>e}\right) - \varepsilon\left(\tau_i, \tau_{\tilde{e}>e}\right) \geq \varepsilon\left(\tau_{\tilde{\imath}>i}, \tau_e\right) - \varepsilon\left(\tau_i, \tau_e\right) \equiv \Delta_i \varepsilon\left(e\right)$.

To estimate the average export control restriction differential for controlled goods we can then use the following difference-in-difference approach. Within each country i we difference out non-controlled export value from controlled , to obtain $\Delta_e r_{ie} = \varepsilon(\tau_i, \tau_e \geq 0) - \varepsilon(\tau_i, 0) = \varepsilon(\tau_i, \tau_e \geq 0)$. The second equality follows from the second property, $\varepsilon(\tau_i, 0) = 0$. Next, we average across countries that are part of an MECR, denoted by i, those that are not, $\tilde{\imath}$ and take their difference. Doing so yields

$$E_i\left[\Delta_e r_{ie}\right] - E_{\tilde{\imath}}\left[\Delta_e r_{\tilde{\imath},e}\right] = E_{\tilde{\imath}}\left[\varepsilon\left(\tilde{\imath}, e > 0\right)\right] - E_i\left[\varepsilon\left(i, e > 0\right)\right] \geq 0. \tag{2}$$

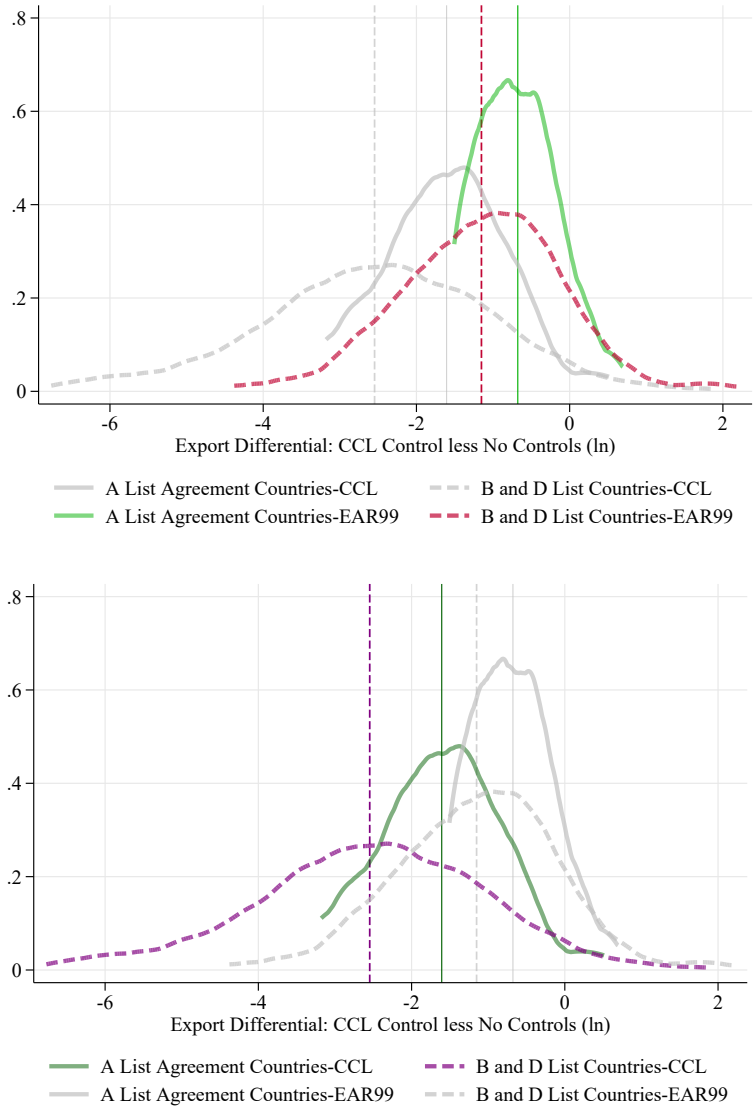
The basic insight extends to a more general model with additional determinants, $\mathbf{X}_{ie}$, but the estimation requires we condition on them or make the standard orthogonality assumptions relative to the export control friction.

3.1.3 Non-parametric Evidence

We test the predicted differential outlined above non-parametrically. For each country we compute the log difference in aggregate controlled exports on the CCL or under EAR99 relative to non-controlled exports. We plot a kernel density of this differential for our A list countries versus the B and D countries.

The results in Figure 2 are consistent with the differentials we predicted for the export control friction above. In the top panel, the kernel density of the export differential of EAR99 controlled products vs no controls for A countries is in solid green. The red dashed line is the analogous density for B and D list countries and we see its mean is shifted left and its lower tail is much heavier than the one for the A list. The bottom panel shows the same but is now applied to the CCL products instead of EAR99 and confirms the same pattern: the B and D list countries distribution is dominated by that of A list. The bottom panel also shows that the CCL densities are shifted to the left relative to the EAR99 differentials. This is true for all country lists and provides additional evidence of the complementarity prediction, not just relative to no controls but also between two controlled groups.

Figure 2: Non-Parametric Evidence on Differences Controlled vs Non-controlled Aggregate Export Values



Notes: Density computed using Epanechnikov kernel. Means for each group denoted by vertical lines for each group in like colors and style.

3.2 Parametric Evidence

We obtain parametric estimates of the differential export control friction by implementing a standard gravity equation as follows:

$$\begin{aligned}\ln(\text{exports}_{ie}) =& \delta_M \mathbf{1}(\text{MECR}_i = 1) + \delta_{ctrl}\mathbf{1}(\text{Ctrl}_{ie} = 1) \\ &+ \delta_{M,ctrl}\mathbf{1}(\text{MECR}_i = 1) \times \mathbf{1}(\text{Ctrl}_{ie} = 1) \\ &+ \beta \mathbf{X}_{ie} + \nu_{ie}. \end{aligned} \tag{3}$$

The coefficient δ_{ctrl} estimates the average difference in exports values of controlled versus non-controlled, which we expect to be negative. The MECR variable is our indicator for countries in list A, those in at least one MECR (i.e. WA, NSG, MTCR, or Australia Group), so its coefficient measures the relative exports to them relative to the ommited group: B or D countries. The key coefficient is $\delta_{M,ctrl}$, which identifies the differential in exports for MECR member countries on controlled export values, and is predicted to be positive in equation (2).

The regressors in $\mathbf{X}$ vary with the specification. First, we include standard controls in gravity equations: distance, destination GDP, PTA and WTO membership indicators. We subsequently replace them with a more general set of country fixed effects. The total number of observations in Table 1 is 194 (the number of countries in the sample) times the type of flow that we aggregate to, which is either three: non-controlled and controlled via EAR99 or CCL, or two when we aggregate the latter two into a controlled category. Later we disaggregate the flows into narrower categories.

In Table 5 we find that the results of estimating (3) are consistent with the main predictions. In column 1, the coefficient estimates are standard; with positive and significant effects for GDP close to unity, positive impacts of PTA and WTO membership and a negative distance elasticity. In column 2, we add the MECR and Any Control indicators and their interaction.[35] Their interaction coefficient is positive $\hat{\delta}_{M,ctrl} = 0.472$ and statistically significant, as predicted.
In column 3, we add country fixed effects. Note that only standard error on $\hat{\delta}_{M,ctrl}$ changes because it's identifying variation is not conditional on country-level controls in our specification. Column 4 disaggregates the controlled trade values into EAR99 and CCL products. We find that membership in an MECR has larger effects for more stringer controls such that $\hat{\delta}_{M,CCL} = 0.940 > 0.475 = \hat{\delta}_{M,EAR99}$. The effect on CCL trade values is nearly double the EAR99 effect.

We investigate if the effects vary not only across product controls but also country characteristics. Column 1 in Table 6 replicates the last column of Table 4. In columns 2 and 3 respectively we find that dropping the 50 countries on the D list from the sample or the 99 countries on the B list, does not change the main estimates. The effect of MECR membership remains higher for CCL versus EAR99 controls in both specifications. Our sample includes a large numbers small islands and micro-states, some of which have very low or high shares of controlled export values. To check

[35] We also include an indicator for countries in group A6 (strategic trade authorizations) and its interactions with the control indicator.

Table 5: Aggregate exports effect differential of agreement countries vs other destinations

Sample:	No Controls vs Any Control			vs EAR99 and ECCN controls
Dependent Variable:	exports (ln)			
	1	2	3	4
GDP(ln)	0.959***	0.951***		
	(0.040)	(0.059)		
Distance (ln)	-1.543***	-1.566***		
	(0.247)	(0.259)		
PTA (binary)	1.005***	0.975***		
	(0.226)	(0.243)		
WTO Member (binary)	0.606*	0.589*		
	(0.311)	(0.310)		
MECR (binary)		-0.162		
		(0.299)		
MECR*Any Control		0.472***	0.472***	
		(0.120)	(0.119)	
A6 List		0.825		
		(1.051)		
A6*Any Control		0.388	0.388	
		(0.473)	(0.469)	
MECR*EAR99				0.475***
				(0.118)
MECR*CCL				0.940***
				(0.173)
A6*EAR99				0.375
				(0.374)
A6*CCL				0.950
				(0.722)
EAR99 (binary)				-1.152***
				(0.087)
CCL (binary)				-2.546***
				(0.123)
Country Fixed Effects	No	No	Yes	Yes
Observations	388	388	388	582
R-squared	0.773	0.790	0.972	0.948
adjusted R-squared	0.771	0.785	0.942	0.920

Notes: Standard errors clustered at country level. Dummary variables for Any Control and EAR99 or CCL groups omitted in columns 1-2 and 3-4, respectively.

whether this matters for our results we drop all countries with population in 2015 of less than 500,000, many of which are on the B list. We also drop either D list or B list countries in columns 4 and 5 and still find a larger effect for CCL listed trade.

We next turn to heterogeneity across product categories of the CCL. As noted above, the first digit of the ECCN denotes one of 10 product categories reported in Table 2. We disaggregate the CCL export values into each product category. We then re-estimate (3) and compare non-controlled export values to controlled exports by each category and EAR99 separately. Figure 3 reports the point estimates for each product category and EAR99 with the 95% confidence interval.[36] The estimated differential is positive for all categories and ordered by magnitude. The largest effects are for higher technology products— electronics, aerospace, and computers—and they are smallest

[36]Detailed regression output is in the appendix

for marine, nuclear materials and materials processing. These patterns are robust to other sample restrictions such as dropping B or D lists and low population countries similarly to the baseline results.

Table 6: Aggregate exports effect differential for agreement countries--sample robustness

Sample:	No Controls vs EAR99 and ECCN				
	Full	Drop Presumed Denial List	Drop B List	Drop Denial and Low Population	Drop B List and Low Population
Dependent Variable:	exports (ln)				
	1	2	3	4	5
MECR*EAR99	0.475***	0.443***	0.537***	0.259*	0.517***
	(0.118)	(0.136)	(0.163)	(0.135)	(0.162)
MECR*CCL	0.940***	1.046***	0.729***	0.763***	0.769***
	(0.173)	(0.193)	(0.249)	(0.200)	(0.251)
A6*EAR99	0.375	0.344	0.438	0.180	0.438
	(0.374)	(0.381)	(0.394)	(0.383)	(0.394)
A6*CCL	0.950	1.056	0.739	0.733	0.739
	(0.722)	(0.729)	(0.749)	(0.732)	(0.750)
EAR99(binary)	-1.152***	-1.120***	-1.214***	-0.957***	-1.214***
	(0.087)	(0.110)	(0.142)	(0.111)	(0.142)
CCL(binary)	-2.546***	-2.653***	-2.336***	-2.330***	-2.336***
	(0.123)	(0.150)	(0.216)	(0.154)	(0.216)
Observations	582	432	285	342	276
R-squared	0.948	0.954	0.953	0.958	0.953
adjusted R-squared	0.920	0.930	0.928	0.936	0.928

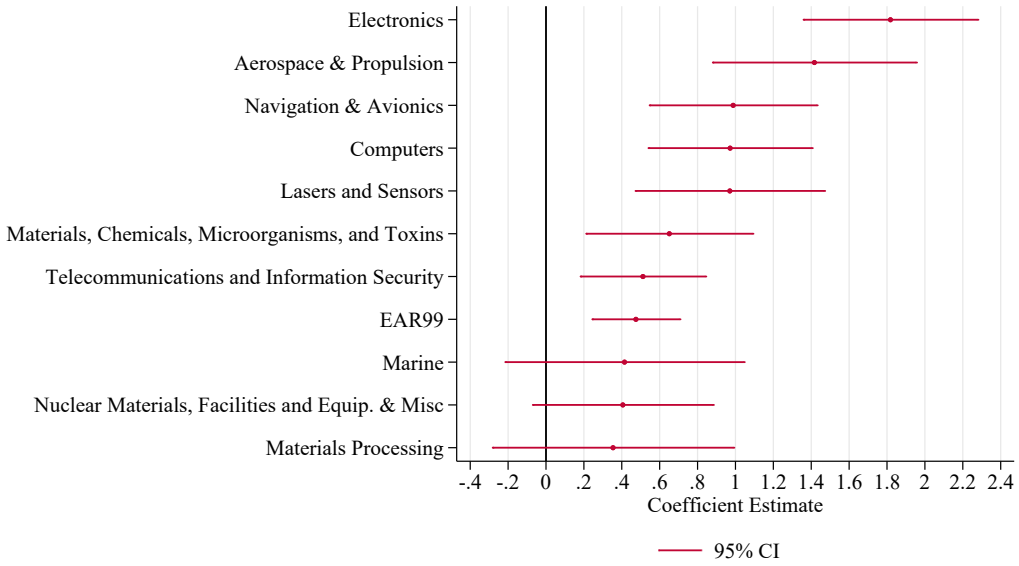
Notes: Standard errors clustered at country level. Country fixed effects included in all specifications.

3.2.1 Robustness and Sector Effects

We test the robustness of the main results to sample restrictions, alternative standard error assumptions, and other outcomes and disaggregation.

Our results were robust to dropping entire groups of countries in the B or D list. In Table 6 we extend these variations further. We first test whether the coefficients on the differential for EAR99 and CCL trade values are driven by China, Russia or both countries by dropping each in sequence in Columns 2-4 of Table 6. The estimates are largely unchanged and are roughly similar to dropping the entire group of D list countries, which we repeat for comparison in column 5. Column 6 that dropping those with population less than 500,000 reduces the magnitude of the estimate effects for EAR99 and CCL, but they remain remain large, significant and the effect for CCL is still twice as large. Our baseline estimates cluster standard errors at the country level to match the level of variation of our MECR and other country group indicators as well as standard gravity controls like destination GDP, when they are included instead of country effects. As Table 8 shows, these standard errors are more conservative than other alternatives. Heteroskedasticty robust standard errors are lower in column 2. We also perform a leave-one-country-cluster-out Jackknife estimator in column 3 and a bootstrap estimate with 100 replication samples resamples on country clusters in column 4. Both the jackknife and the bootstrap standard errors are lower than our baseline for

Figure 3: Heterogeneity in export control effects by product categories



Notes: Point estimates with 95% confidence intervals from estimating (3) by product category. Estimated are ordered from highest to lowest by point estimate. Standard errors clustered by country.

Table 7: Aggregate exports effect differential of agreement countries---Robustness to across country types

Sample:	No Controls vs EAR99 and ECCN					
	Full	Drop China	Drop Russia	Drop China+Russia	Drop D List	Drop Low Population
Dependent Variable:	exports (ln)					
	1	2	3	4	5	6
MECR*EAR99	0.475***	0.480***	0.478***	0.484***	0.443***	0.365***
	(0.118)	(0.118)	(0.118)	(0.118)	(0.136)	(0.116)
MECR*CCL	0.940***	0.954***	0.951***	0.965***	1.046***	0.765***
	(0.173)	(0.173)	(0.173)	(0.174)	(0.193)	(0.179)
A6*EAR99	0.375	0.381	0.379	0.384	0.344	0.286
	(0.374)	(0.374)	(0.374)	(0.375)	(0.381)	(0.375)
A6*CCL	0.950	0.963	0.961	0.975	1.056	0.736
	(0.722)	(0.722)	(0.722)	(0.722)	(0.729)	(0.724)
EAR99(binary)	-1.152***	-1.157***	-1.155***	-1.161***	-1.120***	-1.062***
	(0.087)	(0.088)	(0.088)	(0.088)	(0.110)	(0.088)
CCL(binary)	-2.546***	-2.560***	-2.558***	-2.571***	-2.653***	-2.332***
	(0.123)	(0.123)	(0.124)	(0.124)	(0.150)	(0.126)
Observations	582	579	579	576	432	492
R-squared	0.948	0.948	0.947	0.947	0.954	0.950
adjusted R-squared	0.920	0.920	0.919	0.919	0.930	0.923

Notes: Standard errors clustered by country. Country fixed effects included in all specifications.

EAR99 and CCL differentials of interest.[37]

[37]We resample on country clusters because the identification depends on the comparison export values using 3 observations for no controls, EAR99, and CCL in each country.

Table 8: Aggregate exports effect differential of agreement countries vs other destinations--Robustness to standard error assumptions

Sample:	No Controls vs EAR99 and ECCN			
	Cluster on country	Robust	Jackknife	Bootstrap
Dependent Variable:	exports (ln)			
	1	2	3	4
MECR*EAR99	0.475***	0.475***	0.475***	0.475***
	(0.144)	(0.138)	(0.118)	(0.120)
MECR*CCL	0.940***	0.940***	0.940***	0.940***
	(0.213)	(0.164)	(0.174)	(0.170)
A6*EAR99	0.375	0.375	0.375	0.375
	(0.459)	(0.452)	(0.547)	(0.433)
A6*CCL	0.950	0.950	0.950	0.950
	(0.886)	(0.628)	(1.064)	(0.825)
EAR99(binary)	-1.152***	-1.152***	-1.152***	-1.152***
	(0.107)	(0.101)	(0.087)	(0.087)
CCL(binary)	-2.546***	-2.546***	-2.546***	-2.546***
	(0.151)	(0.118)	(0.123)	(0.120)
Observations	582	582	582	582
R-squared	0.948	0.948	0.948	0.948
adjusted R-squared	0.920	0.920	0.920	0.920

Notes: All specifications include country fixed effects. Jackknife leaves one country cluster out for each rep. Boostrap samples 100 times by country cluster.

We now use all the disaggregated data, at the ECCN product level to estimate a pooled coefficient on the MECR differential for CCL products. This allows us to control for both country and product category fixed effects. In Table 9 we continue to find a positive differential for EAR99 and CCL exports for MECR members. This is the case in column 1, without fixed effects, and in column 2 when we do it increases from 0.545 to 0.643. If we include fixed effects for the 10 product categories and EAR99 the CCL differential increases to 0.892, which is very close to the estimate we obtained when aggregating all CCL export values in our baseline results in Table 4, column 4.

3.2.2 Intensive vs. extensive margins

We can decompose export effects into an intensive and extensive margin effect. We define the extensive margin as the count of the number of traded ECCN codes by each country N_{ie}. The intensive margin is exports per traded ECCN code. We can then write $\ln(\text{exports}_{ie}) = \ln N_{ie} + \ln(\frac{\text{exports}_{ie}}{N_{ie}})$. We can only define these margins using the CCL nomenclature, which is not available for EAR99 or non-controlled exports. So we cannot include country effects, and must rely on the gravity variables to estimate the differential for MECR members relative to the omitted groups of B and D list countries on controlled products. We find a positive MECR effect on exports, which is not statistically significant in this approach. However, in column 2, we find the extensive margin effect for MECR member is positive and significant, but the intensive margin is not. The reduced trade participation by non-MECR members in the cross-section suggests there may be barriers to entering export markets due to licensing costs and delays, as described in section 2. In the next

Table 9: Disaggregated exports effect differential for agreement countries

Sample:	Country by Product Category Disaggregation			
Dependent Variable:	exports (ln)			
	1	2	3	4
GDP(ln)	0.978***		1.023***	
	(0.056)		(0.057)	
Distance (ln)	-0.659***		-0.721***	
	(0.164)		(0.180)	
PTA (binary)	0.975***		0.990***	
	(0.199)		(0.208)	
WTO Member (binary)	0.102		0.173	
	(0.248)		(0.262)	
MECR (binary)	-0.048		-0.197	
	(0.309)		(0.315)	
MECR*EAR99	0.475***	0.475***	0.475***	0.475***
	(0.117)	(0.117)	(0.118)	(0.118)
MECR*CCL	0.545***	0.643***	0.722***	0.892***
	(0.150)	(0.142)	(0.149)	(0.140)
A6 List	0.636		0.547	
	(0.932)		(0.904)	
A6*EAR99	0.375	0.375	0.375	0.375
	(0.374)	(0.373)	(0.374)	(0.374)
A6*CCL	0.977**	0.660	1.042**	0.758
	(0.434)	(0.536)	(0.469)	(0.625)
Country Fixed Effects	No	Yes	No	Yes
Product Category FE	No	No	Yes	Yes
Observations	1,989	1,989	1,989	1,989
R-squared	0.690	0.778	0.790	0.885
adjusted R-squared	0.688	0.753	0.787	0.872

Notes: Standard errors clustered at country level. Dummy variables for EAR99 or CCL groups omitted in columns 1-2, respectively.

section we provide some results and modeling of this mechanism.

3.3 Quantification of MECR Effects

We next quantify how important MECR membership may be relative to non-members by computing the effect of switching countries from groups B and D to an MECR agreement.

As noted in the introduction, geopolitical considerations and conflict do result in countries being moved with respect to the EAR onto more and less favorable lists. For example, India was moved into our definition of the MECR group in January 2015 with respect to the U.S. based on fulfilling requirements from a 2010 security agreement. Other countries are moved from A to B to D. Russia, for example, was already on group D denial lists for nuclear and missile technology in 2015. But after the invasion of Ukraine in 2022, it was also removed from treatment as a Wassenaar Arrangement member and added to the D list of countries under a full arms embargo.[38]

About 33% of total US exports in 2015 (excluding Canada) were to B ($154 billion) and D list countries ($250 billion). To quantify how much larger this trade could potentially be, all else equal, we compute a partial effect of switching countries on the B or D list into the set of MECR members

[38] See Bureau of Industry and Security. (2022, March 3). Implementation of sanctions against Russia under the Export Administration Regulations (EAR). Federal Register, 87(42), 12226–12241.https://www.federalregister.gov/d/2022-04300

Table 10: Intensive and extensive margin effect of agreements countries vs other destinations

Sample:	ECCN trade by country		
Dependent Variable:	Exports(ln)	number of traded ECCNs (ln)	Exports per ECCN (ln)
	1	2	3
GDP(ln)	1.072***	0.369***	0.703***
	(0.077)	(0.027)	(0.056)
Distance (ln)	-0.576*	-0.182	-0.394**
	(0.341)	(0.171)	(0.197)
PTA (binary)	1.341***	0.496***	0.844***
	(0.337)	(0.143)	(0.231)
WTO Member (binary)	0.573	0.406**	0.167
	(0.412)	(0.167)	(0.291)
MECR (binary)	0.545	0.365***	0.180
	(0.362)	(0.130)	(0.262)
A6 List (binary)	1.190	0.240	0.950
	(1.406)	(0.398)	(1.012)
Observations	194	194	194
R-squared	0.761	0.775	0.693
adjusted R-squared	0.753	0.768	0.683

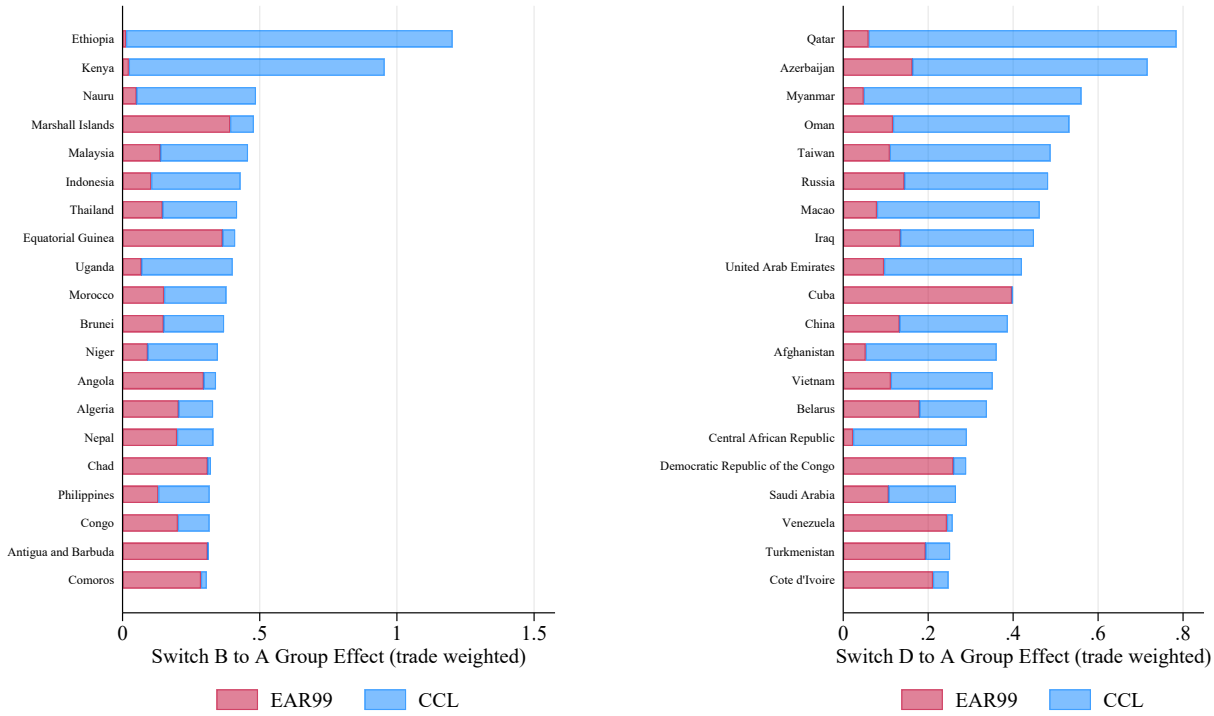
Notes: Robust standard errors clustered by country.

with less stringent licensing restrictions. We use trade shares for each country and product category, including EAR99, to weight up an overall effect from the disaggregated estimates that appear in Figure 3. We then rescale this effect by weighting it by the share of exports subject to any control to each destination. As such, the estimated effects are for aggregate exports and are higher for countries with a large share of controlled exports (e.g. Ethiopia) and lower for those with very small shares (e.g. Benin).

We plot the largest 20 traded weighted trade effects for both the B and D group countries in Figure 4. For B group countries, some aggregate partial effects are quite large and due mostly to CCL controls, for example Ethiopia and Kenya. Other countries have large effects driven mostly by EAR99 controls rather than the CCL. There are large effects for some D list countries: exports to Taiwan and Russia could increase by around 50 log points if they were treated as MECR countries. Likewise, effects on China and Vietnam are more than 30 log points.

An alternative counterfactual, in partial equilibrium, is to remove the MECR preference current U.S. trade partners, i.e. what would happen countries were removed from the A list groups in the EAR? Using the same method as above, we compute trade weighted effects for each export destination among the MECR group of countries. On average, the reduction in exports would be about 30 log points per country. In the quantitative model in section 5, we find similar effects.

Figure 4: Top 20 trade weighted effects of switching country from the B or D list to MECR



Notes: Left panel the effect for B list countries and right panel is the effect for D list countries. For each destination country, the estimated effects by product category were weighted up by export trade shares to obtain a total EAR99 and CCL effect, which was then scaled by the share of controlled exports in total exports.

3.4 Mechanism Evidence: export impacts of delays and rejection rates

We collected data on average licensing delays by country and rejection rates from all BIS reports available. We estimated these reduce the relative export of controlled products vs. none. We also used these and computed an MECR differential, which is close to the MECR estimate in Table 4. Table: TBA

4 Quantitative Model

We augment the Caliendo-Parro framework to have a sub-sector distinction between dual-use and civilian-only technology. This addition allows us to incorporate information from the US BEA make-use tables into the more standard WIOD database for quantitative exercises.

4.1 Setup

- **Countries:** There are N countries indexed by $o, d = 1, \ldots, N$.
- **Sectors:** There are J sectors indexed by $i, j = 1, \ldots, J$.
- **Intermediate varieties:** Within each sector i, there is a continuum of varieties $w \in [0, 1]$.
- **Two technologies per variety:** Each variety w in sector i can be produced via two technologies,

  $$t \in \{C, D\},$$

  where $t = C$ is *civilian-only* and $t = D$ is *dual-use*. We often write w_t to denote the variety w under technology t.
- **Final use:** Sector-i goods are aggregates of all intermediate varieties. They can be used as inputs into other sectors or consumed by civilians or by the military.
- **Export controls:** We model export controls as iceberg-type policies that raise the cost on the importer side (without generating tariff revenue).

4.2 Production of Intermediate Varieties

Let $y_d^i(w_t)$ be the output of variety w (in sector i, country d) with technology $t \in \{C, D\}$. Variety ω_t is produced according to:

$$y_d^i(w_t) = z_d^i(w_t)\left[l_d^i(w_t)\right]^{\gamma_d^{il}} \prod_{j=1}^{J} \left[m_d^{ij}(w_t)\right]^{\gamma_d^{ij}},$$

subject to

$$\gamma_d^{il} \; + \; \sum_{j=1}^{J} \gamma_d^{ij} \; = \; 1.$$

- $z_d^i(w_t)$ follows a (possibly correlated) Fréchet distribution across $\{C, D\}$ for each variety w. A correlation parameter ρ^i captures the idea that productivity in C may be correlated with productivity in D for the same variety. The joint distribution is governed by $\{T_{d,C}^i, T_{d,D}^i\}$ (location parameters), θ^i (dispersion), and ρ^i (correlation).
- $l_d^i(w_t)$ is labor used for (w_t) in sector i, country d.
- $m_d^{ij}(w_t)$ is the quantity of the aggregated sector-j intermediate.
- γ_d^{il} and γ_d^{ij} are factor cost shares (assumed independent of t).

Hence, the unit cost of ω_t in sector i, country d is:

$$c_d^i(w_t) = \frac{1}{z_d^i(w_t)} \Big[w_d\Big]^{\gamma_d^{il}} \prod_{j=1}^{J} \Big[P_{d,t}^j\Big]^{\gamma_d^{ij}},$$

where:

- w_d is the wage in country d.
- $P_{d,t}^j$ is the price of sector-j's composite input relevant for technology t.

4.3 Production of Sectoral Final Goods and Trade

Denote by $Y_{d,t}^i$ the sectoral final good of i in country d that is intended for users with technology t. It is produced by intermediates from the same sector, sourced around the world. $Y_{d,t}^i$ relies more heavily on t technology than $t' \neq t$ technology. And we incorporate this by assuming that there is quality penality when input type t' is mismatched with output type t.

We define two mismatch parameters:

$$a^{i,C} \;\geq\; 1, \qquad a^{i,D} \;\geq\; 1.$$

Interpretation: $\begin{cases} a^{i,C} & \text{: efficiency loss when a dual-use input } (D) \text{ is used in a civilian application } (C), \\ a^{i,D} & \text{: efficiency loss when a civilian-only input } (C) \text{ is used in a dual-use application } (D). \end{cases}$

If the input's technology matches the user (e.g. a civilian-only good is used by a civilian sector), we set that mismatch to 1 (no penalty).

Accordingly, the sectoral aggregator is:

$$Y_{d,t}^i = \left[\int_0^1 \left(\frac{q_{d,t}^i(\omega_C)}{\alpha_{t,C}^i} \;+\; \frac{q_{d,t}^i(\omega_D)}{\alpha_{t,D}^i}\right)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}},$$

where

$$\alpha_{C,C}^i \;=\; 1, \quad \alpha_{D,D}^i \;=\; 1, \quad \alpha_{C,D}^i \;=\; a^{i,C}, \quad \alpha_{D,C}^i \;=\; a^{i,D}.$$

This means:

$$\alpha_{t,t}^i = 1 \quad \text{(matched technology)}, \qquad \alpha_{C,D}^i = a^{i,C}, \quad \alpha_{D,C}^i = a^{i,D}.$$

Price of a Variety. When a user in country d with downstream technology t sources a variety ω_C from country o, the effective (quality-adjusted) cost becomes

$$\alpha_{t,C}^i \; c_o^i(\omega_C) \; \tau_{od,C}^i,$$

where $\tau_{od,C}^i$ is the iceberg cost (including export controls) for technology-C goods shipped from o

to d. Likewise, if they source ω_D, the effective cost is

$$\alpha^i_{t,D}\; c^i_o(\omega_D)\; \tau^i_{od,D}.$$

Thus, for each variety ω,

$$p^i_{od,t}(\omega) \;=\; \min\Big\{\alpha^i_{t,C}\, c^i_o(\omega_C)\, \tau^i_{od,C},\;\; \alpha^i_{t,D}\, c^i_o(\omega_D)\, \tau^i_{od,D}\Big\}.$$

Taking the minimum across all possible origins o then gives

$$p^i_{d,t}(\omega) \;=\; \min_o \{\, p^i_{od,t}(\omega)\}.$$

Price Index. With the Fréchet assumptions as in Eaton and Kortum (2002) or Caliendo and Parro (2015), we have closed-form expressions for trade shares and sectoral price indices. Denoting

$$\Gamma^i_{d,t} \;=\; \sum_o K^i_{od,t}, \qquad K^i_{od,t} \;=\; \left[\Big(T^i_{o,C}\,[\alpha^i_{t,C}\, A^i_{o,C}\, \tau^i_{od,C}]^{-\theta^i}\Big)^{\frac{1}{\rho^i}} \;+\; \Big(T^i_{o,D}\,[\alpha^i_{t,D}\, A^i_{o,D}\, \tau^i_{od,D}]^{-\theta^i}\Big)^{\frac{1}{\rho^i}}\right]^{\rho^i},$$

where $A^i_{o,t}$ is the unit production cost:

$$A^i_{o,t} = [w_o]^{\gamma^{il}_o} \prod_{j=1}^{J} [P^j_{o,t}]^{\gamma^{ij}_o}.$$

The sectoral-level price index for users with technology t is

$$\Big(P^i_{d,t}\Big)^{1-\sigma^i} = \Gamma\Big(\tfrac{1-\sigma^i}{\theta^i}+1\Big)\; [\Gamma^i_{d,t}]^{-\frac{1-\sigma^i}{\theta^i}},$$

and the bilateral trade shares and within-origin technology shares follow standard Frechét/EK logic, with the added twist that each origin's cost draws have two correlated technology options $\{C, D\}$, each multiplied by the mismatch factor $\alpha^i_{t,C}$ or $\alpha^i_{t,D}$.

4.4 Final Use and Budget

Households (civilian, denoted by $t = C$) and the military (denoted by $t = D$) each have Cobb-Douglas preferences:

$$U_{d,t} \;=\; \prod_{i=1}^{J} (Q^i_{d,t})^{\beta^i_{d,t}},$$

where $Q^i_{d,t}$ is the quantity of sector-i final goods assembled as in the previous aggregator.

We assume each country d's total labor income is $Y_d = w_d L_d$. A fraction $s^M_d \in [0,1]$ of labor income is taken (lump-sum) to finance military spending M_d, and the remaining fraction $(1 - s^M_d)$

is disposable income C_d for civilians:

$$M_d = s_d^M \, w_d \, L_d, \quad C_d = (1 - s_d^M) \, w_d \, L_d.$$

Hence,

$$E_{d,C} = C_d, \quad E_{d,D} = M_d.$$

Cobb-Douglas cost shares determine each sector's share of these expenditures.

4.5 General Equilibrium

An equilibrium is defined by:

$$\{ \, w_d, \; P_{d,t}^i, \; X_{d,t}^i, \; V_{d,t}^i, \; \pi_{od,t}^i, \; \phi_{od,t't}^i, \; C_d, \; M_d \, \},$$

satisfying:

1. **Price-Index equations** (Frechét/EK results with correlated draws):

$$\left(P_{d,t}^i\right)^{1-\sigma^i} = \Gamma\!\left(\tfrac{1-\sigma^i}{\theta^i} + 1\right) \left(\Gamma_{d,t}^i\right)^{-\frac{1-\sigma^i}{\theta^i}}, \quad \Gamma_{d,t}^i = \sum_o K_{od,t}^i,$$

$$K_{od,t}^i = \left[\left(T_{o,C}^i \, [\, \alpha_{t,C}^i \, A_{o,C}^i \, \tau_{od,C}^i]^{-\theta^i} \right)^{\frac{1}{\rho^i}} + \left(T_{o,D}^i \, [\, \alpha_{t,D}^i \, A_{o,D}^i \, \tau_{od,D}^i]^{-\theta^i} \right)^{\frac{1}{\rho^i}} \right]^{\rho^i},$$

$$A_{o,t}^i = \left[w_o \right]^{\gamma_o^{il}} \prod_{j=1}^{J} \left[P_{o,t}^j \right]^{\gamma_o^{ij}}.$$

2. **Trade shares**:

$$\pi_{od,t}^i = \frac{K_{od,t}^i}{\Gamma_{d,t}^i}, \quad \phi_{od,t't}^i = \text{(conditional probability the draw is from technology } t \text{ given origin } o),$$

determined by the relative terms in the bracket $\left[\cdots + \ldots \right]^{\rho^i}$. **Note that this is trade shares based on the technology of the *downstream user*, rather than the technologies of producer of the goods**. Exports flow here consists of goods produced using C and D technologies with their shares given by $\phi_{od,t't}^i$.

3. **Expenditure decomposition:** For sector i and user type t,

$$X_{d,t}^i = \sum_{j=1}^{J} \gamma_d^{ji} \, V_{d,t}^j \; + \; \beta_{d,t}^i \, E_{d,t}.$$

4. **Goods-market clearing:**

$$V^i_{o,t} \;=\; \sum_{d=1}^{N} \sum_{t' \in \{C,D\}} X^i_{d,t'}\, \pi^i_{od,t'}\, \phi^i_{od,t't}.$$

5. **Labor-market clearing:**

$$w_d\, L_d \;=\; \sum_{i=1}^{J} \sum_{t \in \{C,D\}} \gamma^{il}_d\, V^i_{d,t}.$$

6. **Income split and final spending:**

$$Y_d = w_d\, L_d, \quad M_d = s^M_d\, Y_d, \quad C_d = (1 - s^M_d)\, Y_d, \quad E_{d,C} = C_d, \quad E_{d,D} = M_d.$$

5 Quantitative Implementation

We conduct counterfactual exercises using exact-algebra. In this section, we introduce the data used to construct the baseline equilibrium and the numerical algorithm to solve the model. We then describe the counterfactual findings.

5.1 Data and Inputs

Trade and input use. We source trade data from the 2016 release of the WIOD, which includes 44 countries (including ROW), and we aggregate other manufacturing and services so in total there are 19 sectors. The mapping from the WIOD industry to these 19 industries are attached in the appendix of this document. Using this data, we construct the empirical bilateral trade shares $\bar{\pi}^i_{od,t}$. In the model only production sectors are tradable, so in constructing these shares we focus on non-final users.

In the model, trade shares can differ by the type of downstream user. In the absence of fully parameterized model, we assume that: $\bar{\pi}^i_{od,D} = \bar{\pi}^i_{od,C}$, under which both shares equal the empirical bilateral trade shares.

Final consumption share. We construct final consumption share $\beta^j_{d,t}$ from WIOD. In WIOD we do not see separate final consumption compositions for military and other final users, so we assume $\beta^j_{d,D} = \beta^j_{d,C}$. Later when we move to full parameterization, we can discipline the relationship between $\beta^j_{d,D}$ and $\beta^j_{d,C}$ using the U.S. data and extrapolate to other countries using sparse parameterization of the model.

Miliary share. We construct military spending share s^M_d in GDP from WDI.

Dual use share. We calibrate $\phi^i_{od,tt'}$ using the U.S. input-output data. Since our data cover only the U.S., we assume that $\forall o, d, o', d',\ \phi^i_{od,tt'} = \phi^i_{o'd',tt'}$.

We observe the input-output linkages at NAICS 6d (after crosswalk from BEA industry to NAICS). We classify the using and supplying industries in the input-output table as under controlled or not. We then aggregate these linkages to the following matrix:

	C	D
C	0.73	0.27
D	0.47	0.53

Table 2: Input-Output Linkages ϕ_{t_tp} (each row sums to 1)

5.2 Numerical Algorithm.

Recovering level outcomes in the baseline equilibrium. Given the shares, we first solve the following system of linear equations to obtain the additional level outcomes. In these equations, all shares (e.g. γ_d^{ij}, $\pi_{do,t'}^i$) have been calibrated. It is therefore a system of linear equations in the level outcomes (e.g. $X_{d,t}^i$, $E_{d,t}$, w_d, $V_{d,t}^i$). After normalization (we normalize the world GDP to be 1), the system of equations is full-ranked and can be inverted to solve for all level variables. For sector i and user type t,

$$X_{d,t}^i = \sum_{j=1}^{J} \gamma_d^{ji} V_{d,t}^j \; + \; \beta_{d,t}^i E_{d,t}.$$

$$V_{o,t}^i \; = \; \sum_{d=1}^{N} \sum_{t' \in \{C,D\}} X_{d,t'}^i \, \pi_{od,t'}^i \, \phi_{od,t't}^i.$$

$$w_d L_d \; = \; \sum_{i=1}^{J} \sum_{t \in \{C,D\}} \gamma_d^{il} V_{d,t}^i.$$

$$Y_d = w_d L_d, \quad M_d = s_d^M Y_d, \quad C_d = (1 - s_d^M) Y_d, \quad E_{d,C} = C_d, \quad E_{d,D} = M_d.$$

With these level variables at hand, we have all information from the baseline equilibrium, with which we implement counterfactuals via exact-hat algebra.

Hat algebra. We proceed as follows to solve for counterfactuals: we guess the changes in wages $\hat{w}_d$, solve for the changes in price and trade shares ($\pi_{od,t}^i$ and $\phi_{od,t't}^i$). Use the above system of equations to solve for the implied wages (and other outcomes) given these trade shares. Iterate until the wages converge to a fixed point.

5.3 Counterfactuals.

Let $\mathcal{A}$ denotes the set of countries that are in agreement. We consider two counterfactuals that evaluate the U.S. participation in agreement on U.S. exports and imports. In the first counterfactual, we set $\hat{\tau}_{US-d,D}^i$ for $d \in \mathcal{A}$ to the coefficient estimated for sector i, divided by trade elasticity $\theta = 4$. The size of shocks for the dual use good in each industry is reported in the appendix. The

U.S. imposes control on other agreement partners, but these partners do not retaliate. Our second counterfactual consider a scenario in which the U.S. exits the agreement, while the remaining countries remain. What this entails is that the U.S. imposes additional control on dual-use goods export to other countries in the agreement, and these countries retaliate with the same shock. However, between two non-U.S. countries, trade barriers stay intact.

5.3.1 U.S. imposes controls on other agreement countries.

The first Column in Table 3 reports the results from the first experiment. Unilaterally imposing controls on other countries in agreement hurts the U.S. real income by 0.1 of a percentage points. The exports effects on dual-use goods are substantial, at 35%. This is substantially higher than the 24% predicted based on aggregation from partial equilibrium gravity models, highlighting the role of GE and linkages.

After the unilateral control, the U.S. exports to allies in civilian-only goods increase by 6.7%, due to the substitution between the two types of technologies and GE, but this increase is not enough to offset the effect due to the control: the total exports to allies decrease by 5.95% from the baseline economy. Through the GE force, the control also reduces imports from allies, decreasing total imports from allies by 3.19%.

5.3.2 U.S. exits agreement unilaterally.

The second column in Table 3 reports the result from the second experiment. Here, in addition to the U.S. imposing control on allies, the allies also reciprocate, thus, the experiment is based interpreted as the U.S. withdrawing from the agreement. The allies' reaction drastically reduce the U.S. imports from allies, by 37.8% for dual-use goods and by 9.23% overall. Higher production costs in the U.S. also mean the U.S. further lose market share in allies markets, in both C and D goods, compared to the case of unilateral control. In net, the U.S. real income decreases by 0.35%.

Table 3: U.S. with Draw through MECRs, in Two Steps

	US imposes control on allies unilaterally	**U.S. exits agreement**
Real income	-0.11%	-0.35%
Exports to allies (D)	-33.07%	-35.38%
——based on PE gravity	-23.78%	
Exports to allies (C)	6.71%	3.88%
Exports to allies (C+D)	-5.95%	-8.62%
Imports from allies (D)	-3.84%	-37.97%
Imports from allies (C)	-2.88%	4.21%
Imports from allies (C+D)	-3.19%	-9.23%

6 Conclusion

We examine the role of ECRs on trade, at the unilateral and multilateral levels, for aggregate and dual-use good exports. Using novel data on U.S. exports and a structural gravity framework, we document that even minimally restrictive controls reduce export volumes. However, participation in multilateral export control regimes (MECRs) significantly mitigates these trade reductions, suggesting that coordinated export policies among allied nations can preserve security goals while minimizing economic distortions.

Through a general equilibrium model incorporating dual-use production and global supply chains, we quantify the broader implications of export controls and the value of multilateral cooperation. Our findings indicate that a unilateral expansion of controls, or withdrawal from MECRs, would lead to substantial declines in U.S. exports. Moreover, retaliation from MECR partners would exacerbate these losses and erode U.S. industrial competitiveness. These results emphasize the importance of carefully balancing strategic security objectives with economic efficiency, and highlight the role of multilateral regimes in reducing the collateral damage of export restrictions in an era of growing geopolitical uncertainty.

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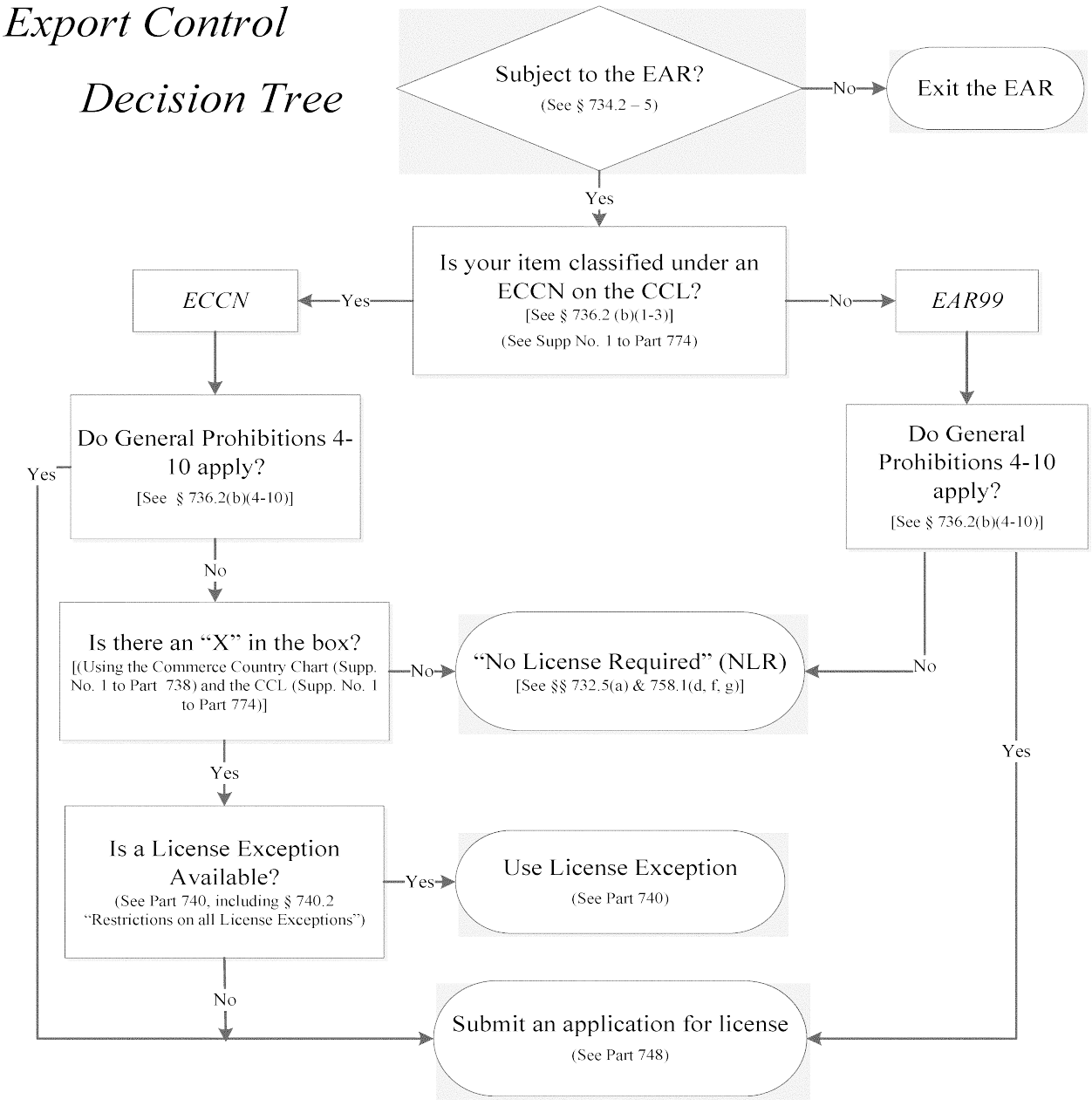
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A Appendix

SUPPLEMENT NO. 1 TO PART 732 – EXPORT CONTROL DECISION TREE



Members of the Wassenaar Arrangement

Founding Members		
• Argentina	• Bulgaria	• Finland
• Hungary	• Japan	• Türkiye
• Poland	• Canada	• France
• Australia	• Austria	• Netherlands
• Portugal	• Slovakia	• Luxembourg
• Republic of Korea	• Czech Republic	• Germany
• Ireland	• Spain	• New Zealand
• Romania	• Denmark	• Switzerland
• Belgium	• Ukraine	• Greece
• Italy	• Sweden	• Norway
• Russian Federation	• United Kingdom	• United States of America
Member joined through Accession		
• India (2018)	• Malta (2005)	• Mexico (2012)
• Slovenia (2004)	• Latvia (2005)	• Estonia (2005)
• Croatia (2005)	• Lithuania (2005)	• South Africa (2006)

B Quantitative Model in Changes

We denote baseline (initial-equilibrium) values with an overbar (e.g. $\overline{w}_d$ for wages). Variables without bars denote counterfactual (post-policy) values. Define *hats* as the ratio of the post-policy outcome to the baseline. For example: $\hat{w}_d = \frac{w_d}{\overline{w}_d}$, $\hat{P}^i_{d,t} = \frac{P^i_{d,t}}{\overline{P}^i_{d,t}}$, $\hat{\tau}^i_{od,t} = \frac{\tau^i_{od,t}}{\overline{\tau}^i_{od,t}}$, etc.

B.1 Price Indexes in Hat Form

In the baseline equilibrium, the sector-i, technology-t price in country d is $\overline{P}^i_{d,t} = \Big[\Gamma\Big(\frac{1-\sigma^i}{\theta^i} + 1\Big)\Big]^{\frac{1}{1-\sigma^i}} \left(\overline{\Gamma}^i_{d,t}\right)^{-\frac{1}{\theta^i}}$, where $\overline{\Gamma}^i_{d,t} = \sum_o \overline{K}^i_{od,t}$, $\overline{K}^i_{od,t} = \Big[\left(\overline{T}^i_{o,C}\left[\alpha^i_{t,C}\,\overline{A}^i_{o,C}\,\overline{\tau}^i_{od,C}\right]^{-\theta^i}\right)^{\frac{1}{\rho^i}} + \left(\overline{T}^i_{o,D}\left[\alpha^i_{t,D}\,\overline{A}^i_{o,D}\,\overline{\tau}^i_{od,D}\right]^{-\theta^i}\right)^{\frac{1}{\rho^i}}\Big]^{\rho^i}$.

Post-policy, let $\Gamma^i_{d,t} = \sum_o K^i_{od,t}$, $K^i_{od,t} = \Big[\left(T^i_{o,C}\left[\alpha^i_{t,C}\,A^i_{o,C}\,\tau^i_{od,C}\right]^{-\theta^i}\right)^{\frac{1}{\rho^i}} + \left(T^i_{o,D}\left[\alpha^i_{t,D}\,A^i_{o,D}\,\tau^i_{od,D}\right]^{-\theta^i}\right)^{\frac{1}{\rho^i}}\Big]^{\rho^i}$.

Dividing new by baseline (noting constants cancel) gives $\hat{P}^i_{d,t} = \frac{P^i_{d,t}}{\overline{P}^i_{d,t}} = \left(\hat{\Gamma}^i_{d,t}\right)^{-\frac{1}{\theta^i}}$, where $\hat{\Gamma}^i_{d,t} = \frac{\Gamma^i_{d,t}}{\overline{\Gamma}^i_{d,t}}$.

Since $\Gamma^i_{d,t} = \sum_o K^i_{od,t}$, $\overline{\Gamma}^i_{d,t} = \sum_o \overline{K}^i_{od,t}$, we write $\hat{\Gamma}^i_{d,t} = \sum_o \frac{K^i_{od,t}}{\overline{\Gamma}^i_{d,t}} = \sum_o \Big(\frac{K^i_{od,t}}{\overline{K}^i_{od,t}} \times \frac{\overline{K}^i_{od,t}}{\overline{\Gamma}^i_{d,t}}\Big) = \sum_o \hat{K}^i_{od,t}\,\overline{\pi}^i_{od,t}$, where $\overline{\pi}^i_{od,t} = \overline{K}^i_{od,t}/\overline{\Gamma}^i_{d,t}$ is the baseline trade share, and $\hat{K}^i_{od,t} = \frac{K^i_{od,t}}{\overline{K}^i_{od,t}}$, where

$$\hat{K}^i_{od,t} = \left[\left(\hat{T}^i_{o,C}\Big(\hat{A}^i_{o,C}\,\hat{\tau}^i_{od,C}\Big)^{-\theta^i}\right)^{\frac{1}{\rho^i}} + \left(\hat{T}^i_{o,D}\Big(\hat{A}^i_{o,D}\,\hat{\tau}^i_{od,D}\Big)^{-\theta^i}\right)^{\frac{1}{\rho^i}}\right]^{\rho^i},$$

and

$$\hat{A}^i_{o,t} = \frac{A^i_{o,t}}{\overline{A}^i_{o,t}} = \left(\frac{w_o}{\overline{w}_o}\right)^{\gamma^{il}_o} \prod_{j=1}^{J}\left(\frac{P^j_{o,t}}{\overline{P}^j_{o,t}}\right)^{\gamma^{ij}_o} = \hat{w}_o^{\gamma^{il}_o} \prod_{j=1}^{J}(\hat{P}^j_{o,t})^{\gamma^{ij}_o}.$$

B.2 Trade Shares in Hat Form

Let $\pi^i_{od,t}$ be the share of sector-i, technology-t spending in d that is sourced from o. In the baseline, $\overline{\pi}^i_{od,t} = \overline{K}^i_{od,t}/\overline{\Gamma}^i_{d,t}$. Post-policy: $\pi^i_{od,t} = \frac{K^i_{od,t}}{\Gamma^i_{d,t}} \implies \frac{\pi^i_{od,t}}{\overline{\pi}^i_{od,t}} = \frac{K^i_{od,t}/\Gamma^i_{d,t}}{\overline{K}^i_{od,t}/\overline{\Gamma}^i_{d,t}} = \frac{\hat{K}^i_{od,t}}{\hat{\Gamma}^i_{d,t}}$.

B.3 Expenditure Decomposition in Hats

Expenditures $X^i_{d,t}$ satisfy $X^i_{d,t} = \sum_{j=1}^{J} \gamma^{ji}_d\, V^j_{d,t} + \beta^i_{d,t}\, E_{d,t}$. In baseline terms, $\overline{X}^i_{d,t} = \sum_j \gamma^{ji}_d\, \overline{V}^j_{d,t} + \beta^i_{d,t}\, \overline{E}_{d,t}$. Dividing new by baseline: $\hat{X}^i_{d,t} = \frac{X^i_{d,t}}{\overline{X}^i_{d,t}} = \frac{\sum_j \gamma^{ji}_d\, V^j_{d,t} + \beta^i_{d,t}\, E_{d,t}}{\sum_j \gamma^{ji}_d\, \overline{V}^j_{d,t} + \beta^i_{d,t}\, \overline{E}_{d,t}}$.

B.4 Goods-Market Clearing in Hats

Market clearing for sector-i, technology-t from origin o: $V^i_{o,t} = \sum_{d=1}^{N} \sum_{t' \in \{C,D\}} X^i_{d,t'}\ \pi^i_{od,t'}\ \phi^i_{od,t',t}$. In baseline, $\overline{V}^i_{o,t} = \sum_{d,t'} \overline{X}^i_{d,t'}\, \overline{\pi}^i_{od,t'}\, \overline{\phi}^i_{od,t',t}$. Taking ratios, $\hat{V}^i_{o,t} = \frac{V^i_{o,t}}{\overline{V}^i_{o,t}} = \frac{\sum_{d,t'} X^i_{d,t'}\, \pi^i_{od,t'}\, \phi^i_{od,t',t}}{\sum_{d,t'} \overline{X}^i_{d,t'}\, \overline{\pi}^i_{od,t'}\, \overline{\phi}^i_{od,t',t}}$.

B.5 Labor-Market Clearing in Hats

Labor-market clearing in country d requires $w_d L_d = \sum_{i=1}^{J} \sum_{t \in \{C,D\}} \gamma^{il}_d\, V^i_{d,t}$. Divide by the baseline: $\hat{w}_d = \frac{w_d}{\overline{w}_d} = \frac{\sum_{i,t} \gamma^{il}_d\, V^i_{d,t}}{\sum_{i,t} \gamma^{il}_d\, \overline{V}^i_{d,t}} = \sum_{i,t} \frac{\gamma^{il}_d\, \overline{V}^i_{d,t}}{\sum_{i',t'} \gamma^{il}_d\, \overline{V}^{i'}_{d,t'}}\ \hat{V}^i_{d,t}$.

B.6 Income Split and Final Spending in Hats

If a fraction s^M_d of labor income is spent on military, we have $M_d = s^M_d\, w_d\, L_d, \quad C_d = (1 - s^M_d)\, w_d\, L_d$. Dividing by baseline values ($\overline{M}_d = s^M_d\, \overline{w}_d\, L_d$, etc.) gives $\hat{M}_d = \hat{w}_d, \quad \hat{C}_d = \hat{w}_d, \quad \hat{E}_{d,C} = \hat{w}_d, \quad \hat{E}_{d,D} = \hat{w}_d$, assuming s^M_d is unchanged.

B.7 Total Sector-i Trade Between Two Countries

In the model, sector-i goods can be produced under two technologies, C (civilian-only) and D (dual-use). From the demand side, country d can use sector-i goods for either civilian or military/dual-use purposes, denoted by $t' \in \{C, D\}$. We are often interested in the *total value of sector-i imports* by d from o, *summing over both supply technologies* (i.e. goods produced in (o, i, C) vs. (o, i, D)).

Thus the *value* of sector-i exports from o to d, denoted X^i_{od}, is

$$X^i_{od} = \sum_{t' \in \{C,D\}} \sum_{s \in \{C,D\}} \Big[X^i_{d,t'}\, \pi^i_{od,t'}\, \phi^i_{od,t's} \Big].$$

In Hats

$\hat{X}^i_{od} = \sum_{t' \in \{C,D\}} \sum_{s \in \{C,D\}} \Big(\frac{\overline{X}^i_{od,t',s}}{\overline{X}^i_{od}} \Big)\, \hat{X}^i_{d,t'}\, \hat{\pi}^i_{od,t'}\, \hat{\phi}^i_{od,t's}$.

B.8 Other Tables and Figures

index_ij	sec_ij	tau_hat_D
1	Food	0
2	Textiles	0.163
3	Wood	0.163
4	Paper	0
5	Media	0
6	Petroleum	0.163
7	Chemicals	0.233
8	Pharmaceutical	0
9	Rubber	0.133
10	Non-Metallic Mineral	0.155
11	Basic Metals	0.177
12	Fabricated Metals	0.182
13	Electronics	0.213
14	Electrical	0.210
15	Machinery	0.222
16	Motor Vehicles	0.179
17	Other Transport	0.179
18	Furnitures	0
19	Others and Non-Manufacturing	0.0737

Table 4: Ad Valorem Equivalent of Dual-use Good Export Control.