Leaky Sanctions*

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Abstract

Discriminatory trade policy creates incentives to circumvent it by transshipping goods through third countries. We study how much transshipment weakens the export bans the European Union imposed on Russia in 2022. Linking Russian transaction-level customs records with new data on the bans, we observe transshipment directly: banned EU goods worth about 20% of pre-war imports keep arriving. The bans act like a 69% trade cost increase, and stricter enforcement shifted sales to third-country intermediaries rather than stopping them. In a general-equilibrium model with endogenous transshipment, the same bans would raise Russia's real-income loss by 32% without transshipment. Closing every route currently in use would recover only 41% of Russia's gain from transshipment, because trade moves to routes not yet used.

Keywords: Sanctions, Export Bans, Transshipment, Geoeconomics.

JEL-Classification: F11, F13, F14, F51, F52.

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1 Introduction

Policymakers increasingly use trade policy as a geopolitical instrument, favoring aligned countries and penalizing distant ones: since 2020, governments have imposed more than 18,000 discriminatory trade measures, compared with fewer than 500 per year before 2015 (Global Trade Alert, 2026). Because such barriers apply to some countries but not to others, they create incentives to circumvent them, most simply by shipping goods through a third country, a practice known as transshipment. The effects of geopolitical trade policy therefore depend on the extent of circumvention. We study how much transshipment weakens the intended effects of discriminatory trade policy, using the export bans the European Union (EU) imposed on Russia after its full-scale invasion of Ukraine in 2022. We also examine through which routes and intermediaries transshipment runs and how bans can be strengthened against it.

Export bans are the sharpest form of discriminatory trade policy, which makes them a natural setting to measure transshipment. By the end of 2024, the EU bans covered, fully or in part, 79% of the goods Russia imported from the EU in 2019, from advanced semiconductors and weapons components to champagne and luxury cars. Together with similar restrictions by the United States and 43 other countries, they form the core of one of the most comprehensive sanctions regimes in modern history (Gorodnichenko et al., 2024; Hausmann et al., 2024). The bans prohibit indirect as well as direct exports, but enforcement largely ends at the EU border, since EU authorities can observe and penalize re-exports from third countries only imperfectly. The bans therefore make EU goods more costly for Russian buyers but not impossible to obtain, since they can still be imported indirectly. Buyers thus choose between paying the higher cost of obtaining EU goods indirectly and substituting toward goods produced outside the coalition. The cheaper transshipment is, the more EU goods continue to reach Russia.

Because transshipment is illicit, official trade statistics reveal it only indirectly. In a wide class of trade models, a prohibitive barrier between two countries leads to trade diversion: the importer buys more from other suppliers, and the exporter sells more to other destinations. Transshipment instead shows up as excess trade, in which exports from the origin country to a third country and from that country to the destination both rise by more than these models predict. Several studies document rising trade on both legs after the US tariffs on China (Freund, 2025) and the EU export bans on Russia (Chupilkin et al., 2023a; Scheckenhofer et al., 2025). Because trade diversion raises both legs as well, such increases point to transshipment only relative to a general-equilibrium counterfactual, which most studies do not construct (an exception is Tyazhelnikov and Romalis, 2024). Even then, excess trade is a residual that attributes to transshipment whatever the counterfactual fails to explain, and it detects rerouting only where it is

large relative to a third country's normal trade. It also misses forms of transshipment that official trade statistics do not record, such as goods declared for a third country but redirected on the way, and reveals little about who transships goods and how.

We measure transshipment directly, linking confidential transaction-level Russian customs declarations with granular data on the EU export bans. For each import, the customs declarations report the country where the good was produced, the country of the seller, the firm that sent the goods on their final leg to Russia, and the country from which that leg began, allowing us to measure how much is transshipped, through which routes, and by whom.[1] We define transshipment as Russian imports of EU-origin products that are banned at the time of import. Some bans cover an entire tariff line, the most detailed product category recorded in trade data, but many cover only some of its variants, so EU-origin imports of partially banned products may be legal. Imports of fully banned products therefore give a lower bound on transshipment, and since EU statistics record no direct exports of these products to Russia, all of them must have arrived indirectly. Adding partially banned products gives an upper bound, which corresponds to the common practice of classifying products only as sanctioned or not (e.g., Egorov et al., 2025). Transshipment amounts to between USD 0.5 and 2 billion per month, about 20% of pre-war imports of the same products.

Russian buyers obtain banned EU goods almost always through a transshipment hub, a third country through which the goods pass before entering Russia. Our data show two ways in which they do so. They either buy the goods from a firm in a third country that had itself bought them from an EU firm and ships them on to Russia (re-exports), or receive goods that left the EU declared for a third country and were redirected to Russia on the way (diversion en route). By December 2024, re-exports account for 60% of the value of these imports and diversions for 39%. Across both modes, 90% of the value is routed through a hub outside the EU. Hubs are typically countries that border Russia or the EU, share a customs union with either, or lie on established freight corridors: Türkiye is the main hub for re-exports, and Belarus for diversion en route.

The bans raised the cost of EU goods for Russian buyers substantially, but far from prohibitively. A gravity-based triple-difference design compares Russian imports of fully banned EU products before and after the bans with imports of the same products from non-coalition origins and with imports of never-banned products. Relative to these benchmarks, imports of fully banned EU products fall by 85%, with no pre-trends. Mapped into trade costs with product-level elasticities (Fontagné et al., 2022), the decline is equivalent to a

[1] A natural concern is whether Russian customs records remain reliable after the invasion. Three pieces of evidence suggest they do: the records closely match the exports reported by Russia's non-sanctioning trading partners, by sector and partner country; Western authorities have used them to bring charges for sanctions violations; and the only documented manipulation consisted of no longer recording certain imports rather than falsifying their origin (Section 2.5).

69% increase in trade costs on the median banned flow. Transshipment, in other words, turns the bans into a tariff: a high one, but far from the infinite tariff that full enforcement would imply.

Stricter enforcement changed how banned goods reached Russia, but did little to reduce how much reached it. From late 2022 to autumn 2024, Russian imports of fully banned EU products remain about 85% below their counterfactual level, even as the EU made indirect exports to Russia increasingly difficult.[2] Instead, the transaction chain between EU producers and Russian buyers grew longer. A growing share of banned goods reached Russia as re-exports, and even goods still dispatched from the EU, where scrutiny was likely highest, were increasingly sold on paper by a firm in a third country: imports both dispatched and sold by EU parties fall by 98%, so that EU firms comply almost perfectly on paper. Each added link makes the bans harder to enforce and reduces the legal exposure of EU firms. The firms that send banned goods to Russia are likewise increasingly trading firms rather than producers, with their share of declarations rising by 15 percentage points relative to never-banned products and non-coalition origins.

To quantify the consequences of transshipment, we develop a general-equilibrium trade model in which Russia can respond to the bans in two ways. It can switch to suppliers outside the coalition or to other products (trade diversion), the only response that standard quantifications of sanctions allow, or it can continue to buy banned coalition goods through a hub. Shutting down the second response recovers the standard case, so comparing the two isolates how much transshipment weakens the bans.

The model is calibrated at the disaggregated 6-digit HS level. Within each product, Russian buyers can substitute across producer countries. We further group products into military-relevant goods, other critical goods, and all remaining goods, allowing substitution to be harder across these three groups than among products within one group. This allows Russia to protect expenditure on strategically important goods when their relative prices rise, rather than treating military inputs and ordinary consumer goods as equally close substitutes.

Transshipment depends on both the existing trade network and the characteristics of the transshipment hubs. We use the triangle inequality of trade costs to map pre-war trade costs into the cost of supplying a banned product through each potential hub, building on recent insights from Foellmi et al. (2024). Hubs also differ in their capability in rerouting banned goods, which we capture by a hub-specific wedge on this cost. Russia buys each banned product through the cheapest route. The model therefore captures both the additional cost of transshipment and the choice of hubs.

[2] To curb transshipment, the EU banned the transit of a growing set of banned goods through Russia from February 2023 and required exporters of the most sensitive goods to include "no re-export to Russia" clauses in contracts from March 2024.

The model takes its transshipment parameters directly from the data: the reduced-form estimates and the hub shares observed in the customs declarations. We construct the pre-war economy from 2019 data, including a matrix of bilateral trade-cost levels consistent with the triangle inequality. The 2024 hub shares in the customs data determine each hub's relative capability of transshipment, and the triple-difference estimate for the full bans determines their common level, so that the model reproduces the observed decline in banned imports. An analogous estimate for products that remain partially banned pins down how much partial bans raise the cost of direct exports. The model also fits patterns it does not target. The pre-war trade network alone identifies four of the five largest hubs in the data, and the calibrated hub-specific wedges improve the fit of hub shares for coalition origins outside the EU.

We find that transshipment substantially weakens the export bans. Under observed transshipment, in which banned goods can be rerouted through hubs at the calibrated cost, Russia's real income falls by 1.26% relative to the no-sanctions baseline. With no transshipment, the same product restrictions raise the loss to 1.66%, an increase of 32% relative to the loss under observed transshipment. Equivalently, transshipment offsets 24% of the loss without transshipment. We refer to the difference between the two losses, in percentage points, as Russia's *transshipment gain*.

The decline in targeted trade overstates the decline in the goods available to Russia. Imports of fully banned coalition-origin products fall by 76% under observed transshipment, but total imports fall by only 9% as Russia switches suppliers and reallocates expenditure across products. The model's measure of access to military-relevant goods, which includes domestic supply, falls by 3.6% under observed transshipment, compared with 4.0% without transshipment.

The losses within the EU are much smaller than Russia's, but concentrated among members with high pre-war exposure to Russia. Under observed transshipment, the median member state loses 0.036% of real income. In our main specification, hubs earn no rents from rerouting. In a thought experiment in which each hub instead charges as much as it can without losing the trade to a competing route, hubs earn at most USD 2.00 billion (Section 5).

How can the coalition strengthen the export bans? One natural response, reflected in current sanctions enforcement, is to target the firms and intermediaries that ship banned goods along active routes (Section 6.1 discusses recent U.S. and EU enforcement measures of this kind). Curbing transshipment in this way, however, is difficult. Even if every hub route through which Russia buys banned coalition products under observed transshipment were identified and closed, only 41% of Russia's transshipment gain would be eliminated. One reason is that once the active routes are removed, previously unused routes become the most attractive alternatives.

Removing an entire country as a hub also blocks its routes that are not yet in use. If the country even joins the coalition, it additionally restricts its own exports to Russia. We compare the two channels for the five largest hubs in the customs data (Türkiye, Belarus, China, United Arab Emirates, Serbia). The importance of these two channels differs remarkably across countries. For Türkiye and the United Arab Emirates, most of the accession effect comes from ending their role as intermediaries, whereas for China, restricting its own exports matters much more than removing its hub role. If all five joined the coalition together, Russia's real-income loss would rise to 2.43%, well above the 1.66% that the current restrictions would cause without transshipment.

We show that expanding the scope of products covered by the export bans can also be very effective. Besides transshipment, the bans leak because many products are banned only partially, and much of their trade with Russia continues. The EU has already narrowed this leak, upgrading 1,188 products from partial to full bans by the end of 2024. To measure what these upgrades achieved, we turn these full bans back into partial bans in the model. Russia's real-income loss would then be 24% smaller.

Many products are still only partially banned or not banned at all, and the EU can add them to the list without the cooperation of third countries. Fully banning 218 of these products, which account for 6% of current EU exports to Russia, raises Russia's loss by as much as closing every hub route through which Russia currently buys banned coalition products. With 965 additional products, Russia's loss reaches the level that the current bans would cause without transshipment, even when transshipment remains possible. We select the products by the loss that a ban would impose on Russia per dollar of newly covered exports, taking into account that part of this trade would be rerouted through third countries. A product-list expansion that neglects transshipment and covers the same value of current EU exports leads to a 16% smaller increase in Russia's real-income loss. This is because it picks some products, such as beer, vegetable seeds, and handbags, that Russia can largely keep buying through existing routes.

Relation to the literature. First, we contribute to work on the circumvention of trade barriers. A large literature studies evasion in the context of taxes (Fisman and Wei, 2004; Laffitte and Toubal, 2022) and tariffs (Fisman et al., 2008; Javorcik and Narciso, 2008), with renewed interest following the U.S.–China trade war (Che et al., 2025; Freund, 2025; Iyoha et al., 2024) and the recent sanctions against Russia (Chupilkin et al., 2025, 2023b; Scheckenhofer et al., 2025; Tyazhelnikov and Romalis, 2024). We observe an important form of evasion directly because the Russian customs records report the origin and dispatch country of each shipment separately. We then use the observed routes to discipline a general-equilibrium model in which transshipment responds endogenously to the bans. This allows us to quantify the aggregate consequences of evasion, distinguish it

from standard trade diversion, and study how trade moves to new routes when existing ones are closed.

Second, we contribute to the growing literature on the trade and income effects of economic sanctions, particularly those imposed on Russia. Existing work studies these effects using firm-level data (Corsetti et al., 2025; Crozet and Hinz, 2020; Crozet et al., 2021; Egorov et al., 2025), more aggregated trade data (Egorov et al., 2025), and quantitative general-equilibrium trade models (Chowdhry et al., 2024; Flach et al., 2024; Hausmann et al., 2024; Hinz and Monastyrenko, 2022). These quantitative studies typically assume that the announced restrictions cannot be evaded. Reduced-form studies of circumvention document the trade that continues despite the restrictions but do not quantify its consequences for real income. We bridge these approaches by estimating how strongly full and partial bans restrict trade and using these estimates to discipline a model of endogenous transshipment. We can then compare the effects of the bans on Russia, coalition members, and intermediary countries with and without transshipment, and evaluate alternative ways of strengthening the restrictions.

Third, we contribute to the measurement of trade sanctions. We compile a uniquely detailed, tariff line-level dataset on EU export bans that identifies which products are affected, the precise timing of each restriction, and whether bans apply fully or only to specific technical characteristics. Constructing such data is non-trivial because the EU's sanctions regime varies widely across products and over time, often within narrowly defined tariff lines. For example, within a single tariff line covering industrial pumps, only certain models, such as those suitable for chemical-weapons production, are restricted, while others remain exportable. As a result, more than half of tariff lines are initially only partially restricted.[3] Existing sanctions datasets either code sanctions at the country-pair level, with the goal of covering all sanctions worldwide and across all sanction types (Felbermayr et al., 2024; Morgan et al., 2023), or include product-level information without resolving the legal scope of restrictions within tariff lines, as in commonly used sources such as the Global Trade Alert or EU Council regulations (Crozet and Hinz, 2020; Flach et al., 2024). Treating a partially banned tariff line as fully banned would misclassify legal shipments as illicit and mechanically overstate evasion. We overcome this limitation by identifying, for each CN8 product, whether restrictions apply fully or only to specific technical specifications, as well as the exact date at which they become binding, based on TARIC and a review of the relevant EU Council regulations and their annexes.

Finally, we show how to bring a multi-product quantitative trade model to highly disaggregated data (see Caliendo and Parro, 2022; Costinot and Rodríguez-Clare, 2014, for overviews), building on the approach by French (2016). We quantify an Eaton and

[3] Partial sanctions reflect the EU's "smart sanctions" approach, which aims to restrict only items with sensitive or military applications while minimizing collateral damage to legitimate trade.

Kortum (2002)-type framework at the HS6 level despite the absence of globally comparable domestic expenditure at this level of detail. This granularity allows product-specific trade costs and elasticities, distinguishes military-relevant and other critical goods from ordinary products, and maps the legal product coverage of the export bans into the model. We further incorporate partial bans, which raise the cost of direct exports without prohibiting them, and transshipment through competing hubs.

The paper proceeds as follows. Section 2 introduces the customs and export-ban data and explains how we identify evasion. Section 3 documents its magnitude, transshipment modes, hubs, and variation across products. Section 4 develops the quantitative model, estimates the effective trade-cost increase generated by the export bans, and uses these estimates to calibrate the overall cost of transshipment. Section 5 quantifies the effects of the export bans with and without transshipment, and Section 6 compares alternative ways of strengthening the bans. Section 7 concludes.

2 Data and Measurement

To measure transshipment, we combine two sources. First, we construct a novel product-level database of the EU export bans, recording which products are banned and since when. Second, we use Russian customs declarations, which show for each import where the good was made and part of the route it took to Russia.

2.1 The EU Export Bans

Since Russia's full-scale invasion of Ukraine in February 2022, the EU has prohibited its firms from exporting a large and growing set of products to Russia. Successive sanctions packages expanded the list of banned products, and by the end of 2024 the bans covered, fully or in part, product categories that accounted for 79% of Russia's 2019 imports from the EU (see Table A.1 for details).[4] The bans are binding legal prohibitions: EU firms may not sell, supply, or export listed products to Russia, whether directly or indirectly via third countries, and may not knowingly take part in activities that circumvent the

[4] Regulation 833/2014 formulates the measures as outright prohibitions, hence export bans. The US, by contrast, implements its Russia sanctions as export controls, which require a license for listed items and review applications under a policy of denial.

restrictions. Member states enforce the bans by investigating violations and imposing penalties, which can be criminal.[5]

Many EU export bans are defined at a more disaggregated level than the tariff line, the fine-grained product classification in which trade is recorded. For the EU, tariff lines are eight-digit Combined Nomenclature codes, or CN8, and bans are either code-based, covering all variants of a CN8 product, or text-based, covering only variants that meet a certain technical description. The February 2022 ban on aircraft exports is code-based and covers all of chapter 88, so every CN8 product within it is banned. Text-based bans instead define banned variants by technical characteristics that the CN8 classification does not record. For example, multi-component integrated circuits (CN8 8542 31 11) are banned only if their clock frequency exceeds 25 MHz, while circuits with lower clock frequencies can still be legally exported from the EU to Russia.[6] We work at the HS6 level, the finest level at which product codes are internationally comparable and hence the level at which we can combine the EU export bans with the Russian customs data. An HS6 product is therefore only partly covered if bans apply to some of its CN8 codes but not to others.

Identifying partial coverage is central to measuring transshipment, because EU-origin imports of partially banned products can reach Russia legally and would otherwise be wrongly counted as transshipment. Our empirical analysis of how much is transshipped, through which routes, and by whom therefore focuses on fully banned products. Partial bans still covered more than a thousand products at the end of 2024, however, so the model that quantifies the effects of transshipment incorporates both groups, with separate trade cost increases for full and partial bans.

We implement the distinction between fully or partially banned products by combining the EU's Integrated Tariff (TARIC), which records which CN8 codes are restricted and since when, with a manual review of the sanctions annexes, which reveals whether a restriction covers the entire code.[7] From TARIC, we retrieve all export restrictions on Russia under Regulation 833/2014 at a daily frequency for 2022–2024. Restrictions defined

[5] See Article 12 of Regulation 833/2014. Directive (EU) 2024/1226, which member states had to transpose into national law by May 2025, requires them to criminalize intentional violations and circumvention of EU sanctions. Since February 2022, authorities in 32 European countries, including the United Kingdom, Switzerland, and Norway, have opened more than 12,500 investigations into violations of sanctions against Russia and other countries such as Belarus and Iran, and fines imposed since 2017 total nearly EUR 615 million (Handley, 2026).

[6] See Annex VII, item X.A.I.001.a, of Regulation 833/2014. Text-based bans restrict the variants most relevant for military use while leaving variants with mainly civilian uses tradable, in line with the targeting logic of so-called smart sanctions, which aim to restrict specific actors, sectors, or goods while limiting harm to the wider population (Morgan et al., 2023).

[7] TARIC records all EU measures governing the import and export of goods, including tariffs, documentation requirements, and import and export restrictions. It is updated daily and covers all CN8 codes. https://taxation-customs.ec.europa.eu/online-services/online-services-and-databases-customs/eu-customs-tariff-taric_en

at a more aggregated level, such as an HS chapter, apply to all CN8 codes within it. When a restriction is defined at a more aggregated level, such as an HS chapter, all CN8 codes within it inherit the restriction. TARIC does not show, however, whether a restriction covers the entire CN8 code or only some of its variants. To determine this, we use the fact that TARIC links each restriction to the provision of the regulation it implements, and thereby to the annex listing the banned goods, and check by hand how each code is listed in that annex. A restriction is text-based if the annex defines the banned goods by technical description, as for dual-use and advanced technology items, or lists the code with exceptions or value thresholds. A CN8 code is fully banned once at least one code-based restriction covers it. An HS6 product is fully banned if all of its CN8 codes are fully banned, and partially banned if at least one CN8 code is restricted but the product is not fully banned.[8]

TARIC also provides product-specific entry-into-force dates, which often differ from the publication dates of the regulations that are commonly used in the literature (e.g., Crozet and Hinz, 2020; Flach et al., 2024). For example, a regulation published on February 25 may ban the export of oil-refining technology, yet continue to allow exports under contracts concluded before that date until May 27. Such phased implementation and exemptions are difficult to capture from the legal texts alone, whereas TARIC records them for each product.

When the first bans took effect in March 2022, all banned products were only partially banned, but the EU converted many partial bans into full bans over time: by the end of 2024, fully banned HS6 products outnumbered partially banned ones. Figure 1 plots both counts over time. By July 2022, 51% of all HS6 products were subject to EU export bans, but only 688 of them fully, compared with 2,023 partially. By the end of 2024, 2,010 products were fully banned, while 1,163 remained partially banned. Most conversions occurred in one of two ways. First, CN8 codes initially restricted only by technical description, typically as dual-use or advanced technology items, were later listed by code in another annex, so that all of their variants became banned. Second, the EU extended a ban to the remaining CN8 codes within an HS6 product.[9] In both cases, the affected CN8 codes receive an additional code-based provision in TARIC, so our daily classification records each conversion on the day it takes effect.

[8] The bans are defined in the 2022 version of the nomenclature, while we express all products in the 2017 revision of the HS using standard UN concordance tables (https://unstats.un.org/unsd/classifications/Econ). An HS2017 product is classified as fully banned only if all of its corresponding HS2022 codes are fully banned, which avoids mechanically overstating the scope of the bans. At the monthly frequency, a product is coded as banned only if the restriction is in force for at least 15 days of the month.

[9] Conversions from text-based to code-based listings are concentrated in dual-use and high-tech goods, such as Optics and Arms & Ammunition, while extensions to the remaining CN8 codes are concentrated in Machinery & Electrical Equipment and in Plastics. See Figure A.1 in the Appendix.

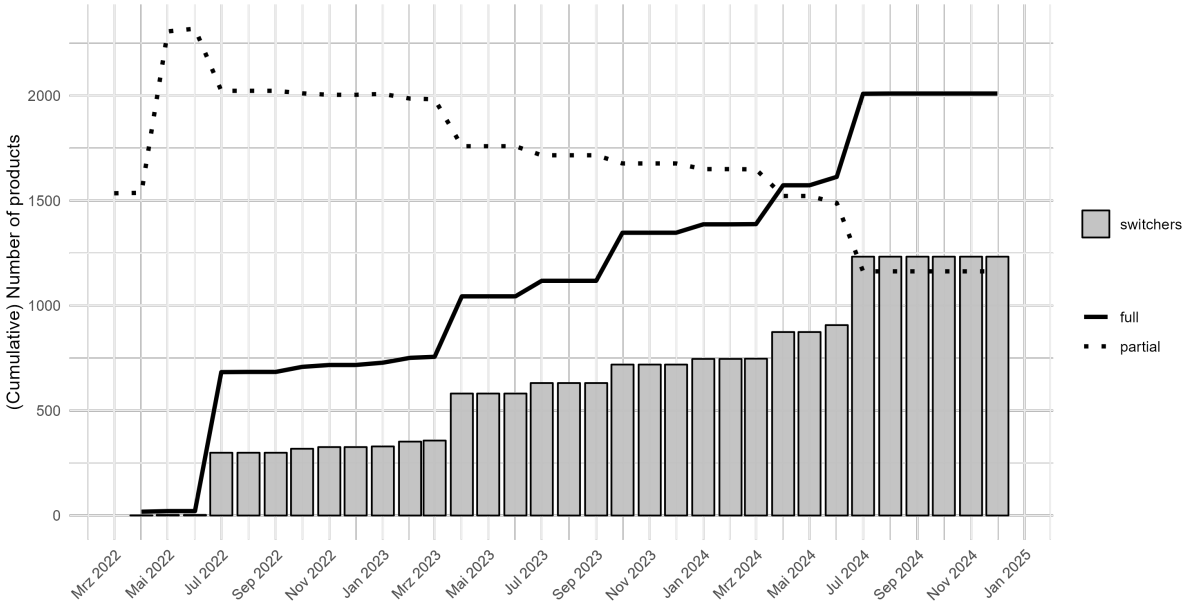


Figure 1. EU Export Bans Over Time

Note: The figure shows the cumulative number of HS6 products covered by EU export bans over time. The solid line denotes fully banned products, the dotted line partially banned products (accounting for transitions from partial to full coverage), and the gray bars indicate the number of products that switch from partial.

2.2 EU Export Statistics

Official EU export statistics confirm that products we classify as fully banned stopped flowing directly to Russia altogether once the bans took effect. We use Eurostat's Comext database, which reports monthly exports of each EU member state by destination and CN8 product, valued in euros. Because Comext is compiled from the export declarations that EU firms file at the border, it records what the EU exports directly to Russia and to third countries. Figure 2 plots monthly EU exports to Russia of products fully banned by July 2022 and of products that remained partially banned through December 2024. Exports of fully banned products fall to zero in the month the full ban takes effect and stay there. Exports of partially banned products decline but do not collapse, consistent with many of their variants remaining legal to export.

2.3 Russian Customs Data

Our data cover the universe of Russian import transactions from countries outside the Eurasian Economic Union (EAEU) in 2019 and 2022–2024, with detailed information on buyers, senders, products, and the start and end points of each shipment's route to

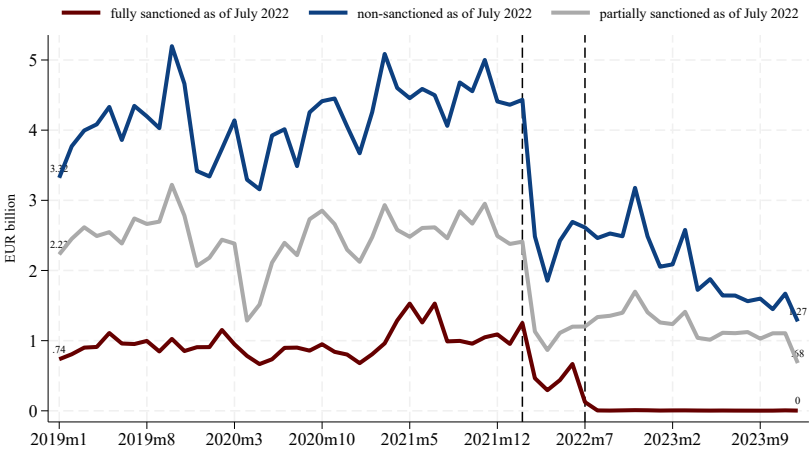


Figure 2. Direct EU Exports to Russia of Fully and Partially Banned Products
Note: The figure shows direct monthly EU exports to Russia in billion euros for products fully banned by July 2022 and products partially banned through December 2024. *Source:* Eurostat, Comext.

Russia.[10] Each customs declaration lists one or more transactions.[11] For each transaction, we observe the Russian buyer (name, tax ID, and address), the sender (name and address), a ten-digit product code, a detailed product description, the value in US dollars, the weight in kilograms, and three countries: the country of origin, the trading country, and the dispatch country. The country of origin is where the good was produced,[12] the trading country is the country of the seller, and the dispatch country is where carriage to the Russian buyer began, as stated in the transport document; earlier legs and transit countries are not recorded.

Two further variables describe how the goods reached Russia: the sender and the clearance office. The sender reported in the declaration is the consignor named in the transport document under which the final carriage to Russia began. The sender therefore need not be the seller: it can be the seller, the Russian buyer, a forwarder acting for either, or an intermediary that bought the goods and shipped them on to Russia.[13] The sender differs from the carrier, the firm that physically moves the goods (e.g., DHL or

[10] The data are not publicly available; we obtained them from a commercial data provider. Appendix B compares them with mirror trade statistics at several levels of aggregation, and Section 2.5 discusses their reliability.

[11] In customs terminology, a transaction corresponds to a goods item of the declaration.

[12] Under EAEU rules, the country of origin is the country in which a good was wholly produced or last sufficiently processed. Transit, storage, or repackaging in a third country does not change a good's origin. See the non-preferential rules of origin approved by Decision No. 49 of the Council of the Eurasian Economic Commission of 13 July 2018, as amended.

[13] See box 2 in the instructions for completing the goods declaration, Decision No. 257 of the Customs Union Commission of 20 May 2010, as amended. The declaration also records the delivery terms (Incoterms). Under E- and F-terms such as EXW or FCA, the buyer or its forwarder books the main carriage; under C- and D-terms such as CPT or DAP, the seller or its forwarder does. The firm that books the carriage is not always the one named as consignor, however: under F-terms, the seller often appears as shipper on the bill of lading.

UPS), which the declaration does not name. The clearance office is the Russian customs office where the goods were cleared and marks the end point of the route we observe.

A single import transaction can involve several countries, each recorded in a different field, as the hypothetical transaction in Table 1 illustrates for a product not subject to the bans. A German producer sells a good to an Austrian distributor, which stores it in Poznań, Poland. A Russian buyer located in Moscow buys the good and hires a Lithuanian forwarder, which is named as consignor in the transport document and has a Polish trucking firm carry the good through Belarus to Moscow. The declaration reports Germany as the country of origin, Austria as the trading country, the Lithuanian forwarder as sender, Poland as the dispatch country, and a Moscow customs office as the clearance office, while neither the carrier's name nor the route through Belarus appears in our data. In most transactions, however, several of these fields coincide, for example, when a manufacturer sells and ships its good directly, so that the country of origin, the trading country, and the dispatch country are the same. In 2019, 83% of EU-origin import value came from such transactions.

Table 1. Parties and Route of a Hypothetical Transaction in the Customs Data

Panel A: Parties to the Transaction

Party	Example	Recorded as (box)	Definition
producer	German manufacturer	origin country, DE (16)	country where the good was produced
seller	Austrian distributor	trading country, AT (11)	country of the firm that sold the goods to the Russian buyer
sender	Lithuanian forwarder, hired by the buyer (FCA)	sender name and address (2)	party to the transport contract with the carrier
carrier	Polish trucking firm	—	not recorded
buyer	Russian buyer	consignee tax ID and name (8)	Russian firm the goods are delivered to

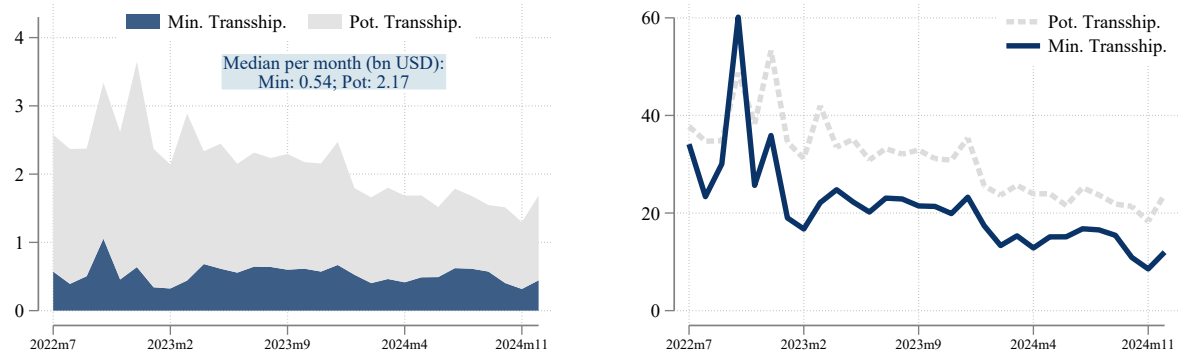
Panel B: Physical Route of the Goods

Leg	Example	Recorded as (box)	Definition
producer	German manufacturer	origin country, DE (16)	country where the good was produced
first trip	to the distributor's warehouse in Poznań	—	carriage to someone other than the Russian buyer
dispatch	Poznań	dispatch country, PL (15)	first country where the goods were accepted for carriage to the Russian buyer
transit	Belarus	—	countries crossed after dispatch
clearance	customs office, Moscow	office code (30)	customs office for the region of the buyer's warehouse

Note: Stylized transaction of a product not subject to the bans. Box numbers refer to the EAEU goods declaration (Decision No. 257 of the Customs Union Commission of 20 May 2010). A dash means the declaration does not record the party or the leg of the physical route.

2.4 Measuring Transshipment

We define transshipment as Russian imports of banned EU-origin goods. Measuring it requires combining the country-of-origin information in the Russian customs records with information on whether the EU export bans cover the respective product fully or only partially. For products fully banned at the time of import, every EU-origin import counts as transshipment, because the ban rules out legal direct exports; consistent with this, EU export statistics record none (Figure 2). Banned variants of partially banned products are likely transshipped as well, but our data are too aggregated to separate them from permitted variants, which EU firms may still export to Russia directly. EU-origin imports of fully banned products therefore give a lower bound on transshipment, and adding EU-origin imports of partially banned products gives an upper bound. Without the distinction between full and partial bans, legal direct exports of permitted variants would be counted as transshipment, overstating its magnitude.[14] The resulting flows are substantial, amounting to between USD 0.5 and 2 billion per month, or about 20% of pre-war imports of the same products (Figure 3).



(A) Volume (USD bn per month) (B) Share of Pre-War Imports

Figure 3. Transshipment of Banned EU-Origin Goods to Russia

Notes: The figure shows monthly Russian imports of EU-origin goods under an EU export ban, from June 2022 to December 2024. The lower bound includes only HS6 products fully banned in that month; the upper bound adds partially banned HS6 products, in which only some tariff lines are banned. Panel B expresses the values relative to average monthly 2019 imports of the products banned in that month.

EU firms largely stopped selling fully banned products to Russian buyers, at least on paper. Transshipment has a contractual and a physical dimension, which the customs declarations record in the trading and the dispatch country, respectively. The trading country captures the contractual dimension, namely who officially sells the goods to the Russian buyer. Because any contract between an EU seller and a Russian buyer would violate the ban, the seller of a fully banned EU-origin product should be located outside the EU, whatever physical route the goods take. In line with the bans, the EU's share as

[14] Studies that classify products solely as sanctioned or not, such as Egorov et al. (2025), correspond to our upper bound.

trading country fell from 77% of the value of these imports in January 2019 to 15% in December 2024 (Figure 4, Panel a). For never-banned products, the share remained high, at 75% in 2019 and 82% in 2024 (Panel b).

Physically, banned goods reach Russia in one of two ways, re-exported from a third country or diverted en route after leaving the EU. For a re-export, a firm in a third country buys the goods and ships them on to the Russian buyer, so that country is both the trading and the dispatch country, and the contractual and physical routes coincide. Goods diverted en route instead leave the EU declared for export to a third country, such as Kazakhstan, and the sender has the carrier redirect them to Russia along the way.[15] They enter Russia either through a non-EU transit country, most often Belarus, where the redirection takes place, or directly, usually from the Baltic states, and are cleared at a Russian customs office.[16]

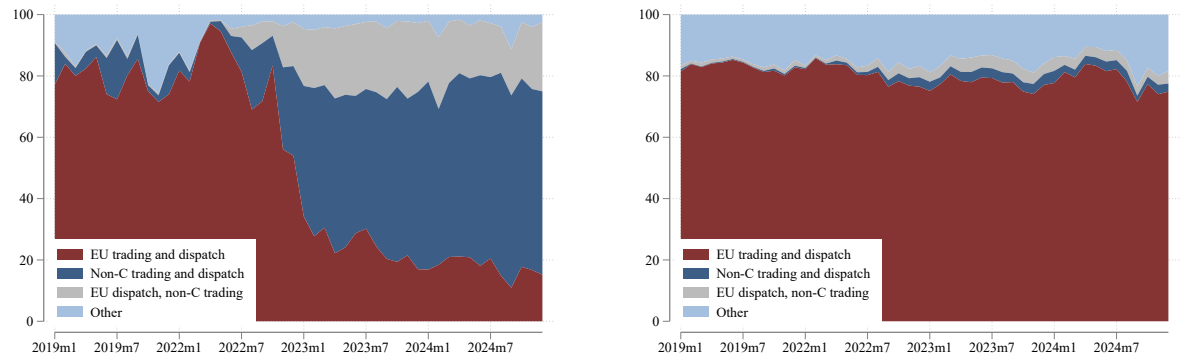
The dispatch country tells the two modes apart, and in December 2024, re-exports accounted for 60% of the value of EU-origin imports covered by the full bans and diversions en route for 39% (Figure 4). Because a diverted shipment began in the EU, the declaration records an EU member as the dispatch country, regardless of where the seller, recorded as the trading country, is located. Were the good in Table 1 fully banned, a re-export via a Turkish trading firm would record Turkey as both dispatch and trading country, whereas a diversion en route would record an EU member as the dispatch country and, depending on the paperwork, a third country or an EU member as the trading country. For never-banned products, by contrast, re-exports through non-coalition countries remain negligible, at 2% of import value.

Diversions en route also explain why the EU share as trading country declined only gradually and never reached zero. Russian customs record as trading country the country in which the Russian importer's counterparty is registered or, absent a contract, the country indicated in the commercial documents, such as the invoice.[17] Shipments diverted en route can keep the EU seller as counterparty, in violation of the ban, or arrive with its invoice, so customs record an EU member as trading country, while EU export statistics show the third country as destination. In the first months after the bans, many diversions ran on such EU paperwork. Over time, intermediaries in third countries increasingly invoiced the goods themselves, so the recorded trading country moved outside the EU even for goods still dispatched from the EU.

[15] The sender recorded in the Russian declaration is often an EU firm, because the shipment starts in the EU and its transport documents name the original shipper unless they are reissued en route. An EU sender therefore need not have violated the ban, since the goods may have been sold to a buyer in a third country who then arranged the diversion.

[16] Goods cleared in another EAEU member, such as Belarus, and then moved on to Russia do not appear in our data, so our measure understates transshipment.

[17] See box 11 in the instructions for completing the goods declaration, Decision No. 257 of the Customs Union Commission of 20 May 2010, as amended.



(A) Fully Banned by July 2022 (B) Never Banned

Figure 4. Trading and Dispatch Countries of EU-Origin Imports (in %)
Notes: Monthly (2019, 2022–24) shares of each trading–dispatch country combination in the value (USD) of Russian imports of EU-origin products, by ban status. For banned products, non-coalition trading and dispatch countries indicate re-exports, and an EU dispatch country indicates diversion en route.

Whatever the mode, nearly all transshipped goods pass physically through a third country before entering Russia, and we call that country the transshipment hub. In a re-export, the hub is simply the country where a firm buys the goods and resells them to the Russian buyer. Goods diverted en route also tend to pass through a third-country hub, because they are easier to redirect once they are beyond the reach of EU enforcement, for example when goods declared in transit to Kazakhstan cross Belarus, which has no customs border with Russia, and end up in Moscow instead. In both cases, goods flow through the countries that make indirect exports from the EU to Russia cheapest. Such countries typically border Russia or the EU, share a customs union with either, or lie on established freight corridors. Our model in Section 4 captures these differences through hub-specific wedges, which determine how costly it is to redirect goods through a country.

For imports diverted en route, the customs declarations do not show where the goods were redirected, so we infer the hub from their most likely route to Russia. The declarations record the EU country from which the goods were dispatched to Russia and the Russian customs office at which they were cleared.[18] We compute the fastest connection between these two locations, which may combine road, ferry, and container-ship legs, and take the first non-EU country along it as the hub. If the route crosses no third country, the redirection must take place within the EU, and we take the last EU country before the Russian border as the hub. In 2024, 58% of the value of diverted imports passed through Belarus and 6% through Turkey, while 17% entered Russia directly from Latvia. Taking both modes together, 90% of the value of all transshipped imports passed through a hub outside the EU.

[18] Clearance offices are available only for 2023–2024 and are missing for the first quarter of 2024. Because direct flights between the EU and Russia ceased in 2022, we assign hubs to EU-dispatched imports cleared at an airport in proportion to their shares among non-EU-dispatched imports cleared at the same airport.

2.5 Data Quality of the Customs Data

A natural concern is whether the Russian customs records remain reliable after the invasion. At least three pieces of evidence make us confident that they do. First, the records closely track the exports reported by Russia's non-sanctioning trading partners, both in aggregate and by HS2 sector and partner country (Figure B.1).[19] The only exception is arms and ammunition, which we therefore exclude from all analyses.

Second, criminal investigations by Western authorities that started from such records corroborate that the records capture even illegal transactions. For example, Dutch journalists used Russian customs records in December 2023 to show that a Dutch firm had shipped sanctioned goods to Russia, and in January 2024 Dutch authorities arrested three people associated with the firm on suspicion of sanctions violations.[20] Similarly, the Munich public prosecutor's office opened an investigation into a German machine tool manufacturer in February 2025, shortly after a television report based on Russian customs records had traced the firm's machines to Russia via third countries, and later charged three of its employees.[21]

Third, the only documented case in which Russian authorities altered the customs records occurred at the end of our sample period, and they did so by ceasing to record sensitive imports rather than by falsifying their origin or product codes. According to investigative reporting, Russian customs stopped recording imports in about 180 product codes covering sanctioned electronics and industrial equipment from the end of 2024 onward (The Insider, 2025). The imports never reappeared under other codes or from other countries of origin, and the importing firms remained active, which rules out that they simply stopped importing. Although none of these checks can rule out manipulation entirely, together they indicate that the Russian customs records provide a reliable basis for our analysis.

[19] Other studies using the Russian customs data compare total Russian imports with official and mirror statistics and find a close match (Babina et al., 2026; Chupilkin et al., 2023a; Egorov et al., 2025; Korovkin and Makarin, 2023). We extend this comparison to sectors and partner countries.

[20] The journalists obtained the customs records from the commercial data provider ImportGenius (https://nos.nl/nieuwsuur/collectie/13964/artikel/2501582-verantwoording-onderzoek-nieuwsuur-handel-naar-rusland), which distributes the same underlying customs records as our data; the entries we compared are identical. On the arrests, see the press release of the Dutch Fiscal Information and Investigation Service (https://www.fiod.nl/drie-aanhoudingen-in-onderzoek-naar-omzeiling-sanctiewetgeving/) and the report linking the investigation to the journalists' findings (https://nltimes.nl/node/70750).

[21] The report, broadcast by Arte on January 29, 2025, draws on records from the commercial data provider ExportGenius (https://www.zdf.de/video/magazine/collection-index-page-artede-collection-artede-rc-024364-1746/page-video-artede-mit-offenen-daten---enthuellungen-ueber-einen-verbotenen-handel-100), which likewise distributes the same underlying customs records as our data. On the investigation, see the prosecutor's statement as reported in https://www.produktion.de/wirtschaft/sanktionsverstoss-durchsuchungen-bei-werkzeugmaschinenhersteller-284.html and https://www.handelsblatt.com/unternehmen/mittelstand/mittelstand-ermittlungen-gegen-maschinenbauer-wegen-russland-sanktionen/100145150.html.

3 Reduced Form Evidence of Transshipment

Next, we document three facts about transshipment of banned EU goods to Russia: how much more costly it made these goods, which firms carried it out, and which routes it took.

3.1 Estimating the Actual Trade-Cost Increase

Gravity lets us infer how much the bans raised trade costs from how much Russian imports of banned EU goods fell. A broad class of trade models, including the Armington, Krugman, Eaton–Kortum, and Melitz–Pareto models, delivers the same gravity structure (Arkolakis et al., 2012; Head and Mayer, 2014). In all of them, Russian imports of product k from origin e in month t take the following form in logs:

$$\log X_{et}^k = \underbrace{\log A_{et}^k}_{\text{exporter-specific}} + \underbrace{\log B_t^k}_{\text{importer-specific}} - \underbrace{\theta^k \log \tau_{et}^k}_{\text{bilateral trade cost}} . \tag{1}$$

The exporter-specific term A_{et}^k summarizes the supply side: how competitive origin e is in product k in a given month, regardless of the destination. On the demand side, the importer-specific term B_t^k measures how much Russia buys of product k in a given month and how many suppliers compete for those purchases. It rises, for example, when the war economy increases Russian demand for certain products.[22] The bilateral term τ_{et}^k is the iceberg trade cost for Russia of sourcing product k from origin e, to which imports respond with the trade elasticity θ^k. The bans enter through this term as $\log \tau_{et}^k = \delta_t^F S_F^k \, EU_e + \log \tau_e^k + \log \tau_{et}$, where S_F^k indicates fully banned products, EU_e indicates the 27 EU member states, and δ_t^F is the log increase in trade costs caused by the full bans in month t. The remaining terms capture time-invariant and origin-wide trade costs. Substituting this expression into equation (1) and replacing the exporter- and importer-specific terms and the remaining trade-cost terms with fixed effects yields our estimating equation, whose coefficient on the ban indicator measures the average of $-\theta^k \delta_t^F$ across fully banned products.

We estimate the trade cost increase with a triple-difference-in-differences (triple DiD) event study at the HS6–origin–month level for 2019 and 2022–2024.[23] Identification comes from the change in Russian imports of banned products from the 27 EU member states, relative to the same products from non-coalition origins and to never-sanctioned products,

[22] In the Eaton–Kortum model, for example, $A_{et}^k = T_e^k \, w_{et}^{-\theta^k}$, where T_e^k is technology and w_{et} the wage, and $B_t^k = X_t^k \, (P_t^k)^{\theta^k}$ up to a constant, where X_t^k is Russian expenditure on product k and P_t^k its price index.

[23] The sample excludes coalition countries outside the EU, for which we lack comparably detailed data on the export bans.

estimated separately for each month. Besides never-sanctioned products, the sample includes only products fully banned by July 2022, so that each product's treatment status stays fixed after the bans take effect. The estimating equation is

$$X_{et}^{k} = \exp\Big[\sum_{m \neq m_0} \beta_m^F \cdot S_F^k \cdot EU_e \, \mathbf{1}\{t = m\} + \mu_e^k + \mu_{et} + \mu_t^k\Big] + \epsilon_{et}^k, \tag{2}$$

where X_{et}^k denotes Russia's imports of product k from origin e in month t, the ban indicator is defined as above, and m_0 is January 2019, the reference month. We estimate equation (2) by Poisson pseudo-maximum likelihood (Santos Silva and Tenreyro, 2006). Unlike a log-linear regression, PPML is consistent under heteroskedasticity and keeps zero flows, which matter here because the bans aim to push flows to zero. Standard errors are two-way clustered by product and origin country.

The fixed effects absorb the supply and demand terms of the gravity equation and the trade costs unrelated to the bans, so the treatment coefficients capture only the ban-induced change in trade costs. Product–origin fixed effects μ_e^k absorb persistent supply strengths and time-invariant trade costs τ_e^k, such as distance. Origin–month fixed effects μ_{et} absorb changes in each origin's competitiveness, such as wages, and origin-wide trade cost shocks τ_{et} that hit all of an origin's products alike. Other sanctions and war-related shocks fall into this category: financial sanctions, the exclusion of Russian banks from SWIFT, each origin's exchange rate against the ruble, and the reputational risk of trading with Russia affect all exports of an EU member state, not only banned products. Product–month fixed effects μ_t^k absorb the demand side, that is, Russian demand for product k and the competition among its suppliers. They also absorb Russia-wide shocks such as swings in the ruble or in oil prices, which shift demand for a product regardless of its origin.[24]

The full export bans reduced Russian imports of fully banned EU-origin products by 85%, and the effect persisted through the end of 2024 (Figure 5). The decline is measured relative to imports of the same products from non-coalition origins and relative to imports of never-sanctioned products. We find no evidence of differential pre-trends, and the coefficients remain insignificant in the first months of the war, when most of the bans were not yet in force.

The declines imply that importing banned EU goods became considerably more costly, but far from prohibitively so. We recover the trade cost increase for each product by rescaling the static estimate with its own trade elasticity, $\exp(-\hat{\beta}/\theta^k) - 1$, using the product-specific elasticities from Fontagné et al. (2022). For the median fully banned flow,

[24] With Russia as the only importer, the product–month fixed effects are importer–product–month fixed effects. Origin–product–month fixed effects would absorb the treatment, so we assume that supply shocks in EU member states, such as wage changes, did not differ systematically between banned and other products.

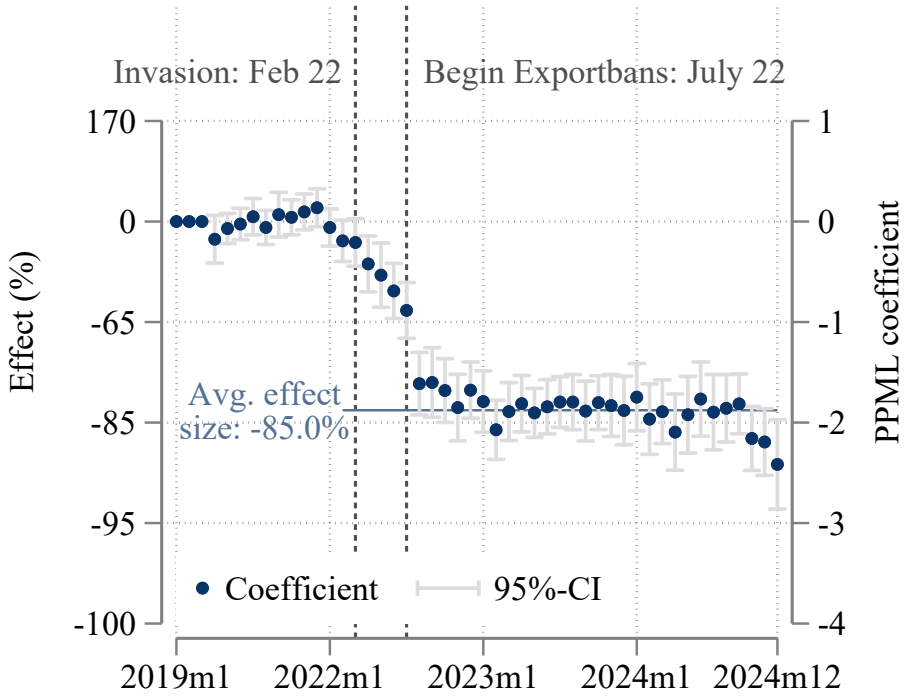


Figure 5. Event Study: Full Export Bans and Russian Imports

Notes: The figure plots monthly PPML coefficients $\hat{\beta}_m^F$ of equation (2) for Russian imports of products fully banned by July 2022, with never-sanctioned products as controls and HS 88 excluded. Coefficients are relative to January 2019 (right axis); the left axis shows implied trade-flow changes, $(e^{\hat{\beta}_m^F} - 1) \times 100\%$. The horizontal line marks the average post-ban effect. Bars show 95% confidence intervals clustered by product and origin; vertical lines mark the invasion (February 2022) and the export bans (July 2022).

sourcing the product after the ban is 69% more costly than importing it directly before the war. A perfectly enforced ban would raise trade costs to infinity; the finite increase instead reflects the cost of reaching Russia through transshipment.

3.2 Adjustment Along Routes and Sellers

The stable aggregate effect of full export bans masks a shift in how the remaining imports reach Russia. From late 2022 to autumn 2024, the effect in Figure 5 stays near −85 percent, although the coalition stepped up enforcement against circumvention throughout the period, from bans on transit through Russia to contractual re-export clauses and sanctions on third-country intermediaries.[25] To see whether the type of transshipment changes, we split the treated EU-origin imports in two ways and re-estimate equation (2) for each subset, keeping imports from non-coalition origins as controls. The first split compares goods dispatched from the EU with goods dispatched by non-coalition countries. The second takes goods dispatched from the EU and compares all of them with the subset

[25] The EU banned the transit of a growing set of banned goods through Russia from February 2023 (Regulations (EU) 2023/427 and 2023/1214) and required exporters of the most sensitive goods to include "no re-export to Russia" clauses in contracts from March 2024 (Regulation (EU) 2023/2878).

sold by an EU trading party. Since each series comes from its own regression, we compare how the series evolve, not their levels. In the second split, one series is a subset of the other, so the gap between them approximates the change in the share sold by EU trading parties.

Imports of EU-origin goods dispatched from non-coalition countries respond immediately to the ban and then stay at that high level, while those dispatched from the EU erode gradually. Panel A of Figure 6 shows that non-coalition dispatch rises by roughly 170% ($\hat{\beta}_m^F \approx 1$) as soon as the ban takes effect and remains at that level through 2024.[26] EU dispatch instead keeps falling, from −85% in August 2022 ($\hat{\beta}_m^F = -1.9$) to −96% in September 2024 ($\hat{\beta}_m^F = -3.3$). Since the aggregate effect remains stable over the same period, non-coalition dispatch must absorb the lost value, consistent with its rising share in Figure 4; panel A is too imprecise to detect the corresponding increase directly.

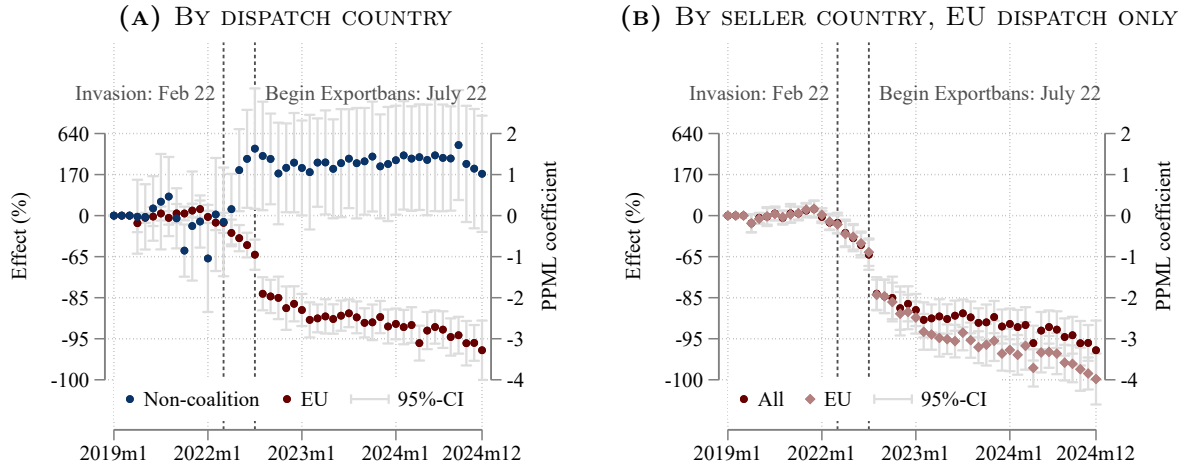


Figure 6. Event Study: Banned EU-Origin Imports by Dispatch and Seller

Notes: The figure plots monthly PPML coefficients $\hat{\beta}_m^F$ of equation (2) for Russian imports of EU-origin products fully banned by July 2022, with non-coalition origins and never-sanctioned products as controls and HS 88 excluded. Panel A compares EU-origin goods dispatched from the EU with those dispatched and sold by non-coalition countries (re-exports); panel B compares all goods dispatched from the EU with the subset also sold by an EU trading party, so a gap signals a shift to non-EU sellers on paper. Each series comes from a separate regression, so coefficients do not add up across series. Coefficients are relative to January 2019 (right axis); the left axis shows implied trade-flow changes, $(e^{\hat{\beta}_m^F} - 1) \times 100\%$. Bars show 95% confidence intervals clustered by product and origin; vertical lines mark the invasion (February 2022) and the export bans (July 2022).

As enforcement tightens, the remaining EU sellers lengthen the transaction chain on paper only, adding a trading party in a third country while the goods are still dispatched from the EU and diverted en route.[27] Panel B of Figure 6 shows that imports dispatched and sold by EU parties move with all EU-dispatched imports until late 2022 and then fall

[26] The increase starts from a low base: before the war, non-coalition countries dispatched only a small share of EU-origin imports of fully banned products (Figure 4).

[27] The shift is specific to EU dispatch. Imports dispatched from non-coalition countries are almost always also sold by a non-coalition trading party.

faster, reaching −98% by the end of 2024 ($\hat{\beta}_m^F = -3.98$). Direct sales of banned goods by EU parties to Russia, the transshipment mode that leaves the clearest record of a violation, have thus nearly vanished from the Russian customs data. The gap between the two series shows, however, that the decline in EU-sold imports is not matched by a decline in EU dispatch; the goods increasingly leave the EU with a non-EU seller.

3.3 The Role of Intermediaries

Banned EU-origin goods increasingly reach Russia through trading firms rather than through the firms that produce them. We identify trading firms from the sender names on the customs declarations.[28] A hand-coded dictionary of 29 terms in eight languages, matched as whole words, flags a sender as a trading firm if its name contains terms such as "trading," "import-export," or the Turkish *dış ticaret* (foreign trade).[29] Trading firms account for 13.2% of the 1.1 million distinct sender names. Because names without such a term remain unflagged, the measure is a lower bound on the role of trading firms.

The shift toward trading firms began right after the bans and grew steadily through 2024. We re-estimate equation (2) by OLS with the share of declarations filed by trading firms in each HS6–origin–month cell as the outcome, keeping only the interaction for fully banned products. The specification weights each cell by its number of declarations, and clusters standard errors by origin and product. Relative to the control groups the share of declarations for fully banned EU-origin products filed by trading firms rose by 5 percentage points in August 2022, the month after the bans took effect, and by 15 percentage points by 2024, with no pre-trends (Figure 7).

4 A Quantitative Model of International Trade and Transshipment

To quantify how much transshipment undermines the export bans and how alternative policies would change that, we develop a general-equilibrium trade model in which banned goods reach Russia endogenously through transshipment hubs. The framework combines a multi-product Eaton and Kortum (2002) (henceforth, EK) structure, which captures substitution across source countries within narrowly defined products, with two features that matter for export bans. First, nested final demand distinguishes military-relevant goods, other critical goods, and all remaining goods, allowing substitution across these broad groups to be harder than substitution across products within a group. Second,

[28] The sender is the firm named as consignor in the transport document, that is, the firm that booked the transport (Section 2.4).
[29] Appendix C.1 lists the full dictionary.

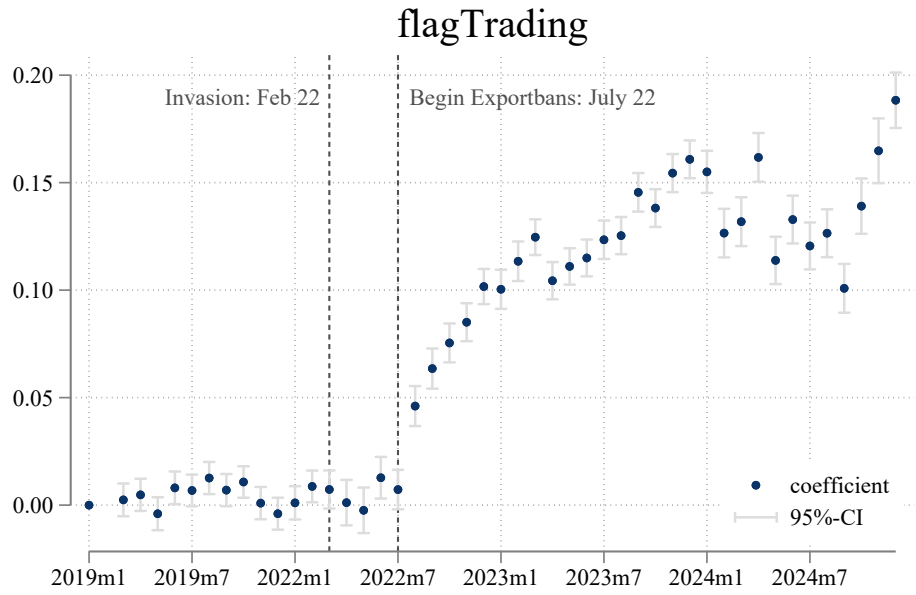


Figure 7. Trading Firms Among Senders of Fully Banned Products

Notes: The figure shows the monthly coefficients of the triple-difference event study in equation (2), estimated with the share of declarations filed by trading firms in each HS6–origin–month cell as the outcome. The coefficients compare fully banned with never-sanctioned products and EU member states with non-coalition origins, relative to [reference month], and are expressed in percentage points. The regression is linear and weighted by the number of declarations per cell. Bars show 95% confidence intervals based on standard errors clustered by origin and product. The years 2020 and 2021 are not observed.

export bans do not necessarily stop Russia from buying banned goods. Partial bans raise the cost of direct exports (without prohibiting them), and fully banned coalition-origin goods can reach Russia through third-country intermediaries, which differ in their capability in rerouting banned goods.

The model distinguishes trade diversion, Russia's substitution toward non-sanctioning producers, from transshipment, through which a banned EU-product still reaches Russia through a hub. We use it to quantify the effects of the export bans on trade flows, real income, and access to military-relevant and critical goods, and to study how transshipment opportunities affect the design of export bans. The calibration in Section 4.3 builds on the estimated trade cost increases from the bans that we estimated with the triple-difference design in Section 3.1.

4.1 The Baseline Economy

The framework builds on the multi-product version of EK (see Costinot et al., 2012; French, 2016). Countries trade intermediate varieties that are assembled into a finite set of non-tradable final products. Countries are indexed by $e, i \in \{1, 2, \ldots, N\}$, where

e denotes the exporter and i the importer. Products are indexed by $k \in \{1, 2, \ldots, K\}$, while ω^k indexes the tradable intermediate varieties used to assemble product k.

We divide products into three mutually exclusive and exhaustive groups, $\mathcal{G} = \{M, C, O\}$, where M denotes military-relevant goods, C other critical goods, and O all remaining goods. Let $\mathcal{K}_g$ denote the set of products assigned to group g, and let $g(k)$ denote the group containing product k.

Labor is the only production input and households supply it inelastically to competitive domestic producers. We first describe final demand and then turn to production, trade, and equilibrium.

4.1.1 Demand Side: Households

Country i is populated by L_i households, each of which inelastically supplies one unit of labor to domestic producers. For tractability, we represent their aggregate final absorption through a representative household.[30] The representative household has CES preferences over the three non-tradable group composites,

$$U_i = \left[\sum_{g \in \mathcal{G}} (\alpha_i^g)^{1/\nu} (Q_i^g)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \qquad \nu > 0, \tag{3}$$

where $\alpha_i^g > 0$ is a group-specific demand weight, normalized such that $\sum_g \alpha_i^g = 1$, and ν is the elasticity of substitution across the three broad groups (M, C, and O).

Each group composite is assembled from the products assigned to that group, $\mathcal{K}_g$,

$$Q_i^g = \left[\sum_{k \in \mathcal{K}_g} (q_i^k)^{\frac{\sigma_g - 1}{\sigma_g}} \right]^{\frac{\sigma_g}{\sigma_g - 1}}, \qquad \sigma_g > 0, \tag{4}$$

where σ_g governs substitution across products within group g. Finally, every product k is composed of a continuum of k-specific tradable varieties, with the measure of varieties normalized to one,

$$q_i^k = \left[\int_0^1 \left(q_i^k(\omega^k) \right)^{\frac{\eta^k - 1}{\eta^k}} \mathrm{d}\omega^k \right]^{\frac{\eta^k}{\eta^k - 1}}.$$

We assume $\eta^k > \sigma_{g(k)} \geq \nu > 0$, with the usual limiting expressions when an elasticity equals one. Thus, varieties within a specific product are closer substitutes than different

[30] This is only an expositional convention. Equivalently, competitive assemblers could purchase the tradable varieties, combine them first into product k and then into the three group composites M, C, and O, and sell those composites to the representative household. With constant returns and zero profits, the assemblers' unit costs are exactly the price indices derived below, so the demand and equilibrium conditions are unchanged.

products, while products within the same broad group can be closer substitutes than products of different groups. When $\sigma_g = \nu = \sigma$ for all groups, the two upper tiers reduce to a single CES aggregator over products, in which each product has the demand weight of its group.

The representative household maximizes utility subject to the budget constraint $E_i \geq \sum_{k=1}^{K} \int_0^1 p_i^k(\omega^k) q_i^k(\omega^k)\, \mathrm{d}\omega^k$, where E_i is aggregate income and $p_i^k(\omega^k)$ is the minimum delivered price of variety ω^k across all potential source countries, as explained in the next subsection. Let P_i^k, P_i^g, and P_i denote the product-, group-, and aggregate price indices in country i, respectively. Expenditure minimization yields

$$P_i^k = \left[\int_0^1 \left(p_i^k(\omega^k) \right)^{1-\eta^k} \mathrm{d}\omega^k \right]^{1/(1-\eta^k)}, \tag{5}$$

$$P_i^g = \left[\sum_{k \in \mathcal{K}_g} (P_i^k)^{1-\sigma_g} \right]^{1/(1-\sigma_g)}, \tag{6}$$

$$P_i = \left[\sum_{g \in \mathcal{G}} \alpha_i^g (P_i^g)^{1-\nu} \right]^{1/(1-\nu)}. \tag{7}$$

Let $X_i^g = P_i^g Q_i^g$ and $X_i^k = P_i^k q_i^k$ denote group- and product-level expenditure, with $X_i = \sum_{g \in \mathcal{G}} X_i^g = \sum_{k=1}^{K} X_i^k$. The expenditure shares are then

$$\frac{X_i^g}{X_i} = \alpha_i^g \left(\frac{P_i^g}{P_i} \right)^{1-\nu}, \tag{8}$$

$$\frac{X_i^k}{X_i^g} = \left(\frac{P_i^k}{P_i^g} \right)^{1-\sigma_g}, \qquad k \in \mathcal{K}_g. \tag{9}$$

Combining the two expressions,

$$\frac{X_i^k}{X_i} = \alpha_i^{g(k)} \left(\frac{P_i^{g(k)}}{P_i} \right)^{1-\nu} \left(\frac{P_i^k}{P_i^{g(k)}} \right)^{1-\sigma_{g(k)}}. \tag{10}$$

The upper nest governs substitution across the three broad product groups. For a given increase in a group's relative price, a lower ν causes its expenditure share to fall less (and even to rise if $\nu < 1$). The model therefore allows Russia to protect expenditure on strategically important products when they become more costly, rather than assuming that Russia substitutes between, for example, military inputs and ordinary consumer goods as easily as between products of the same group.[31]

Next, we outline how the intermediate varieties are produced and shipped.

[31] The military-relevant composite is a model-based measure of real access to that product group. It should not be interpreted as a direct measure of military capability or as a military production function.

4.1.2 Supply Side: Production of Tradable Varieties

Intermediate varieties are produced and shipped by perfectly competitive firms using labor as the only input in production.

Trade costs. Throughout the paper, we index the exporter by e and the importer by i. A subscript ei can be read as "from country e to i." Intermediate varieties can be traded subject to standard iceberg trade costs. Firms in e need to ship $\tau_{ei}^k \geq 1$ units of a variety ω^k for one unit to arrive in i. We normalize $\tau_{ii}^k = 1$ and assume that the so-called triangle inequality holds, such that $\tau_{ei}^k \leq \tau_{eh}^k \tau_{hi}^k \ \forall (e, h, i, k)$. This no-arbitrage condition will be central in the transshipment analysis, as detailed in Section 4.2.

Production technology. Labor is perfectly mobile across products but immobile across countries, which yields a common wage across products within each country. Firms operate under perfect competition with constant returns to scale, and $\varphi_e^k(\omega^k)$ denotes the labor productivity of country e in producing variety ω^k. Hence, the cost of producing one unit of ω^k and shipping it to i is given by the marginal cost, $c_{ei}^k(\omega^k) := (w_e \tau_{ei}^k)/\varphi_e^k(\omega^k)$, where w_e is the wage rate in country e. Note that $c_{ei}^k(\omega^k)$ is also the price offered by e to i under perfect competition.

Following the literature, we assume that $\varphi_e^k(\omega^k)$ is drawn independently from a Fréchet distribution, $F_e^k(\varphi) = \exp(-T_e^k \varphi^{-\theta^k})$ for $\varphi > 0$, where T_e^k measures country e's overall level of technology in producing the varieties of product k (a higher T_e^k raises average productivity) and hence governs comparative advantage across products, and θ^k is inversely related to the dispersion of productivities and thereby governs the forces of comparative advantage across the varieties of a product.

4.1.3 Trade Flows and Equilibrium

Trade. Consumers pick the lowest-cost source of a variety across the world. This, coupled with the Fréchet distribution, yields the familiar gravity equation of trade flows (i.e., the expenditure share in country i on varieties from e and product k)[32]

$$\pi_{ei}^k := \frac{X_{ei}^k}{X_i^k} = \frac{T_e^k \left(w_e \tau_{ei}^k\right)^{-\theta^k}}{\sum_{l=1}^N T_l^k \left(w_l \tau_{li}^k\right)^{-\theta^k}}, \tag{11}$$

where X_{ei}^k is country i's expenditure on product-k varieties sourced from e, and $X_i^k := \sum_{e=1}^N X_{ei}^k$ is country i's total expenditure on product k. We refer to π_{ei}^k as the "trade share." Intuitively, trade flows are higher, the more productive e is on average (higher T_e^k), and the

[32] This follows from standard derivations (see Costinot et al., 2012; Eaton and Kortum, 2002).

lower its input and trade costs (lower $w_e\tau_{ei}^k$) relative to the other countries. We refer to θ^k as the "trade elasticity," because a higher θ^k implies that trade flows are more elastic with respect to changes in trade costs (as technologies are less dispersed and technological cost differences hence less pronounced). After a product-specific normalization of technology, the denominator in equation (11) gives the product-level price index,[33]

$$P_i^k = \left[\sum_{e=1}^{N} T_e^k \left(w_e\tau_{ei}^k\right)^{-\theta^k}\right]^{-1/\theta^k}. \tag{12}$$

Note that the nested final-demand structure affects how total expenditure is allocated across and within product groups, but it does not change the sourcing problem conditional on product k. The gravity equation and the product-level EK price index therefore retain their standard form with and without upper-tier demand nests.

Baseline equilibrium. Because firms are perfectly competitive and labor is the only production input, labor-market clearing requires producer income to equal total expenditure on the country's goods,

$$w_e L_e = \sum_{i=1}^{N}\sum_{k=1}^{K} \pi_{ei}^k X_i^k. \tag{13}$$

Labor is also the only source of household income, so $X_i = w_i L_i$. Together with the nested expenditure shares, these conditions determine the baseline wage vector up to a numéraire. They also imply the standard balanced-trade condition, i.e., the value of each country's total imports equals the value of its total exports.

4.2 Export Bans and Transshipment

We introduce export bans and transshipment in three steps. First, we use the triangle inequality (TI) to recover the minimum post-sanction rerouting costs implied by the pre-war trade network. Second, we allow third-country transshipment hubs to differ in their capability in rerouting banned goods, which helps the model match the observed distribution of transshipment hubs and the estimated effect of the full bans (see Section 3.1).

[33] Before this normalization, the exact price index is

$$P_i^k = A_k\left[\sum_{e=1}^{N} T_e^k \left(w_e\tau_{ei}^k\right)^{-\theta^k}\right]^{-1/\theta^k}, \qquad A_k := \Gamma\left(\frac{\theta^k+1-\eta^k}{\theta^k}\right)^{1/(1-\eta^k)}.$$

Because A_k (consisting of the Gamma function, $\Gamma(\cdot)$) is common to all origins and destinations within product k, we can define $\widetilde{T}_e^k := A_k^{-\theta^k} T_e^k$. This rescaling leaves the trade shares in equation (11) unchanged and absorbs A_k into the technology term. Relabeling $\widetilde{T}_e^k$ as T_e^k gives equation (12) with equality. We assume $\theta^k > \eta^k - 1$, which ensures that the product-level price index is finite.

Third, we introduce partial bans, which raise the cost of direct exports without prohibiting them. For notational convenience, let R denote Russia from here on.

4.2.1 The Triangle Inequality and Benchmark Transshipment

To measure transshipment opportunities, we rely on the triangle inequality of trade costs,

$$\tau_{ei}^{k} \leq \tau_{eh}^{k}\tau_{hi}^{k} \qquad \forall(e,h,i,k), \tag{14}$$

building on recent insights from Foellmi et al. (2024). In words, the TI is a no-arbitrage condition. The trade cost assigned to supplying product k from country e to country i cannot exceed the cost of supplying the same product through an intermediary located in a third-country hub h. Otherwise, firms would use the cheaper indirect route, and the effective bilateral trade cost would become $\tau_{eh}^{k}\tau_{hi}^{k}$.[34]

The TI becomes particularly important after a shock. Starting from the TI-consistent baseline matrix τ, let $\tilde{\tau}'$ denote the trade-cost matrix immediately after the direct policy shock, before rerouting is taken into account. For a coalition origin e that fully bans exports of product k to Russia, $\tilde{\tau}_{eR}^{k\prime} \to \infty$. Partial bans raise the direct cost by a finite factor (Section 4.2.3). Bilateral costs that are not directly affected by the policy remain at their baseline values.

The direct-shock matrix $\tilde{\tau}'$ need not satisfy the TI. If for some transshipment hub h $\tilde{\tau}_{eR}^{k\prime} > \tilde{\tau}_{eh}^{k\prime}\tilde{\tau}_{hR}^{k\prime}$, the direct post-sanction cost cannot be the effective trade cost, and we replace it by the cheaper indirect cost.[35] Denote the resulting TI-consistent post-shock matrix by $\bar{\tau}_{ei}^{k\prime}$. By construction, no route through a third-country hub is cheaper than the corresponding bilateral cost recorded in $\bar{\tau}'$. This matrix constitutes our benchmark transshipment technology. It gives the minimum post-sanction trade costs implied by the pre-war trade network, before we add the hub-specific wedges introduced below.[36] In the

[34] This condition can be microfounded using link-level trade costs (Foellmi et al., 2024). In that case, the bilateral cost τ_{ei}^{k} is the cost of the cheapest available path from e to i, which is not necessarily the cost of a direct shipment. The TI therefore does not imply that all observed trade flows go directly from the origin to the destination. It implies only that the reduced-form bilateral trade costs in the gravity equation already incorporate any (cost-saving) indirect routes that firms use in equilibrium.

[35] Only countries outside the coalition can serve as intermediaries, and only for products that the origin may export to them. For instance, Belarus cannot serve as a hub for products that the EU also bans for exports to Belarus (Section 5).

[36] In general, the updating is repeated because the cheapest route to an intermediary may itself use another country. Iterating until no TI is violated incorporates one-hub and multi-leg paths into a TI-consistent post-shock bilateral cost matrix, and Foellmi et al. (2024) show that the procedure converges to a unique solution after a finite number of iterations. In our setting, the bans raise only the direct costs from coalition origins, while the links of the countries that can serve as intermediaries remain unchanged. Starting from a TI-consistent baseline, any route that uses multiple intermediaries can then be weakly shortened to a route through a single hub. The bilateral legs in $\bar{\tau}'$ may nevertheless themselves summarize multi-country paths (see Foellmi et al., 2024).

benchmark without these wedges, the relative trade-cost change used in the counterfactual exercise would therefore be $\bar{\tau}_{ei}^{k\prime}/\tau_{ei}^{k}$.

This logic shows why we need to calibrate trade-cost *levels*. Knowing only that the direct coalition–Russia cost goes to infinity does not reveal whether Türkiye, China, the United Arab Emirates, or another country becomes the cheapest transshipment hub. Identifying the lowest-cost hub and the corresponding increase in trade costs from rerouting requires the levels of the two relevant bilateral costs, τ_{eh}^{k} and τ_{hR}^{k}, for every potential hub. This is why the calibration below recovers a TI-consistent matrix of baseline trade-cost levels rather than relying only on relative changes (see Foellmi et al., 2024, for more details).

The TI benchmark also makes the distinction between trade diversion and transshipment clear. If Russia responds to an export ban by buying product k from a producer in a non-sanctioning country, this is standard trade diversion. If, instead, it keeps buying the coalition-origin product through an intermediary, it circumvents the ban through transshipment. In the TI benchmark, rerouting banned products requires covering only (indirect) baseline trade costs. However, circumventing an export ban involves additional costs, which may differ across hubs. Without such costs, the pre-war trade network would fully determine which hub is selected for a banned product, and exports of fully banned goods would drop much less than the triple-difference estimates in Section 3.1 imply. We therefore allow rerouting through a hub to cost more than the baseline trade costs imply, by a factor that differs across hubs, as we explain next.

4.2.2 Hub Capability

Because a full ban closes the direct link to Russia, banned goods reach Russia only through a hub, the country in which they are redirected (Section 2.4). Whether goods are re-exported or diverted en route, the redirection takes place where the goods physically are, so the hub lies on their physical route. How costly the redirection is depends on features of the hub country, such as its logistics infrastructure, its customs arrangements with Russia, and local enforcement. Transshipping a fully banned import of product k from coalition origin e through hub h costs

$$m_{h,eR}^{k} = \rho_h \, \bar{\tau}_{eh}^{k\prime} \bar{\tau}_{hR}^{k\prime}, \qquad \rho_h \geq 1, \tag{15}$$

where $\bar{\tau}_{eh}^{k\prime}$ and $\bar{\tau}_{hR}^{k\prime}$ are the baseline trade costs to and from the hub, and the wedge ρ_h captures the hub-specific cost of redirection. Both trade costs are reduced form and may summarize more complicated transportation paths, since we neither observe nor model every transport node along the route (see, e.g., Allen and Arkolakis, 2022; Ganapati et al., 2024).

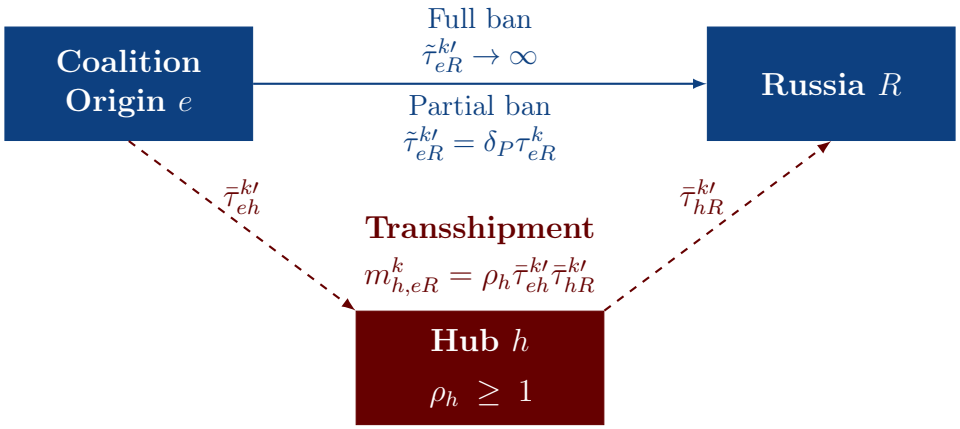


Figure 8. Transshipment through a Hub

Notes. When the direct export of product k from coalition origin e to Russia is fully banned, the product can be rerouted through an intermediary located in h. The two legs of this route have the TI-consistent costs $\bar{\tau}^{k\prime}_{eh}$ and $\bar{\tau}^{k\prime}_{hR}$, and potential hubs differ in the wedge $\rho_h \geq 1$ (equation (15)). Russia buys the product through the cheapest route. Under a partial ban, the direct link remains open at the cost $\delta_P \tau^k_{eR}$, and Russia buys the product through the cheaper of the direct link and the cheapest hub route (equation (17)).

A lower ρ_h makes h more attractive for transshipment. Since $\rho_h \geq 1$ and the bans only raise costs, the TI implies that rerouting never makes a banned good cheaper than it was before the bans. With $\rho_h = 1$ for all h, the model reduces to the TI benchmark, in which banned goods are rerouted at baseline trade costs only.

For each origin and product, Russia buys through the cheapest hub, so the wedges and the baseline trade costs together determine which country serves as the hub. With $m^k_{(1),eR}$ denoting the lowest route cost across hubs, the trade cost of a fully banned import is

$$\tau^{k\prime}_{eR} = m^k_{(1),eR}, \tag{16}$$

and $m^k_{(1),eR} = \infty$ if no hub is available.[37] Figure 8 illustrates the resulting transshipment technology.

In the customs data, the hub is the dispatch country for re-exports and the first country outside the coalition on the inferred route for imports diverted en route (Section 2.4). Imports that cross from the Baltic states directly into Russia pass through no third country and have no counterpart in the model. We drop them, implicitly assuming that they reach Russia through the same hubs, in the same proportions, as the re-exports we observe.

The model routes all transshipped imports of an origin-product cell through a single hub, and in the data, one hub carries most of them. We refer to the exports of product k from

[37] In our main specification, rerouting earns no rents. Section 5 and Appendix E consider a thought experiment in which intermediaries in each hub instead charge a markup, the highest one they can charge without losing the trade flow to a competing route.

origin e to Russia as the origin-product cell (e, k). Among the fully banned origin-product cells of the EU and the countries mirroring its sanctions that reach Russia through a hub, 53% use exactly one hub. When several hubs are used, the main hub accounts for a median share of 73% of the transshipped value. We therefore interpret the hub selected in the model as the main hub of an origin-product cell.

4.2.3 Partial Bans

Because the model is defined at the product level, a partially banned product can either still be exported directly to Russia at a higher cost or be transshipped, whichever is cheaper. A partial ban covers only some variants of a product (Section 2.1), whereas trade data, and hence the model, distinguish products but not variants. At the product level, a partial ban thus leaves part of the direct trade legal and bans the rest, which we capture by raising the direct trade cost by a factor $\delta_P \geq 1$, common to all partially banned products and origins. As with fully banned goods, the product can also be rerouted through a hub (equation (15)). Russia buys the product through the cheaper of the two routes, so its trade cost is

$$\tau_{eR}^{k\prime} = \min\left\{\delta_P\, \tau_{eR}^{k},\ m_{(1),eR}^{k}\right\}. \tag{17}$$

A partial ban therefore raises the trade cost by at most the factor δ_P, which we calibrate to the estimated trade cost increase for partially banned products (Section 4.3).

4.2.4 Solving the Model in Changes

The export bans affect the counterfactual equilibrium only through the trade costs that importers face, τ', which reflect both the bans on direct exports and the option to transship. Since hubs earn no rents from rerouting, labor remains the only source of income. Let $X_{ei}^{k\prime}$ denote importer i's counterfactual expenditure on product k from origin e. Labor-market clearing and income then take the same form as in the baseline,

$$w_e' L_e = \sum_{i=1}^{N}\sum_{k=1}^{K} X_{ei}^{k\prime}, \qquad X_i' = w_i' L_i, \tag{18}$$

and they again imply balanced trade.

Counterfactual equilibrium. For given trade-cost changes, we solve the counterfactual equilibrium in relative changes using the exact-hat-algebra approach popularized by Dekle et al. (2007). Let x' denote the counterfactual value of variable x, and let $\hat{x} := x'/x$. The trade-cost change entering the gravity equation is $\hat{\tau}_{ei}^{k} = \tau_{ei}^{k\prime}/\tau_{ei}^{k}$.

Given wages and trade costs, the product-level price changes are

$$\hat{P}_i^k = \left[\sum_{e=1}^{N} \pi_{ei}^k \left(\hat{w}_e \hat{\tau}_{ei}^k \right)^{-\theta^k} \right]^{-1/\theta^k}. \tag{19}$$

The corresponding group-price changes are

$$\hat{P}_i^g = \left[\sum_{k \in \mathcal{K}_g} \frac{X_i^k}{X_i^g} (\hat{P}_i^k)^{1-\sigma_g} \right]^{1/(1-\sigma_g)}, \tag{20}$$

and the aggregate price-index change is

$$\hat{P}_i = \left[\sum_{g \in \mathcal{G}} \frac{X_i^g}{X_i} (\hat{P}_i^g)^{1-\nu} \right]^{1/(1-\nu)}. \tag{21}$$

Counterfactual product-level trade shares are

$$(\pi_{ei}^k)' = \frac{\left(\hat{w}_e \hat{\tau}_{ei}^k \right)^{-\theta^k} \pi_{ei}^k}{\sum_{\ell=1}^{N} \left(\hat{w}_\ell \hat{\tau}_{\ell i}^k \right)^{-\theta^k} \pi_{\ell i}^k}. \tag{22}$$

Our nested demand system determines counterfactual product expenditure:

$$X_i^{k\prime} = \hat{X}_i X_i^k \left(\frac{\hat{P}_i^{g(k)}}{\hat{P}_i} \right)^{1-\nu} \left(\frac{\hat{P}_i^k}{\hat{P}_i^{g(k)}} \right)^{1-\sigma_{g(k)}}. \tag{23}$$

Bilateral expenditure is then

$$X_{ei}^{k\prime} = (\pi_{ei}^k)' X_i^{k\prime}. \tag{24}$$

Using the baseline identity $X_e = w_e L_e$, we can write equation (18) in changes as

$$\hat{w}_e X_e = \sum_{i=1}^{N} \sum_{k=1}^{K} X_{ei}^{k\prime}, \tag{25}$$

$$\hat{X}_i = \hat{w}_i. \tag{26}$$

The counterfactual equilibrium consists of wage changes $\{\hat{w}_i\}_{i=1}^N$ that satisfy equations (19)–(26), together with a numéraire normalization. These changes determine product and group prices, trade shares, and bilateral expenditure. We solve for the equilibrium using a tâtonnement algorithm (see also Alvarez and Lucas, 2007).

Real income changes are given by $\hat{W}_i = \hat{X}_i/\hat{P}_i = \hat{w}_i/\hat{P}_i$. The nested demand structure also yields group-specific real absorption. Let $X_i^{g\prime} = \sum_{k\in\mathcal{K}_g} X_i^{k\prime}$. Then

$$\hat{Q}_i^g = \frac{\hat{X}_i^g}{\hat{P}_i^g} = \hat{W}_i \left(\frac{\hat{P}_i}{\hat{P}_i^g}\right)^{\nu}. \tag{27}$$

Real absorption of a group thus falls relative to real income, $\hat{Q}_i^g < \hat{W}_i$, whenever the group's price index rises relative to the aggregate price index. For a given rise in this relative price, the gap is larger the higher ν. In particular, $\hat{Q}_R^M$ and $\hat{Q}_R^C$ measure changes in Russia's real access to military-relevant and other critical goods.

Note that when setting $\sigma_g = \nu$ for all groups and $\rho_h = 1$ for all h, the framework nests the standard multi-product EK model with one CES nest, in which banned goods are rerouted at baseline trade costs only. In Section 4.3, we explain how we bring the model to the data.

4.3 Bringing the Model to the Data

We bring the model to the data in two stages. First, using 2019 data, we construct the pre-sanction economy: bilateral trade flows, total, group-, and product-level expenditure, and a TI-consistent matrix of bilateral, baseline trade-cost levels. Second, we calibrate the hub-specific wedges, ρ_h, and the partial-ban cost increase, δ_P. The distribution of hubs in the 2024 Russian customs data disciplines the relative wedges. The estimated effect of the full bans in Section 3.1 pins down the common level of the wedges, and an analogous estimate for the partial bans pins down δ_P. Post-sanction outcomes therefore enter the calibration only through ρ_h and δ_P.[38] Appendix D provides further details and lists the parameters in Table D.1.

Trade flows, production data, and elasticities We use bilateral trade flows from UN Comtrade at the 6-digit HS level and production data from the OECD Inter-Country Input-Output tables and the International Trade and Production Database for Estimation. These data and our cleaning steps yield a final sample of 74 countries, which account for 96% (98%) of Russia's total exports (imports), and 5,136 products. We assign the 5,136 products to the three groups based on existing lists of battlefield-relevant and strategic goods. For Russia, the three groups account for 1.6% (M), 30.7% (C), and 67.8% (O) of total expenditure. We cannot read X_i^k (i.e., product-level expenditure) directly from the data, because expenditure is not observable at this level of disaggregation globally.

[38] The country-selection rule also uses the 2024 customs data to ensure that empirically important hubs are represented in the model's country sample. All baseline flows, expenditures, elasticities, and trade-cost levels are constructed from 2019 or other pre-sanction sources.

We therefore recover k-level expenditure (and, accordingly, domestic product-level trade) using the model's structure.

As is common in the literature, we do not estimate the elasticities ourselves. We take the trade elasticities, θ^k, from Fontagné et al. (2022), who estimate product-level trade elasticities using gravity regressions consistent with our setup. The resulting trade elasticities range from 1.5 to 44.1, with a median of 8.2. Russia can therefore replace a sanctioned supplier much more easily for some products than for others. Within groups, we set $\sigma_g = 2.2$ for all three groups, in line with French (2016). Across groups, we set $\nu = 1.1$, close to the Cobb–Douglas case and half the within-group elasticity. Russia therefore substitutes much less easily across the three groups than within them.

Baseline trade costs Once a counterfactual trade-cost change ($\hat{\tau}$) is specified, the model can be solved in changes using baseline trade shares, as described in Section 4.2.4. The transshipment mechanism additionally requires bilateral trade-cost *levels*, because identifying the cheapest intermediary requires comparing alternative routes to Russia. We recover these levels in two steps. We first invert the gravity equation to obtain the bilateral trade barriers that rationalize the observed baseline trade shares and then use the triangle inequalities to recover the TI-consistent baseline trade-cost matrix used to compare routes after the export bans.

The gravity-implied barriers need not satisfy the triangle inequalities, because the bilateral term recovered from gravity combines route-related trade costs with other pair-specific barriers, such as bilateral preference shifters (Foellmi et al., 2024). To recover trade costs, we apply the algorithm from Foellmi et al. (2024, Section 4). It verifies the TIs, and if a TI is violated, it sets the updated trade cost equal to the minimum indirect cost. This procedure is repeated until there are no more TI violations.[39]

Post-sanction parameters We calibrate the hub-specific wedges, ρ_h, and the partial-ban cost increase, δ_P, to post-sanction outcomes for the EU and the countries that mirror its sanctions, since our sanctions data identify which of their products are fully and which are partially banned.[40] We write each wedge as the product of a common level, which is the same for all hubs, and a relative wedge. The relative wedges capture each country's relative capability in rerouting banned goods. A country with a lower relative wedge offers

[39] The wedge between the initial value of trade barriers and the final value of trade costs can be interpreted as a bilateral preference shifter through the lens of standard gravity theory (cf. Foellmi et al., 2024). Because exact hat algebra conditions on the observed baseline trade shares, this residual need not be recovered separately. The levels τ^k_{ei} are needed only to determine rerouting opportunities and the corresponding trade-cost changes.

[40] From here on, "the EU" includes these countries (in our sample, Albania, Bosnia and Herzegovina, Iceland, Montenegro, North Macedonia, and Norway) when we refer to the bans and the exports they cover. Real-income results for the EU refer to its 27 member states.

the cheapest route for more banned products and has a larger hub share. We therefore calibrate the relative wedges to the observed hub shares. The common level, in turn, determines how much more costly rerouting is than in the TI benchmark on average, and we calibrate it to the estimated effect of the full bans.

Relative wedges. We measure hub shares in the data as the number of fully banned EU origin-product cells that reach Russia through each hub. Counting cells rather than values matches the model, in which all transshipped exports of an origin-product cell go through the hub with the cheapest route, and the choice of hub depends on trade costs and the wedges but not on the value of the exports. Hubs in the data (Section 2.4) and in the model share the same definition: the country in which banned goods are redirected to Russia, which lies on their physical route, as in Figure 8. Because the hubs of imports diverted en route are inferred rather than directly observed (Section 2.4), we show in Section 5 that our results do not hinge on this imputation of the hubs by calibrating the relative wedges to re-exports alone.

Figure 9 compares the observed hub shares with those in the TI benchmark, in which all hub wedges ρ_h equal one and each fully banned flow is rerouted through the hub with the cheapest route at baseline trade costs. Even though the TI benchmark uses no information on the observed hubs (beyond the choice of the country sample), the pre-war trade network alone identifies most of the main hubs. The five largest hubs in the data are Türkiye, Belarus, China, the United Arab Emirates, and Serbia, and in the TI benchmark, Mexico takes the place of the United Arab Emirates among them. Across all hubs, the correlation between the two sets of shares is 0.76. In both the data and the TI benchmark, transshipment is highly concentrated among a few countries. The five largest hubs have a combined share of 82% in the data and 64% in the TI benchmark. At the level of individual hubs, however, the TI benchmark understates the roles of Türkiye, Belarus, and the United Arab Emirates and overstates those of Mexico, Serbia, and India. We then choose the relative wedges such that the model's hub shares match the observed ones as closely as possible (see Appendix D.4 for details).

Common level. We choose the common level of the wedges such that the model reproduces the estimated effect of the full bans. Recall from Section 3.1 that fully banned flows fall by 85% relative to flows of never-sanctioned products. Through the lens of our model, this estimate measures the direct effect of the bans on the banned flows, before prices, wages, and other trade flows adjust. Through the gravity equation (11), the direct effect depends on how much more costly the cheapest hub route is than the pre-war direct route. Intuitively, more costly rerouting makes the banned goods more expensive relative to the goods of other suppliers, so Russia buys less of them. Specifically, the direct effect of the bans in the model reduces the banned flows by the same 85% on average (see Appendix D.4 for details). For the median fully banned flow, the cheapest hub route is

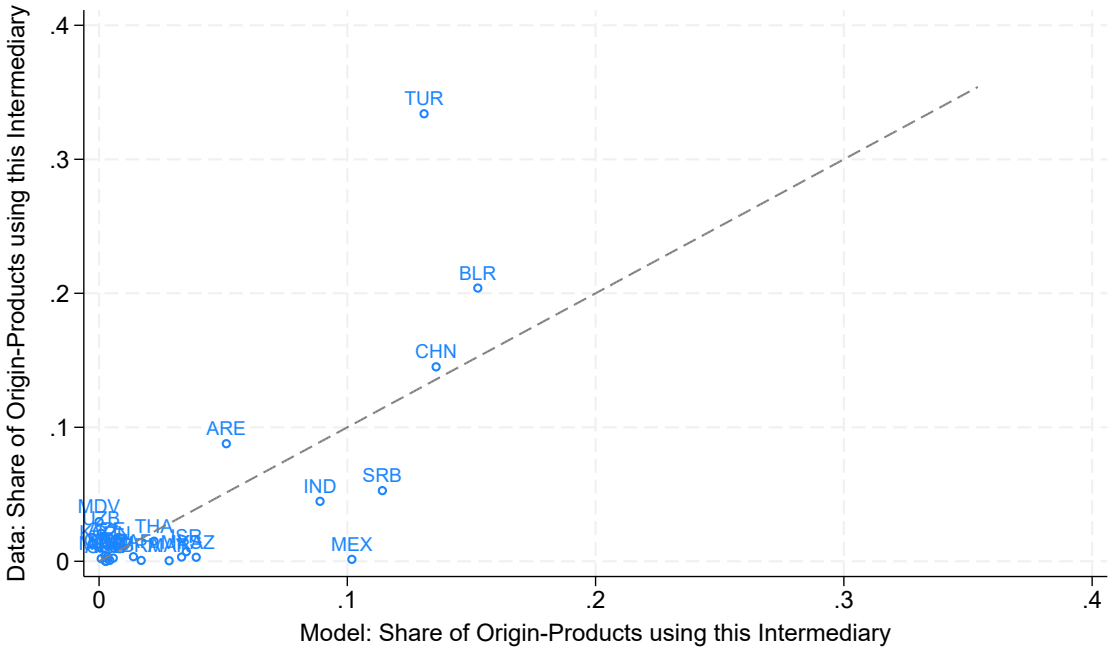


Figure 9. Transshipment Hubs: TI Benchmark vs. Data

Note: This figure compares the hub shares in the Russian customs data for May to December 2024 (vertical axis) with those in the TI benchmark (horizontal axis), in which all wedges equal one and banned goods are rerouted at baseline trade costs only. Both refer to the fully banned products of the EU and the countries that mirror its sanctions. A hub's share is the number of origin-product cells that it serves divided by the total across hubs. Section 4.3 explains how we measure hub shares in the data. The dashed line is the 45°-line.

then 69% more costly than the pre-war direct route. In the counterfactuals, the calibrated wedges apply to the banned goods of all coalition origins.

Partial-ban cost increase. We calibrate δ_P to the estimated effect of the partial bans, in the same way as the common level of the wedges. A partial ban raises the cost of direct exports to Russia by the factor δ_P, and Russia buys the product through the cheaper of the direct link and the cheapest hub route (equation (17)). To estimate the effect of the partial bans, we rerun the triple-difference gravity specification in equation (2) with products that remain partially banned through December 2024 as the treated group, so that later upgrades to full bans do not contaminate the estimate. Relative to never-sanctioned products, these flows fall by 47% (see Appendix Figure D.1 for the event-study plot). Through the gravity equation (11), and given the product-level trade elasticities, this decline implies $\delta_P = 1.100$, which raises the cost of exporting the product directly to Russia by 10%. Since this cost increase is small relative to the cost of rerouting, Russia buys most partially banned goods directly, and only 7.4% of their 2019 value is rerouted in the model.

Untargeted fit The relative wedges target only the aggregate hub shares of the EU. For the remaining coalition origins, the correlation between the model's and the observed hub shares rises from 0.39 in the TI benchmark to 0.67 with the calibrated wedges (Appendix

Figure D.2a). The main exception is Belarus, whose hub share for these origins is much larger in the calibrated model than in the data. For hub shares computed within each coalition origin, the correlation across origin-hub pairs rises from 0.55 to 0.90 (Appendix Figure D.2b). The calibrated wedges thus improve the fit beyond the aggregate hub shares they target. This is reassuring, since the counterfactuals apply the same wedges to the banned goods of all coalition origins. These comparisons use the same 2024 customs data as the calibration target and are therefore untargeted rather than out-of-sample.

5 The Aggregate Effects of Export Bans and Transshipment

This section asks how much the current export bans reduce Russia's imports and real income once transshipment is taken into account, and how much larger these effects would be without transshipment. We compare two post-ban equilibria. In the first, which we call *observed transshipment* (OT), Russia can still obtain fully banned coalition-origin goods through third-country hubs. It buys partially banned goods either directly, at a cost that is about 10% higher than before the bans (Section 4.3), or through a hub if this route is cheaper. In the second, which we call *no transshipment* (NT), the same bans apply, but no goods can be rerouted. Russia can then still buy partially banned goods directly, but fully banned coalition-origin goods are no longer accessible.

We apply the full and partial export bans in force by the end of 2024, accounting for differences in product coverage across coalition members. Partial bans apply to exports from the EU and the countries that mirror its sanctions, while we treat the restrictions of the other coalition members as full bans. Coalition countries cannot serve as intermediaries, including for products they do not themselves ban.[41] The export bans that the EU imposed on Belarus apply throughout, such that the goods they cover cannot reach Belarus, not even through third countries, and Belarus can never be used as a hub for them.[42]

All scenarios start from the same theory-consistent 2019 baseline without sanctions, for which we first solve the equilibrium with balanced trade. Like the other scenarios, observed transshipment is a counterfactual that applies the bans in force at the end of 2024. Because nominal flows are identified only relative to the model's numéraire, we report import effects as percentage changes in the corresponding flows' shares of world expenditure, which do not depend on this normalization. Although real income changes correspond to

[41] This treats coalition membership as a commitment not to facilitate the circumvention of another member's export bans. We treat Ukraine as part of the coalition but assume that none of its goods reach Russia or Belarus, directly or through third countries.

[42] We do not model partial bans on exports to Belarus or the Belarus restrictions of the other coalition members.

welfare changes in our model, sanctions are typically motivated by reasons beyond income effects, which is why we will explicitly call them real income losses throughout.

Russia's transshipment gain. Table 2 gives the main quantitative result. Under observed transshipment, the export bans reduce Russia's real income by 1.26% relative to the no-sanctions baseline. A loss of this size is substantial by the standards of quantitative trade models.[43] Without transshipment, the same bans would raise the loss to 1.66%. We call the difference between the two losses Russia's *transshipment gain*, since it measures what Russia gains from still being able to buy banned goods through hubs. In relative terms, the transshipment gain amounts to 32% of the loss under observed transshipment. We refer to this ratio as the *relative transshipment gain*. Put differently, transshipment spares Russia 24% of the loss that the bans would otherwise cause.

Russia's transshipment gain also has a money-metric interpretation. With homothetic preferences, the difference in equivalent variation between OT and NT, evaluated at baseline prices, is $X_R\left(\hat{W}_R^{\mathrm{OT}} - \hat{W}_R^{\mathrm{NT}}\right)$, where X_R is Russia's annual baseline expenditure. This amounts to approximately USD 4.5 billion per year in 2019 dollars. It is a welfare-equivalent amount rather than a fiscal transfer or a measure of resources directly available to the Russian state. To put the scale into perspective, this amount is numerically equivalent to the reported cost of about 130,000 Russian-produced strike drones, or to the first-year compensation packages of about 70,000 contract soldiers recruited in Moscow.[44]

Trade flows and strategic access. The trade responses explain why the sanctions can eliminate most targeted flows without producing a comparable fall in Russia's overall access to goods. Under observed transshipment, imports of fully banned coalition-origin products fall by 76%. Rerouted products retain their coalition origin in the model, so this decline already accounts for the goods that still reach Russia through hubs. For EU exporters, the decline is similar (Table 3). Both declines are smaller than the 85% estimated in Section 3.1, since the calibration matches that estimate only for the direct effect of the bans, before prices, wages, and other trade flows adjust (see Section 4.3). If banned goods could instead be rerouted at baseline trade costs only, as in the TI benchmark of Section 4.2, imports of fully banned coalition-origin products would fall by only 37%, and Russia's real-income loss would be 0.58% instead of 1.26%. Ignoring

[43] For comparison, using a related framework, Caliendo and Parro (2015) estimate that NAFTA's tariff reductions raised U.S. welfare by 0.08%. See Costinot and Rodríguez-Clare (2014) for an overview of welfare magnitudes in quantitative trade models.

[44] We value drones at USD 35,000, the midpoint of reported unit costs of USD 20,000 to 50,000 for Russian-produced Shahed-type strike drones (CSIS, May 2025; Kyiv Independent, May 2025), and soldiers at the USD 60,000 of first-year pay that Reuters (July 2024) reports for contract soldiers recruited in Moscow. These prices are in 2024–2025 dollars, whereas the welfare equivalent is in 2019 dollars, so adjusting for inflation would raise the implied counts.

Table 2. The Aggregate Effects of the Sanctions on Russia

	Change in Imports			Change in Real Income, $\hat{W}$	
Scenario	Full	Partial	Total	Change	vs. Observed Transshipment
Observed Transshipment	-76%	-27%	-9%	-1.26%	
No Transshipment	-100%	-24%	-11%	-1.66%	+32%

Notes. This table reports how Russia's imports and real income change relative to the baseline without the sanctions. The import columns refer to Russia's imports of fully banned (Full) and partially banned products (Partial) from the coalition countries that ban them, and of all products (Total). Import entries are percentage changes in the corresponding flows' shares of world expenditure. Real-income changes are reported in percent, that is, $(\hat{W} - 1) \times 100$, and the last column reports the increase in Russia's real-income loss without transshipment, in percent of the loss under observed transshipment. Under "Observed Transshipment," fully banned coalition-origin goods can reach Russia through third-country hubs, and partially banned goods are bought directly at a higher cost or through a hub if that route is cheaper. Under "No Transshipment," fully banned coalition-origin goods no longer reach Russia, while partially banned goods can still be bought directly at the higher cost. The results are discussed in Section 5.

the additional costs of circumvention would thus understate both the decline in banned trade and the costs of the bans for Russia. Even this smaller loss is substantial by the standards of quantitative trade models. It arises because, even at baseline trade costs, rerouting through a hub is typically more costly than shipping directly, and partial bans still raise the cost of direct exports.

The fully banned flows account for 27% of Russia's baseline imports. If no other import flow changed, their decline would reduce total imports by approximately 21%. Instead, total imports fall by only 9%, because Russia substitutes toward non-sanctioning origins and products that are not banned. Without transshipment, fully banned coalition-origin flows stop entirely, whereas the decline in total imports rises only from 9% to 11%. Imports of partially banned products even fall by less without transshipment than with it (Table 2). Intuitively, once fully banned goods can no longer be rerouted, Russia substitutes toward the products it can still buy, including the partially banned ones. At the same time, losing the hub routes hardly matters for partially banned goods, since only a small share of them is rerouted under observed transshipment.

The same pattern holds for military-relevant products. Fully banned coalition-origin flows account for 51% of Russia's baseline imports in group M and fall by 91% under observed transshipment. Total imports of military-relevant products, however, fall by only 12%, and Russia's real absorption of these goods, which includes domestic supply, falls by 3.6%[45]. The reason is that Russia shifts toward non-sanctioning or domestic suppliers

[45] Note that Russia's real absorption of military-relevant products may well have *increased* after the onset of the war and the introduction of Western export bans, as the war shifts Russian demand. This is explicitly not covered in our counterfactual analysis that focuses fully on the effects of the trade sanctions. We reconsider the sanction effect in a scenario with higher Russian military demand in the robustness section below.

Table 3. The Effects of the Sanctions on the EU

Country	Baseline Exports of Fully Banned Products (USD in M)	Change in Exports to Russia (%)						Change in Real Income (%)	
		Full		Partial		Total			
		OT	NT	OT	NT	OT	NT	OT	NT
EU27	58,838	-76%	-100%	-27%	-23%	-39%	-48%	-0.036%	-0.048%

Notes. This table reports changes in the exports of the EU members to Russia and in their real income under observed transshipment (OT) and no transshipment (NT), as defined in Table 2. The first column reports the baseline value of EU exports of fully banned products to Russia in millions of 2019 USD. Export changes are percentage changes relative to the baseline exports of fully banned (Full), partially banned (Partial), and all products (Total), summed over member states. They include goods rerouted through hubs, which keep their EU origin. Under NT, no fully banned EU goods reach Russia. Real-income changes refer to the median member-state change, $(\hat{W} - 1) \times 100$, so that the entry reflects a typical member state rather than the most exposed members. Appendix Table G.3 reports the member-state results.

and substitutes across products within group M. Moreover, because substitution across the three broad groups is harder than within them, Russia also does not reallocate much of its total expenditure away from military-relevant goods. Without transshipment, the decline in military-relevant real absorption rises only to 4.0%.

Impact on the EU. The real-income effects on the EU are modest relative to Russia's losses (Table 3). Under observed transshipment, the median member state loses 0.036% of real income, and the losses are concentrated among members with high pre-war exposure to Russia. Lithuania loses 0.46% and Estonia 0.33%, while the losses in Ireland and Portugal are close to zero (Appendix Table G.3).

Without transshipment, EU exporters lose all their sales of fully banned products to Russia, and the median member state's loss rises by 35%, somewhat larger than the corresponding 32% increase for Russia. Transshipment therefore lowers the losses on both sides in similar proportions, while the median member-state loss remains more than an order of magnitude smaller than Russia's in levels.

Robustness. Appendix Table G.1 recomputes the main comparison under alternative parameter choices and an alternative hub-share target. Unless noted otherwise, we recalibrate the hub wedges and the partial-ban cost increase in every specification. The main object of interest is the relative transshipment gain, which equals 32% in the main specification.

The demand-side elasticities, which are set rather than estimated, have little effect on this aggregate comparison. Varying the cross-group elasticity ν between 0.5 and 2.2, where $\nu = 2.2$ imposes equally easy substitution across and within groups, and lowering the within-group elasticity for military-relevant products to $\sigma_M = 1.2$ leaves the relative

transshipment gain virtually unchanged. The nested structure matters more for how the sanctions affect the composition of Russian absorption than for this aggregate comparison (Appendix Table G.2). The harder it is to substitute across groups, the more of its spending Russia keeps on military-relevant goods as their prices rise, and the more it cuts back on the remaining goods. The effect of transshipment on military-relevant absorption, however, is similar in all of these variants.

The product-level home-share floor matters more. Because domestic product expenditure is recovered rather than directly observed, the main specification imposes a 10% lower bound on home shares (Appendix D.2). Lowering the bound to 5% changes both the baseline trade shares and, after recalibration, the hub wedges and the partial-ban cost increase. Russia's loss under observed transshipment then falls slightly, to 1.24%, while its loss without transshipment rises to 1.70%. Both changes raise the relative transshipment gain to 37%. The 10% bound is therefore conservative with respect to the size of the transshipment gain.

We further test whether the choice of the hub-share target drives our results. The main target also counts in-transit shipments, whose hub we infer from their point of entry into Russia (Section 4.3). When we instead calibrate the relative wedges to re-exports only, whose hub is the recorded dispatch country, the relative transshipment gain is 31%, close to the main specification.

Wartime conditions may shift Russian expenditure toward military-relevant goods relative to the 2019 baseline. We therefore triple Russia's demand weight for group M ($\hat{\alpha}_R^M = 3$) and first solve for the corresponding no-sanctions equilibrium. This raises the military-relevant group's baseline expenditure share from 1.6% to 4.5%. We then impose the export bans on this economy, holding the calibrated hub wedges and the partial-ban cost increase fixed. The greater weight on military-relevant goods raises Russia's losses modestly, to 1.32% with observed transshipment and 1.72% without it. This is due to military products being over-proportionately targeted in the Western export bans. The relative transshipment gain remains 31%, close to the main specification.

Finally, the product-level trade elasticities are based on long-run gravity estimates, while the relevant trade elasticities over the first years of the sanctions may be smaller. Boehm et al. (2023), for example, estimate a short-run elasticity that is less than half their long-run value. Halving our trade elasticities raises Russia's loss to 2.29% under observed transshipment and to 2.92% without transshipment. Intuitively, when it becomes harder to substitute across source countries, a given increase in trade costs raises Russia's import prices by more. The relative transshipment gain, however, remains of a similar size, at 28%.

Across all specifications in Appendix Table G.1, Russia's imports of fully banned coalition-origin products fall by between 75% and 78% under observed transshipment, and the relative transshipment gain lies between 28% and 37%. Transshipment therefore remains quantitatively important throughout.

Effects on third countries. Third countries can benefit from the sanctions as Russia diverts its purchases from coalition suppliers toward their own products. Relative to the no-sanctions baseline, real income rises by 0.01% in Türkiye, 0.04% in the United Arab Emirates, and 0.08% in Serbia. These gains are larger without transshipment, because Russia then buys more of these countries' own products instead of rerouting coalition goods. Belarus, which is itself sanctioned throughout, loses real income in both scenarios, but less without transshipment.

In our main specification, hubs earn no rents from rerouting. What if they could instead charge a markup? To assess how much hubs could earn in this way, we consider a thought experiment in which each hub charges the highest markup it can without losing the trade flow to a competing route. Appendix E derives this markup and the resulting rents, and shows how we recalibrate the model so that it still matches the observed hubs and the estimated effects of the bans. Under observed transshipment, hubs then earn USD 2.00 billion, or 2.2% of Russia's baseline spending on fully banned coalition-origin goods, with the largest share going to Türkiye (Appendix Table E.1). Russia's losses barely change, at 1.26% with observed transshipment and 1.66% without it. This is because Russia's losses depend mainly on how much more it has to pay for banned goods, and the estimated effects of the bans pin down this price increase in both versions of the model. With markups, part of this increase goes to the hubs as rents instead of covering the cost of rerouting.

The scope of the current bans in perspective. The loss without transshipment takes the coalition's *current* product lists as given. If coalition countries instead stopped exporting every product to Russia, and no goods could be rerouted, Russia's real-income loss would reach 3.47% and its total imports would fall by 26%. The gap between this loss and the 1.66% loss that the current lists cause without transshipment reflects the products that these lists do not ban or ban only partially. How much the EU can add to Russia's loss by fully banning further products is one of the questions of the next section.

6 Sanctions Design: Strengthening Export Bans

Transshipment substantially weakens the current export bans. In this section, we compare ways of strengthening them and ask by how much measures to curb transshipment and

changes in the product scope raise Russia's real-income loss.[46] We first take the current product lists as given and compare the closure of the routes that banned goods currently take, the shutdown of entire hubs, and the addition of new coalition members. We then ask how much the past upgrades from partial to full bans contribute to Russia's current loss, consider fully banning further products, and compare the costs of route closure and of these expansions to the EU members.

Route and hub closures make it harder to reroute goods that the current lists already ban. At most, they raise the cost of each restricted flow to its level without transshipment, so the loss without transshipment is the natural benchmark for these exercises. Recall that the difference between this loss and the loss under observed transshipment is Russia's transshipment gain (Section 5). We therefore report how much of this gain the route and hub closures eliminate.

6.1 Routes, Hubs, and Coalition Enlargement

The most direct response to transshipment is to target the routes that banned goods currently take. Enforcement of this kind is already an important part of the sanctions regime. In October 2024, for example, the U.S. Treasury designated 275 individuals and entities across 17 jurisdictions for supplying Russia's military-industrial base or moving sanctioned goods through intermediary networks.[47] The EU's Common High Priority Items list similarly supports exporters' due diligence and the anti-circumvention work of customs authorities in partner countries.[48] Route-specific enforcement naturally targets the routes that banned goods currently take. A route that is unused today, however, may become attractive once these routes are closed.

Our model does not contain individual firms, so we represent route-specific enforcement at the origin-product-hub level. We close every hub route through which Russia buys banned coalition products under observed transshipment, both for fully banned products and for partially banned products that currently go through a hub. The affected goods then reach Russia through the cheapest remaining route, which for a partially banned product can also be the direct one. We thus consider a very strong form of route-specific enforcement, in which every route currently in use is identified and closed. In practice, closing a route requires monitoring trade flows through the hub and the cooperation of the hub country.

[46] As in Section 5, every exercise applies a policy to the 2019 economy. Throughout this section, "current" refers to observed transshipment with the bans in force at the end of 2024, and current exports are exports to Russia in this equilibrium, valued in 2019 dollars.

[47] See "Treasury Takes Aim at Third-Country Sanctions Evaders and Russian Producers Supporting Russia's Military Industrial Base," U.S. Department of the Treasury, October 30, 2024.

[48] See the European Commission's List of Common High Priority Items.

Russia's real-income loss rises from 1.26% to 1.42%, so even this strong form of enforcement eliminates only 41% of Russia's transshipment gain.[49] The effect is limited partly because routes that were not used before become the cheapest alternatives once the active ones are closed, and Russia can buy the banned goods through them.

A hub shutdown removes a country as an intermediary for every product, including on routes that are currently unused, but adds no restrictions to its own exports. A country that joins the coalition stops serving as a hub as well, and in addition adopts the full and partial EU bans on its own exports to Russia and the EU's full bans on its exports to Belarus. Like the goods of the current coalition members, its newly banned goods can still reach Russia through the remaining hubs outside the coalition.[50]

Table 4 compares the two counterfactuals for the five countries that most often serve as hubs in the customs data (Türkiye, Belarus, China, United Arab Emirates, Serbia). The difference between the two shows how much a country's own exports matter beyond its role as a hub. For Türkiye, the hub shutdown alone accounts for 63.5% of the total effect of joining, and for the United Arab Emirates 62.7%, so most of the effect for these two countries comes from ending their role as intermediaries. For China, the hub shutdown accounts for only 4.6%, because restricting Chinese exports to Russia matters much more than removing China's role as an intermediary. Belarus and Serbia resemble China, although their hub role accounts for a larger part of the effect of joining, 22.6% and 23.5%, respectively.

If the five countries in Table 4 (Türkiye, Belarus, China, United Arab Emirates, Serbia) all stopped serving as hubs, Russia's real-income loss would rise to 1.48%, which eliminates 54% of Russia's transshipment gain. By contrast, coalition enlargement also restricts exports from additional origins. If these five countries joined the coalition together, Russia's real-income loss would rise to 2.43%, well above the 1.66% loss without transshipment under the current restrictions. The joint effect exceeds the sum of their individual effects of joining in Table 4, since joint accession also removes the suppliers and hubs that remain available to Russia when each country joins alone. Whether such an enlargement is feasible, however, depends on the willingness of all five countries to impose the bans themselves.

6.2 Upgrading Partial to Full Bans

Besides transshipment, the export bans leak because many products are banned only partially. Under a partial ban, Russia can still buy the product directly from the

[49] If we close only the hub routes through which Russia currently buys banned EU products, Russia's real-income loss rises to 1.38%, which eliminates 30% of Russia's transshipment gain.

[50] When Belarus itself joins, it adopts the bans on exports to Russia, while the EU's bans on exports to Belarus remain in force.

Table 4. Closing Hubs and Enlarging the Coalition

Country	Increase in Russia's Real Income Loss			
	Hub Shutdown (pp)	Further Effect of Joining (pp)	Joining in Total (pp)	Hub Shutdown (% of Total)
Türkiye	0.080	0.046	0.126	63.5
Belarus	0.027	0.092	0.119	22.6
China	0.031	0.650	0.681	4.6
United Arab Emirates	0.015	0.009	0.025	62.7
Serbia	0.003	0.010	0.013	23.5

Notes. This table reports the effects of closing hubs and enlarging the coalition for the five countries that most often serve as hubs in the customs data (Section 4.3). The first three columns report increases in Russia's real-income loss in percentage points. "Hub Shutdown" is the increase relative to observed transshipment when the country no longer serves as an intermediary for any product, with no restrictions on its own exports. "Joining in Total" is the increase relative to observed transshipment when the country joins the coalition. It then no longer serves as a hub, and its exports face the full and partial EU bans on exports to Russia and the EU's full bans on exports to Belarus. When Belarus joins, it adopts the bans on exports to Russia, while the EU's bans on exports to Belarus remain in force. "Further Effect of Joining" is the difference between the two, that is, the additional effect of restricting the country's own exports. The last column reports the hub shutdown as a percentage of the total effect of joining. The results are discussed in Section 6.1.

sanctioning countries, at a cost that is about 10% higher (Section 4.3). A full ban removes this direct option and leaves only the routes through third-country hubs. The EU has narrowed this leak over time by upgrading partial to full bans (Figure 1). Of the products that the EU fully bans at the end of 2024, 1,188 (59%) were first banned only partially. To measure what these upgrades achieved, we turn these full bans back into partial bans in the model.[51] Russia's real-income loss under observed transshipment would then be 24% smaller, at 0.96% instead of 1.26%. In other words, the upgrades raise Russia's loss by more than closing every hub route through which Russia currently buys banned coalition products would.

6.3 Widening the Scope of the Export Bans

Beyond these past upgrades, the sanctioning countries can also fully ban further products. Unlike closing routes and hubs or enlarging the coalition, this does not depend on the cooperation of countries outside the coalition. Russia, however, can still buy the newly banned goods through these countries.

We evaluate expansions of the product list against two benchmarks. The first is the 1.42% loss after closing every hub route through which Russia currently buys banned coalition products. The second is the 1.66% loss that the current restrictions would cause

[51] We hold the hub-specific wedges, the partial-ban cost increase δ_P, the restrictions on all other products, the EU's bans on exports to Belarus, and the bans of the other coalition members at their current values.

without transshipment. This is also the loss that standard quantifications, which ignore transshipment, would predict for the current bans.

We consider additional bans by the EU and the countries that mirror its sanctions. Such bans can cover the 3,193 products that this group does not fully ban at the end of 2024, whether never-sanctioned or partially banned. Adding product k to the list means that all countries in the group, collected in the set $\mathcal{B}^k$, fully ban their exports of k to Russia, while their bans on exports to Belarus remain unchanged. The lists of the other coalition members remain unchanged, so Russia can still buy the newly banned products from them. Route closure, in contrast, applies to the banned goods of all coalition members. In this sense, the comparison with route closure is demanding for the product list.

Ranking products. These products differ in their importance for Russian expenditure, Russia's dependence on the sanctioning origins, their trade elasticities, and the routes available for rerouting around a new ban. We rank them by the first-order reduction in Russian real income per dollar of the group's current exports that a full ban would newly cover. The ranking thus favors products whose ban causes Russia the largest losses for a given value of newly restricted trade. This value is not the real-income cost to the sanctioning countries, which we later compute for the EU members in Section 6.4. The ranking is simple and in some sense one-dimensional, as it does not take into account that sanctions also pursue objectives other than lowering Russia's real income. Nevertheless, it gives a simple rule for the order in which products are added to the list. This allows us to quantify how much a targeted expansion of the product list can raise Russia's loss.

Russia's real income is $W_R = X_R/P_R$. Holding wages and nominal expenditure fixed at their levels under observed transshipment, we obtain, to a first order around this equilibrium,

$$\Delta \ln W_R = -\Delta \ln P_R \approx -\sum_k s_R^{k,\mathrm{OT}} \, \Delta \ln P_R^k,$$

where $s_R^{k,\mathrm{OT}} = X_R^{k,\mathrm{OT}}/X_R^{\mathrm{OT}}$ is product k's share in Russian expenditure under observed transshipment. A ban on product k alone therefore lowers Russian real income by approximately $s_R^{k,\mathrm{OT}} \, \Delta \ln P_R^k$.

Consider first the case in which the newly banned exports cannot be rerouted through third countries, while all other restrictions and routes remain as under observed transshipment. We label this case NR, for no rerouting. Let $\pi_{eR}^{k,\mathrm{OT}}$ denote origin e's share in Russia's expenditure on product k under observed transshipment and $b^k = \sum_{e \in \mathcal{B}^k} \pi_{eR}^{k,\mathrm{OT}}$ the combined share of the group. Holding wages fixed, equation (19) then implies

$$\Delta \ln P_R^{k,\mathrm{NR}} = -\frac{1}{\theta^k} \ln\left(1 - b^k\right). \tag{28}$$

Under observed transshipment, the newly banned exports instead move to their cheapest hub route, and the partial-equilibrium price change becomes

$$\Delta \ln P_R^{k,\mathrm{OT}} = -\frac{1}{\theta^k} \ln \left[1 - b^k + \sum_{e \in \mathcal{B}^k} \pi_{eR}^{k,\mathrm{OT}} \left(\frac{m_{(1),eR}^k}{\tau_{eR}^{k,\mathrm{OT}}} \right)^{-\theta^k} \right]. \tag{29}$$

Here, $m_{(1),eR}^k$ is the cost of the cheapest hub route, and $\tau_{eR}^{k,\mathrm{OT}}$ is the cost at which the product currently reaches Russia, which for partially banned products already includes the effect of the partial ban. Unlike in the case without rerouting, Russia can keep buying the newly banned goods from their original suppliers through a hub. The product's price index therefore rises by less, and more so the cheaper the hub route is relative to the current cost.

In both cases, we divide the first-order loss by the group's current exports of product k to Russia, $v^k = \sum_{e \in \mathcal{B}^k} X_{eR}^{k,\mathrm{OT}}$. For products with positive exports, this yields the score

$$r_z^k = \frac{s_R^{k,\mathrm{OT}} \, \Delta \ln P_R^{k,z}}{v^k}, \qquad z \in \{\mathrm{NR}, \mathrm{OT}\}. \tag{30}$$

Ranking the products by r_{OT}^k yields the transshipment-adjusted list. Ranking them by r_{NR}^k yields the list that neglects transshipment, that is, the ranking implied by standard quantifications that ignore transshipment. Hausmann et al. (2024) rank products in a similar way, by the cost of a ban to Russia per dollar of foregone coalition exports, assuming that the bans cannot be circumvented. We use these scores only to rank the products and compute the effects of all packages in the full GE model.

Results. Figure 10 shows how Russia's real-income loss increases as more products from the transshipment-adjusted list are banned. The curve is steep at first and flattens out as the list grows. Intuitively, the list starts with the products whose ban imposes the largest loss on Russia per dollar of newly covered exports. Banning the first 218 of these 3,193 products raises Russia's loss to the level reached by closing every hub route through which Russia currently buys banned coalition products. These 218 products account for USD 5.0 billion, or 6%, of current EU exports to Russia. With the first 965 products, which account for USD 20.0 billion, or 25%, of current EU exports to Russia, the loss reaches the level that the current bans would cause without transshipment, even when transshipment remains possible.

How much does it matter that the products are chosen taking transshipment into account? We compare the transshipment-adjusted list with the list that neglects transshipment for the same budget, namely the current exports of the first 218 products of the transshipment-

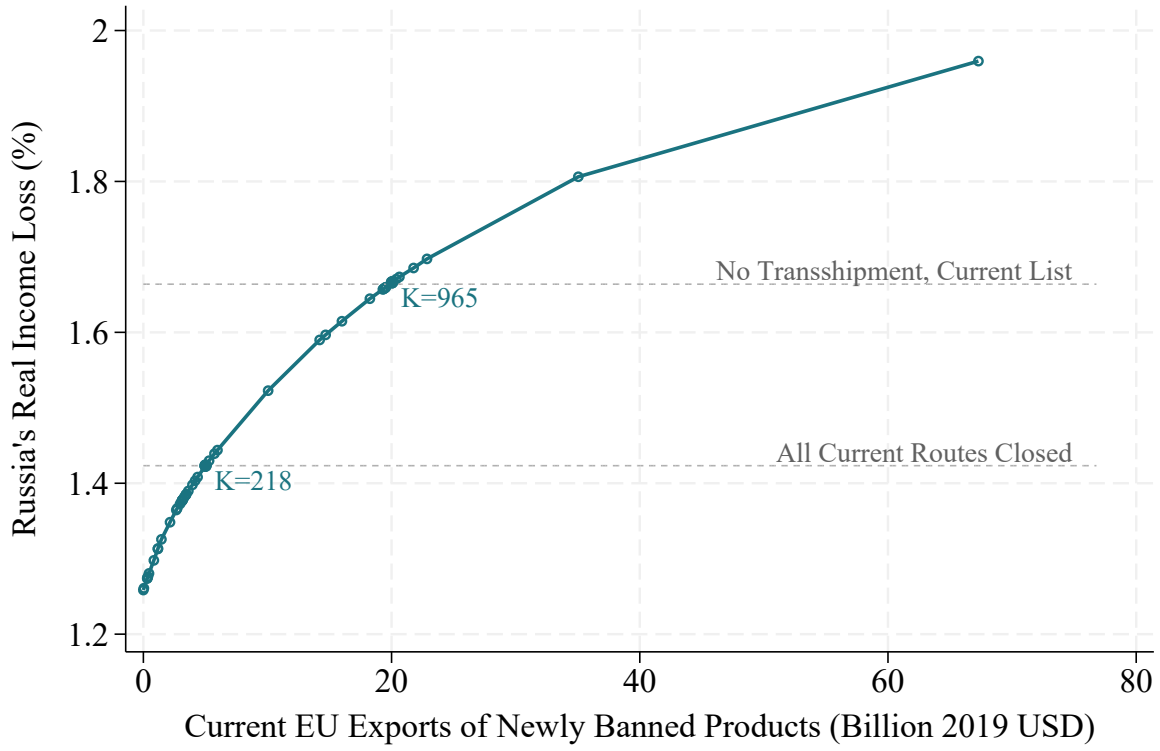


Figure 10. Widening the Product Scope under Observed Transshipment

Note: This figure reports Russia's real-income loss under observed transshipment, in percent of its real income without sanctions, as the EU and the countries that mirror its sanctions fully ban additional products from the transshipment-adjusted list on top of the current restrictions. The horizontal axis measures the current exports of the newly banned products from these countries to Russia, in billions of 2019 USD. The lists of the other coalition members remain unchanged. Both horizontal lines refer to the current bans of all coalition members. The upper line marks the loss that these bans would cause without transshipment, and the lower one the loss after closing every hub route through which Russia currently buys banned coalition products. The labels $K = 218$ and $K = 965$ mark the packages that reach these two levels. The results are discussed in Section 6.3.

adjusted list. With this budget, the list that neglects transshipment selects 124 products.[52] Under observed transshipment, these products raise Russia's loss by 16% less than the 218 products of the transshipment-adjusted list. The reason is that the two lists contain quite different products, as only 86 of the 124 products are also among the 218. The remaining 38, such as beer, vegetable seeds, and handbags, rank high only because the list ignores that Russia can keep buying them through third countries once they are banned. For the median of these products, existing routes absorb 70% of the price increase that a ban would cause without rerouting. The two lists become more similar as more products are added and coincide once all of these products are banned.

[52] We add products from the top of this list as long as their combined current exports do not exceed those of the 218 products. If these products could not be rerouted, they would raise Russia's loss by 0.24 pp, more than the 0.20 pp that the 218 products would add without rerouting. Once rerouting is taken into account, however, their effect falls to 0.14 pp.

Table 5. Comparing Ways to Strengthen the Export Bans

Instrument	Add. Russian Loss (% of Transship. Gain)	Add. Median EU Member Loss (% of Real Income)
Close current routes	+0.165pp (41%)	0.0043%
Transshipment-adjusted product expansion	+0.165pp (41%)	0.0021%

Notes. This table compares two ways of strengthening the export bans. Both raise Russia's real-income loss by about the same amount. "Close current routes" closes every hub route through which Russia buys banned coalition products under observed transshipment. The product expansion fully bans the first 218 products of the transshipment-adjusted list. These bans apply to exports to Russia from the EU and the countries that mirror its sanctions, while the lists of the other coalition members remain unchanged. The first column reports the increase in Russia's real-income loss relative to observed transshipment, in percentage points, and in parentheses as a share of Russia's transshipment gain. The second column reports the additional real-income loss of the median EU member state, in percent. Costs to the countries that mirror the EU sanctions and to the other coalition members are not included. The results are discussed in Section 6.4.

Our ranking relies on a first-order, partial-equilibrium score. To check how well it approximates the exact effects, we ban 18 products one at a time on top of the current restrictions and solve the full GE model for each.[53] The exact losses amount to 52% to 89% of the losses implied by the score. Part of this gap arises because the score holds Russia's expenditure shares fixed and thus ignores that Russia substitutes toward other products. The ranking of the products, however, is largely preserved, with a rank correlation of 0.88 between the score and the exact loss per dollar of newly covered exports. The order changes only among the first products, whose scores are close to each other. The score also predicts well which steps along the expansion path in Figure 10 raise Russia's loss the most. Across these steps, the rank correlation between the exact increase in the loss and the increase implied by the score is 0.992.

6.4 Comparing the Instruments

Table 5 compares closing every hub route through which Russia currently buys banned coalition products with fully banning the first 218 products of the transshipment-adjusted list. The two exercises generate almost the same additional loss for Russia, which makes their costs to the EU members directly comparable. Unlike the product expansion, however, closing routes depends on the cooperation of countries outside the coalition.

For the median EU member state, the product expansion has a lower additional real-income cost than route closure. This is consistent with the logic of the product ranking, which favors products whose ban causes Russia the largest losses for a given value of newly restricted trade.

[53] These are the first eight products of the transshipment-adjusted list and those at ranks 12, 20, 35, 60, 100, 200, 400, 800, 1,600, and 2,800. Without dividing by exports, the rank correlation between the partial-equilibrium and the exact losses is 0.99.

The main insight from these exercises is twofold. First, transshipment is quantitatively important, but curbing it is difficult. Closing every route currently in use eliminates only 41% of Russia's transshipment gain, since trade shifts to routes that were not used before. The accession of new coalition members can raise Russia's loss considerably more, in particular if a new member is an important supplier to Russia as well as a hub, but it requires these countries to impose the bans themselves. Second, the product scope of the bans is quantitatively important as well. The product list is under the direct control of the sanctioning countries. The upgrades from partial to full bans already account for 24% of Russia's current loss. Fully banning a targeted set of further products raises Russia's loss about as much as closing every route currently in use. With 965 products, the loss reaches the level that the current bans would cause without transshipment. Whether the costs of these measures are worth bearing depends on the geopolitical objective and lies outside the scope of our analysis.

7 Conclusion

Discriminatory trade policy invites transshipment, and the EU export bans on Russia show how much it matters. Linking Russian customs records with new data on the bans, we find that banned EU goods worth about 20% of pre-war imports keep reaching Russia, almost always through a hub outside the EU. The bans act like a 69% tariff rather than a ban, and stricter enforcement shifted sales to third-country intermediaries rather than stopping them. In a general-equilibrium model disciplined by these facts, the same bans would raise Russia's real-income loss by 32% without transshipment. Closing every route currently in use would recover only 41% of Russia's gain from transshipment, because trade moves to routes not yet used. Enlarging the coalition does more, since a new member stops serving as a hub altogether: if the five largest hubs joined, Russia's loss would exceed the loss the current bans would cause without transshipment.

Our analysis applies the bans to an economy calibrated to 2019 and holds the hubs' transshipment capabilities fixed. In practice, enforcement closes routes and intermediaries build new ones over time, and modeling these dynamics is a natural next step. The framework also extends to other discriminatory barriers that can be circumvented through third countries, such as targeted tariffs, where transshipment typically requires misdeclaring the origin of goods.

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A Construction of Data on Export Bans

1st package	Feb, 23^{rd} 2022	-
2nd package	Feb, 25^{th} 2022	dual-use/high-tech*, oil technologies*, aviation*
3rd package	March, 1^{st} 2022	banknotes*
compliance	March, 9^{th} 2022	maritime navigation*
4th package	March, 15^{th} 2022	steel and iron* †, luxury*
5th package	April, 8^{th} 2022	goods strength. the ind. capability*, aviation*, luxury*, oil technologies*, dual-use/high-tech*, coal†, strategic†, steel & iron†
6th package	June, 3^{rd} 2022	dual-use/high-tech*, petroleum oils†, strategic†
maintenance & alignment	July, 21^{st} 2022	dual-use/high-tech*, goods strengthening the ind. capability*, oil technologies*, gold†
8th package	Oct, 10^{th} 2022	aviation*, dual-use/high-tech*, firearms*, goods strengthening the ind. capability*, iron and steel†, strategic†
9th package	Dec, 16^{th} 2022	dual-use/high-tech*, aviation*, goods strengthening the ind. capability*, petroleum oils†, iron and steel†
10th package	Feb, 25^{th} 2023	dual-use/high-tech*, aviation*, goods strengthening the ind. capability*, strategic†
11th package	June, 23^{rd} 2023	dual-use/high-tech*, firearms*, goods strengthening the ind. capability*, luxury*, strategic†, steel and iron†
12th package	Dec, 18^{th} 2023	dual-use/high-tech*, goods strengthening the ind. capability*, strategic†, diamonds†
13th package	Feb, 23^{rd} 2024	dual-use/high-tech*, goods strengthening the ind. capability*
14th package	June, 24^{th} 2024	dual-use/high-tech*, goods strengthening the ind. capability*, strategic†

Table A.1. Timeline of EU sanctions packages against Russia

Note: * export sanction, † import sanction

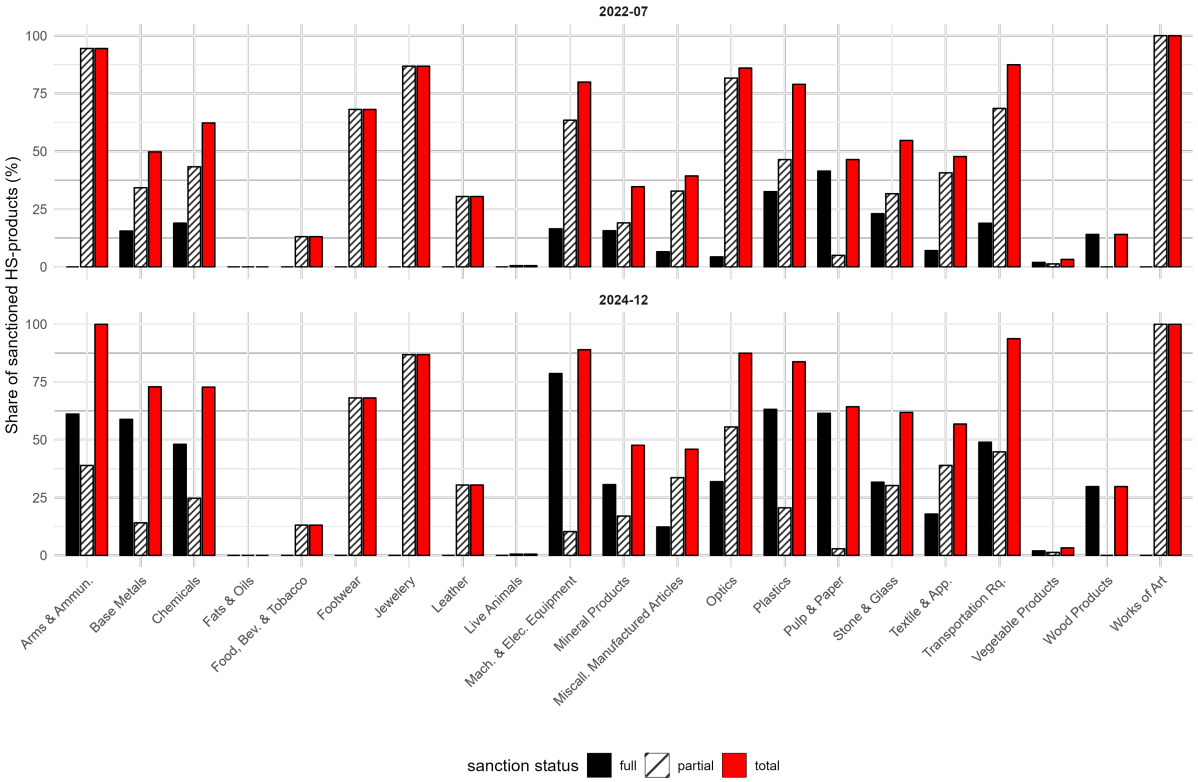


Figure A.1. EU Export Bans By Sectors

Note: The figure reports, by sector, the share of HS6 products covered by EU export bans. Black bars indicate fully banned products, striped bars partially banned products, and red bars total banned products. The upper panel shows coverage as of July 2022, and the lower panel as of December 2024.

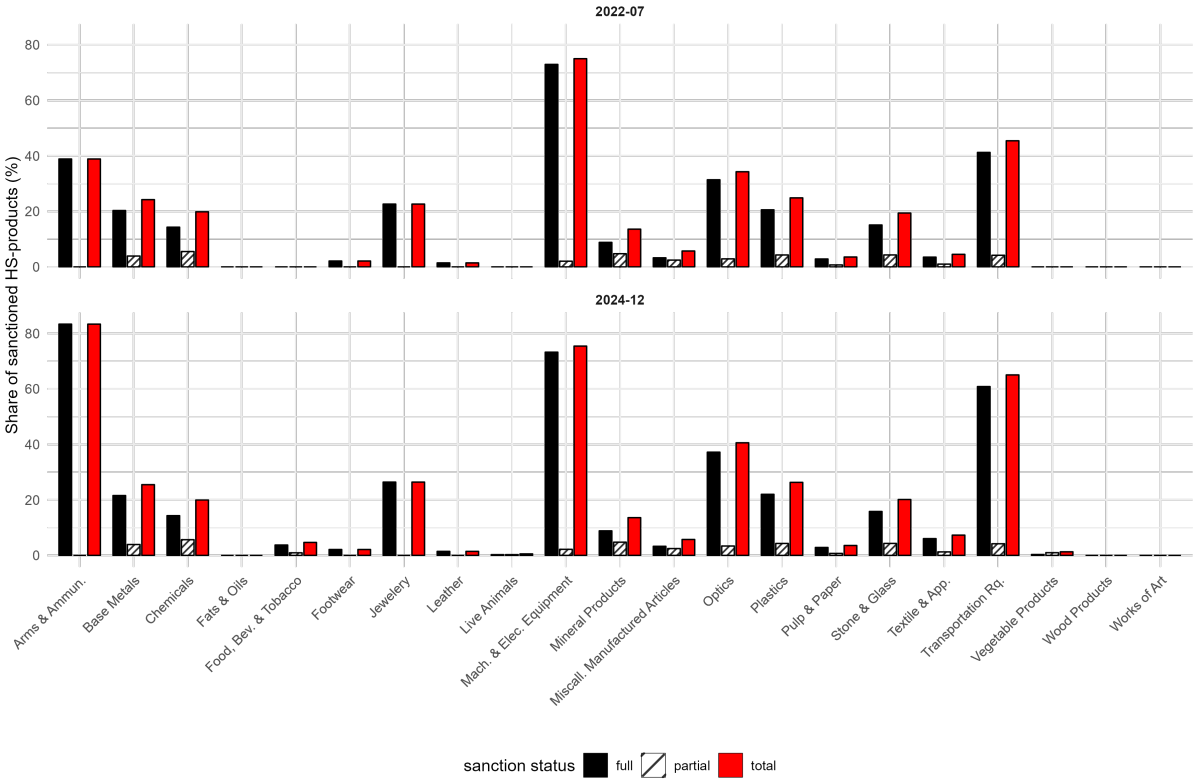


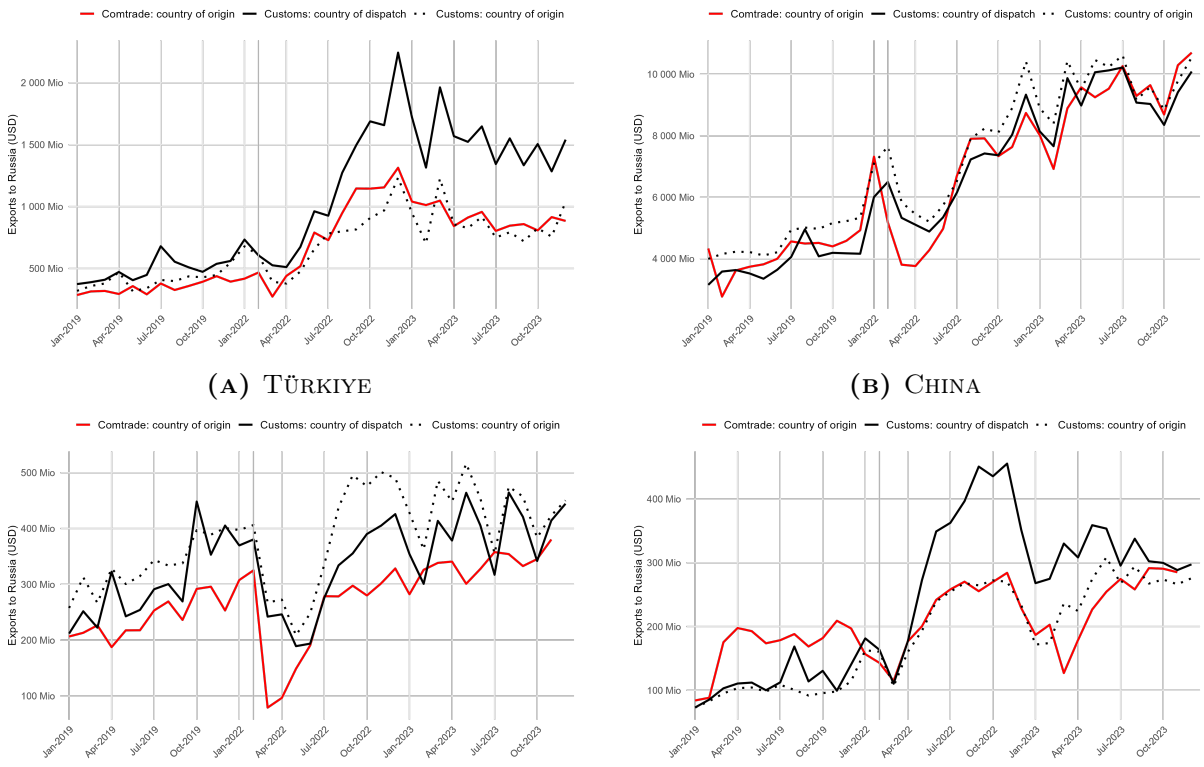
Figure A.2. Sectoral Coverage of EU-BLR sanctions by status and EIF date

Note: This figure reports, by sector, the share of EU-sanctioned products vis-a-vis Belarus at the 6-digit HS2017 level, distinguished by sanction status. Black bars indicate the share of fully sanctioned products, striped bars the share of partially sanctioned products, and red bars the total share of sanctioned products. The upper panel includes all sanctions that came into force by July 2022, while the lower panel includes

B Validation of Russian Customs Data

We further assess data quality by comparing Russian import records to mirror export data from UN Comtrade, which report exports to Russia by country of origin as declared by partner countries. Such comparisons are uninformative for sanctioning countries, for which discrepancies are expected by construction and are precisely how we measure evasion. We therefore focus on non-sanctioning countries, whose exports to Russia remain legal and unrestricted and for which there is no incentive to misreport trade. If Russian customs data were systematically manipulated, imports from these countries would also diverge from partner-reported exports. We examine the four largest post-invasion exporters to Russia outside the sanctioning coalition for which UN Comtrade data are available; additional examples are reported in Appendix Figure B.2.

Figure B.1 shows that, for Türkiye, China, and Uzbekistan, UN Comtrade mirror exports closely track Russian customs imports by country of origin. For India, Comtrade flows are systematically lower, but this pattern predates the full-scale invasion of Ukraine in February 2022 and likely reflects known limitations of mirror statistics, such as valuation differences between CIF and FOB prices or reporting thresholds, rather than manipulation of the customs data. Overall, these comparisons suggest that the Russian customs data reliably capture trade flows and origin information.



(A) Türkiye (B) China

(C) India (D) Uzbekistan

Note: The figure compares Russian customs imports with mirror exports to Russia reported in UN Comtrade, by month, year, and partner country. Data are shown for 2019 and for 2022–2023 for the largest exporters to Russia outside the sanctioning coalition, for which UN Comtrade data are available. Trade values are expressed in millions of U.S. dollars.

Figure B.1. Comparison UN Comtrade and Russian Customs Data (biggest trade partner)



(A) Brazil

(B) South Korea

(C) Vietnam

(D) Ecuador

(E) United Arab Emirates

(F) Azerbaijan

(G) Chile

(H) Egypt

Note: The figure shows Russian imports from the customs data (by month, year, and country of dispatch & origin) alongside exports to Russia from the same countries reported in UN Comtrade. Data are shown for 2019 (pre-period) and 2022–2023 (post-onset of the Russian war) for other non-EU, non-coalition exporters with available Comtrade data. Trade values are in millions of US dollars.

Figure B.2. Comparison UN Comtrade and Russian Customs Data (Other Examples)

C Export Bans of the Coalition

Coalition group. In the counterfactual exercises below, we need to specify which countries sanctioned (banned) which products. These countries will form the "coalition."

Following Li et al. (2024), we identify 38 U.S.-aligned countries exempt from U.S. licensing requirements for exports to Russia, as listed in Supplement No. 3 of Part 746 of the Export Administration Regulations (EAR), which recognizes countries implementing "substantially similar export controls." Beyond the EU-27, several countries align with EU sanctions to varying degrees, through selective adoption, voluntary compliance, or formal implementation as part of EU accession. A core group—including Albania, Bosnia and Herzegovina, Iceland, Liechtenstein, Montenegro, North Macedonia, Norway, and Ukraine (IN THE MODEL I ALWAYS SET UKRAINE TO FULL EMBARGO?)—consistently follows EU sanction packages.[54] For these countries, we assume the EU sanction regime applies identically. For the remaining countries (see part III of Table C.1), we rely on product-level sanction information from the Global Trade Alert (GTA) database. We retain sanctions at the 6-digit product level, applied to either all firms or individual firms, classified as discriminatory, and with an implementation date before December 2024. In the absence of explicit entry-into-force dates, we define sanctions using a two-step approach: (i) product–country observations are explicitly listed as sanctioned in GTA, and (ii) product–country–time observations for which exports to Russia fall below 10% of their pre-shock average.[55] The EU's sanction regime broadly encompasses the products targeted by these coalition countries (Table C.2), justifying their designation as such. Nevertheless, with roughly 3,000 sanctioned products, the EU's coverage extends beyond that of its coalition partners. For the remaining non-EU coalition countries, GTA provides product-level sanction flags but does not distinguish between partial and full bans across 6-digit codes. We therefore refrain from using these countries in analyses that require a precise full-versus-partial classification, such as in the triple-difference event-study design of Section 3.1.

Sanctions vis-a-vis Belarus. The EU has also extended its sanction regime to Belarus in response to the country's involvement in Russia's military aggression against Ukraine. This is important for our quantification, because we will block transshipment via Belarus in the model for the products where it was also hit by sanctions. Sanction data are drawn from TARIC, applying the same inheritance rules as for EU-Russia sanctions. By July 2022, 1,195 products were subject to export bans, rising to 1,299 products by December 2024 (see Figure A.2). The overlap with EU-Russia sanctioned products was initially

[54] Council alignment statement, December 8, 2025

[55] For product–origin pairs absent from the pre-period, we proxy the EIF date with the implementation date.

Table C.1. Sanctioning Coalition Countries

EU-27			
AUT — Austria	BEL — Belgium	BGR — Bulgaria	CYP — Cyprus
CZE — Czechia	DEU — Germany	DNK — Denmark	ESP — Spain
EST — Estonia	FIN — Finland	FRA — France	GRC — Greece
HRV — Croatia	HUN — Hungary	IRL — Ireland	ITA — Italy
LTU — Lithuania	LUX — Luxembourg	LVA — Latvia	MLT — Malta
NLD — Netherlands	POL — Poland	PRT — Portugal	ROU — Romania
SVK — Slovakia	SVN — Slovenia	SWE — Sweden	—
Mirrors EU sanctions			
ALB — Albania	BIH — Bosnia & Herzegovina	ISL — Iceland	LIE — Liechtenstein
MKD — North Macedonia	MNE — Montenegro	NOR — Norway	UKR — Ukraine
Other sanctioning countries			
AUS — Australia	CAN — Canada	CHE — Switzerland	GBR — UK
JPN — Japan	KOR — South Korea	NZL — New Zealand	SGP — Singapore
TWN — Taiwan	USA — United States	—	—

Note: The table distinguishes three groups of sanctioning countries. The first group comprises the EU-27 member states. The second group includes non-EU countries that closely mirror the EU sanctions regime and for which the same sanctions are applied consistently. The third group consists of non-EU coalition countries that have imposed their own sanctions regimes on Russia, which differ to varying degrees from the EU regime.

Table C.2. Coverage of EU-Russia sanctions by non-EU Coalition countries

Country	Share of products covered by EU's regime [%]	Total products sanctioned	Overlap with EU
Singapore	100.0	15	15
Switzerland	99.8	432	431
Canada	98.6	148	146
South Korea	97.7	386	377
United Kingdom	96.9	294	285
USA	88.9	416	370
Japan	74.2	458	340
Australia	70.0	30	21
New Zealand	42.9	7	3

Note: This table reports, for each country in the non-EU coalition group, the extent to which its sanctions regime with respect to Russia is covered by the EU-Russian sanction regime, measured as the share of sanctioned products that are also sanctioned by the EU vis-a-vis Russia. Columns (2) and (3) report the total number of products sanctioned by each country and the number of those products that are also sanctioned by the EU.

limited: only 29% of products fully sanctioned against Russia by July 2022 were also fully sanctioned vis-à-vis Belarus. By December 2024, this share increased to approximately 38%.[56] The sanctioned products for the remaining coalition countries are again taken from Global Trade Alert (GTA).

C.1 Dictionary for Classifying Trading Firms

We classify a sender as a trading firm if its name contains at least one of the 29 terms in Table C.3, matched as whole words. Because names without any listed term remain unflagged, the resulting shares are lower bounds on the role of trading firms.

[56] For EU–Belarus sanctions, the implementation date rather than the entry-into-force date is used to define sanctioned products. Consequently, these overlap figures likely represent an upper bound, as wind-down periods and exemptions may delay the actual enforcement of the sanctions.

Table C.3. Dictionary Terms for Trading Firms

Language	Terms
English	trading, trade, traders, general trading, international trade, commerce, commercial, mercantile, import (and) export, imp (and) exp, impex
Turkish	*ticaret* (trade), *dış ticaret* (foreign trade), *ihracat* (export), *ithalat* (import), *pazarlama* (marketing)
Russian	*eksport* (export), *import* (import), *torgovyi dom* (trading house), VED (foreign economic activity)
Other	*Handel, Handels* (trade, DE/PL); *comercio, comercial* (ES/PT); *commercio* (IT); *exportação, importação* (PT)
Example	`VDV DIS TICARET LIMITED SIRKETI`

D Details on the Calibration

This appendix provides the details of the calibration summarized in Section 4.3.

Table D.1. Model Parameters

Parameter	Value	Source or Target
Trade elasticities, θ^k	1.5 to 44.1 (median 8.2)	Fontagné et al. (2022)
Within-group elasticity, σ_g	2.2	French (2016)
Cross-group elasticity, ν	1.1	Assumption
Lower bound on home shares	10%	Assumption
Baseline trade costs, τ^k_{ei}	By product and country pair	Gravity inversion, triangle inequalities
Relative hub wedges, $\widetilde{\rho}_h$	By hub	Hub shares, Russian customs data
Common level of the wedges, a	1.34	Estimated effect of the full bans
Partial-ban cost increase, δ_P	1.100 (an increase of 10%)	Estimated effect of the partial bans

Notes. This table reports the parameters of the model, their values in the main specification, and where these values come from.

D.1 Data, Sample, and Elasticities

We calibrate the model at the 6-digit HS level, the most detailed product classification that is harmonized across countries. At this level, we can impose the export bans product by product. In the more aggregated quantifications that are standard in the literature, the bans cannot be mapped cleanly into sectors. Product-specific import shares and trade elasticities also allow the ease of replacing a sanctioned origin to vary across narrowly defined products, and the model's rerouting of each origin and product can be compared directly with the customs data. The cost of this disaggregation is that expenditure is not observed at the product level, so we recover it from the structure of the model, as explained below.

Trade and absorption data. We use data from 2019, the last full year before COVID and the war. Bilateral product-level trade flows from UN Comtrade measure X^k_{ei} for $e \neq i$, with products defined at the HS6 level in the HS2017 vintage. For each reporting side, we first aggregate records that are split by customs procedure, transport mode, and second partner country. To limit the effect of missing or incomplete mirror reports, we then use the larger of the importer's reported imports and the exporter's reported exports.

To measure total expenditure, X_i, and the domestic expenditure underlying X^g_i, we use the OECD Inter-Country Input-Output tables (regular ICIO, 2025 edition). For each of the ICIO's goods industries, expenditure on domestically produced goods equals gross output minus exports (set to zero where recorded exports exceed recorded output), and total expenditure adds imports to this amount. For countries missing from ICIO, we use

the International Trade and Production Database for Estimation (ITPD-E, Release 2; see Borchert et al. (2021)).[57]

To keep the quantification tractable at the HS6 level, we restrict the sample to the countries in the UN Comtrade data that (i) implement export bans against Russia,[58] (ii) are among Russia's top 50 import origins or top 50 export destinations in 2019, (iii) are members of the Eurasian Economic Union, or (iv) dispatched at least 0.5% of the value of the fully banned goods of the EU and the countries mirroring its sanctions that Russia imported through countries outside the coalition in 2024. This leaves 74 countries, which account for 96% (98%) of Russia's total exports (imports) and 93% (92%) of world exports (imports).[59] Finally, we drop HS6 products for which Russia's total 2019 trade is less than USD 10,000 on both the import and the export side. A further 11 products trade in too few markets for the regression below to estimate their product-level effects, leaving 5,136 products in the final sample.[60]

Elasticities. As is common in the literature, we do not estimate the elasticities ourselves. We take the trade elasticities, θ^k, from Fontagné et al. (2022), who estimate product-level trade elasticities using gravity regressions consistent with our setup. For 6-digit products that cannot be matched to their data, we use the average elasticity within the product's 4-digit heading. Because the estimates contain some outliers, we winsorize them at the 1st and 99th percentiles. We assign the median of the matched elasticities to the 85 products without a match at either level. The resulting trade elasticities range from 1.5 to 44.1,

[57] The ITPD-E data sometimes imply very small (or even negative) expenditure on domestically produced goods. We therefore use these data only for countries for which ITPD-E reports positive domestic expenditure in at least 50 of its 153 goods industries, which are more disaggregated than the ICIO industries, and these industries cover at least 40% of the country's recorded imports. For the other countries missing from ICIO, we use as a reference group the ICIO countries whose population lies on the same side of the sample median, which allows home-expenditure shares to differ with country size. We choose a country's total domestic expenditure such that, given its imports, its home-expenditure share (expenditure on domestically produced goods divided by the sum of this expenditure and imports) equals the unweighted average across the reference group. We then distribute this total across industries according to the pooled domestic expenditure of the reference group.

[58] For Taiwan, we use its own reports to UN Comtrade (reporter code 490), because its partners record their trade with Taiwan only under the residual category "Other Asia, not elsewhere specified," which may also contain other flows.

[59] We treat China and Hong Kong as a single country when calibrating the model (reassigning Hong Kong's flows to China) due to large shares of re-exports between these countries, as is frequently done in the quantitative trade literature. We treat Liechtenstein and Switzerland in the same way, as Liechtenstein has no separate customs territory and no separate presence in UN Comtrade. In both cases, we combine the two territories' flows on each reporting side before taking the maximum across sides. We do not aggregate the remaining countries into a rest-of-the-world region.

[60] These are the products for which the regression yields no importer-product effect or no exporter-product effect for any country.

with a median of 8.2. Russia can therefore replace a sanctioned supplier much more easily for some products than for others.[61]

Within groups, we set $\sigma_g = 2.2$ for all three groups, in line with French (2016). Across groups, we set $\nu = 1.1$, close to the Cobb–Douglas case and half the within-group elasticity. Russia therefore substitutes much less easily across the three groups than within them. However, Section 5 shows that Russia's real-income losses and its transshipment gain barely change when we lower ν below one, raise it to σ_g, which places all products in a single CES nest, or lower the within-group elasticity of military-relevant goods to $\sigma_M = 1.2$.

D.2 Product Groups and Expenditure

Product groups. We assign the 5,136 products to the three groups based on existing lists of battlefield-relevant and strategic goods. Group M starts from the 44 battlefield-relevant products listed in Table A1 of Scheckenhofer et al. (2025) and, after two adjustments, contains 42 products.[62] Beyond battlefield goods, sanctions target products with high strategic value. The EU's export-control framework identifies these products through two lists. The dual-use list covers goods with both civilian and military uses, and the advanced-technology list (Annex VII) covers goods and technology that might contribute to Russia's military and technological enhancement. Both lists are defined at a more disaggregated level than HS6, and group C contains every HS6 product with at least one tariff line on either list.[63] Net of the products already in M, this yields 967 products, spanning machine tools, electronics, precision instruments, chemicals, and metals.[64] Table A1 predates the February 2024 update of the Common High Priority Items list (version of February 2024),

[61] Every θ^k exceeds $\sigma_g - 1$, with σ_g as set below. This ensures that the exponent used in the expenditure recovery below is positive and that one can choose an η^k satisfying both $\eta^k > \sigma_g$ and $\theta^k > \eta^k - 1$ (see Section 4.1). Because η^k otherwise affects only the product-specific price-index constant that we absorb into T_e^k, it need not be calibrated separately, a standard result in EK-type models.

[62] First, we move the three products of the HS 8517 phone family (851712, 851762, and 851769) to C, because they entered the battlefield list as sources of components rather than as military equipment. Second, we add HS 854150 (other semiconductor devices), because the battlefield list, which uses a later HS version, contains both codes into which 854150 was split.

[63] Accordingly, if one line of an HS6 product is listed, we attribute the full HS6 product to that specific group. By contrast, in Section 2.1, we treat an HS6 product as fully banned only if the bans cover all of the goods within that HS6 category.

[64] The product lines come from the European Commission's correlation tables. For the dual-use list (Regulation 2021/821), we use the table valid through 31 December 2024 (available here; retrieved 4 August 2026), matching our end-2024 sanctions data, while for Annex VII (Regulation 833/2014), the 2026 vintage (available here; retrieved 28 July 2026) is the earliest available to us. The dual-use table lists ten-digit TARIC codes, which we truncate to six digits, and where it lists only a four-digit heading, we include all products of that heading. From the Annex VII table we take every complete eight-digit CN code, whereas rows without one (software and technology items, free text) identify no product line and are dropped. Codes published in later HS vintages are converted to HS2017 with the one-to-one conversion sheet of the official UN conversion table.

which added five machine-tool products (Tier 4.B). These products are covered by the two EU lists and therefore fall into C. The remaining 4,127 products form group O.

Group expenditure, X_i^g, consists of imports and domestic absorption of the group's products. For imports, we simply add up the imports of the products in each group. Domestic absorption, however, is recorded by ICIO industry rather than by product, and we allocate it in two steps. First, we map each HS6 product to one of the ICIO's 26 goods industries (agriculture, mining, and manufacturing) using all rows of the official UN correspondence tables (HS2017 to CPC 2.1 to ISIC Rev. 4), including those flagged as partial. For 95.6% of import value in our sample, these rows single out one industry.[65] Second, we split each industry's domestic absorption across M, C, and O in the same proportions as the country's imports within that industry, since imports are the only expenditure we observe at the product level. If a country has no imports in an industry, we use the industry's import composition summed over all sample countries. Group imports plus allocated domestic absorption then give X_i^g.[66] This allocation assumes that, within an ICIO industry, expenditure on domestically produced goods is split across M, C, and O in the same way as imports. For Russia, the three groups account for 1.6% (M), 30.7% (C), and 67.8% (O) of total expenditure.

Product-level expenditure. We cannot read X_i^k (i.e., product-level expenditure) directly from the data, because expenditure is not observable at this level of disaggregation globally. We therefore recover k-level expenditure (and, accordingly, domestic product-level trade) using the model's structure.[67]

Next, we allocate group expenditure, X_i^g, across the products of each group. By equation (9), this allocation is pinned down by the product-level price indices, P_i^k, which we need to estimate. We cannot simply use equation (11) to estimate P_i^k, because the dependent variable itself is scaled by X_i^k. However, combining equations (9), (11), and

[65] For the remaining 4.4% of import value, the correspondence tables give no industry or several. In these cases, we use the industry that produces the goods of the product's HS2 chapter (for instance, chemicals for chapters 28 and 29). If the tables offer several industries and the chapter's industry is not among them, we choose the industry to which most of the unambiguously mapped products of the same HS4 heading belong. For the products where neither rule decides (HS 310100, 440210, 440290, and 940690), we take the industry that comes first in the ICIO industry code order.

[66] Let D_{ir} denote domestic absorption and I_{ir}^g imports of group g in country i and ICIO industry r. The allocation is

$$D_{ir}^g = \begin{cases} D_{ir}\dfrac{I_{ir}^g}{\sum_s I_{ir}^s}, & \text{if } \sum_s I_{ir}^s > 0, \\ D_{ir}\dfrac{\sum_j I_{jr}^g}{\sum_j \sum_s I_{jr}^s}, & \text{if } \sum_s I_{ir}^s = 0, \end{cases}$$

where s runs over the three groups and j over the sample countries, with $X_i^g = \sum_r \left(D_{ir}^g + I_{ir}^g\right)$.

[67] French (2016) recovers product-level expenditure while assuming that trade costs and trade elasticities are common across products, whereas Torun (2025) uses a non-homothetic final-goods aggregator to do so.

(12), we obtain

$$\frac{X_{ei}^k}{X_{ei}} = \frac{T_e^k w_e^{-\theta^k} \Lambda_i^{g(k)} (P_i^k)^{\theta^k - (\sigma_{g(k)}-1)} (\tau_{ei}^k)^{-\theta^k}}{\sum_{s=1}^K T_e^s w_e^{-\theta^s} \Lambda_i^{g(s)} (P_i^s)^{\theta^s - (\sigma_{g(s)}-1)} (\tau_{ei}^s)^{-\theta^s}},$$

where $X_{ei} := \sum_{s=1}^K X_{ei}^s$ denotes total bilateral trade and the group scale $\Lambda_i^g := X_i^g (P_i^g)^{\sigma_g - 1}$ collects the group-level terms, which are common to all products of group g in country i. Taking logs of this equation yields

$$\log\left(\frac{X_{ei}^k}{X_{ei}}\right) = \log\left(T_e^k w_e^{-\theta^k}\right) + \log\left(\Lambda_i^{g(k)} (P_i^k)^{\theta^k - (\sigma_{g(k)}-1)}\right) - \log\left(\Psi_{ei}\right) - \theta^k \log\left(\tau_{ei}^k\right),$$

where $\Psi_{ei} := \sum_{s=1}^K T_e^s w_e^{-\theta^s} \Lambda_i^{g(s)} (P_i^s)^{\theta^s - (\sigma_{g(s)}-1)} (\tau_{ei}^s)^{-\theta^s}$. We run an OLS regression with $\log\left(X_{ei}^k / X_{ei}\right)$ as the dependent variable on all positive bilateral flows. The first three elements on the right-hand side can be captured by an exporter-product fixed effect (FE), an importer-product FE, and an exporter-importer FE, respectively. To parametrize the impact of τ_{ei}^k, we interact a set of product dummies with several standard bilateral variables: the log of population-weighted distance, as well as dummy variables indicating whether the country pair has a free trade agreement or is part of the same customs union, and whether it shares a common border, language, or colonial history. These control variables are obtained from the standard CEPII Gravity database (Conte et al., 2022).

Therefore, through the lens of the model, the exponentiated importer-product FE yields the composite $B_i^k := \Lambda_i^{g(k)} (P_i^k)^{\theta^k - (\sigma_{g(k)}-1)}$ rather than the price index alone. Because every θ^k exceeds $\sigma_g - 1$, this exponent is positive, so a higher B_i^k corresponds to a higher P_i^k at a given group scale. The regression pins down the exporter-product and importer-product FEs only jointly, so a product-specific constant can be shifted from one set of effects to the other without changing any fitted share. We normalize the estimated B_i^k to a geometric mean of one across importers within each product and absorb the offsetting constant into the exporter-product effects. For importer-product cells where the regression yields no estimate, we set B_i^k equal to the maximum estimate within k (recall that a higher P_i^k implies more difficult access to cheap sources). Moreover, due to outliers in these estimates, we winsorize B_i^k by bounding values below the 10th and above the 90th percentiles within each importer i and group g. Recovering P_i^k from B_i^k then requires the group scales Λ_i^g, which the regression does not pin down. We normalize $\Lambda_i^O = 1$ and solve, country by country, for the two remaining scales such that the implied group expenditures match their measured ratios (with X_i^g measured as described above),

$$\frac{\Lambda_i^g (P_i^g)^{1-\sigma_g}}{(P_i^O)^{1-\sigma_O}} = \frac{X_i^g}{X_i^O}, \qquad g \in \{M, C\},$$

where the group price indices follow from equation (6) and $\Lambda_i^g (P_i^g)^{1-\sigma_g}$ is the group expenditure for a given scale. The left-hand side is strictly increasing in Λ_i^g, so each equation has a unique solution. Equation (9) then yields X_i^k, which adds up to X_i^g within each group, and hence to X_i, by construction. Domestic product-level trade follows as the residual $X_i^k - \sum_{e \neq i} X_{ei}^k$. The elasticity ν plays no role in this step, because group expenditure is already measured at this point, but it governs how expenditure shifts across the three groups in the counterfactuals.

Because product-level expenditure is recovered rather than directly observed, it is sometimes only slightly larger than a country's observed imports of the product, and sometimes even smaller. Expenditure on domestically produced goods, the difference between the two, is then very small or even negative. Since the home share, together with the trade elasticity, is known to be a main determinant of welfare changes in this class of models, such cases may produce extreme results. As a final step, we therefore impose a lower bound of 10% on each product's home share, π_{ii}^k, which initially binds for 15% of all country-product pairs. Where the bound binds, we raise the product's expenditure until its home share reaches 10%, and we scale down expenditure on the other products of the same group proportionally, which leaves group expenditure unchanged. We repeat this until all products satisfy the bound. Imports remain at their observed values throughout. In 19 of the 74 countries, the measured expenditure of a group is too small to satisfy the bound for all of its products. In these countries, we raise the group's expenditure share by as little as necessary and scale down the shares of the other groups proportionally, which changes group shares by at most 1.8 pp and leaves total expenditure unchanged. Russia is not among these countries. The resulting domestic and bilateral flows give the baseline trade shares, π_{ei}^k. Section 5 reports results with a lower bound of 5%.

D.3 Baseline Trade Costs

To recover the initial trade barriers, we use the trade shares, π_{ei}^k, and the exporter-product FEs of the regression above, whose exponential yields $T_e^k w_e^{-\theta^k}$. For exporter-product cells where the regression yields no estimate, we set $T_e^k w_e^{-\theta^k}$ equal to the minimum estimate within k (recall that a lower $T_e^k w_e^{-\theta^k}$ implies less export competitiveness), and we winsorize by bounding values below the 10th and above the 90th percentiles within each exporter e across all products. The winsorization of B_i^k is done within group instead, because B_i^k contains the group scale Λ_i^g, whose level differs across groups. According to the gravity equation, trade barriers can be backed out using bilateral relative to domestic flows,

$$\tau_{ei}^k = \left(\frac{\pi_{ei}^k / (T_e^k w_e^{-\theta^k})}{\pi_{ii}^k / (T_i^k w_i^{-\theta^k})} \right)^{-1/\theta^k}, \tag{31}$$

which matches the positive baseline trade flows exactly, in line with the hat-algebra logic.[68]

We then need to ensure that the initial trade costs satisfy the TIs to have a theory-consistent starting point. The gravity-implied barriers from equation (31) need not satisfy the triangle inequalities, because the bilateral term recovered from gravity combines route-related trade costs with other pair-specific barriers, such as bilateral preference shifters (Foellmi et al., 2024). To recover trade costs, we apply the algorithm from Foellmi et al. (2024, Section 4) and update the τ_{ei}^{k} values from equation (31) iteratively until we have no more TI violations. This yields a set of TI-consistent trade costs, which we then use to measure transshipment opportunities following a shock.[69]

D.4 Hub Shares and Hub Wedges

Multiplying all wedges by the same factor makes every hub route more costly but does not change which one is the cheapest. The observed hub shares thus identify the wedges only up to a common scale, and we write them as

$$\rho_h = a\,\widetilde{\rho}_h, \tag{32}$$

where a is their common level and the relative wedges, $\widetilde{\rho}_h$, have a geometric mean of one across potential hubs.

Hub shares. For each potential hub, we count the fully banned origin-product cells of the EU and the mirroring countries for which at least USD 1,000 of imports reached Russia through this hub between May and December 2024. A hub's share is this count divided by the total across hubs.[70] Since the customs data report the point of entry (Section 4.3) mostly from May 2024 onward, we use the months from May to December 2024 for all shipments. In the data, Belarus serves as a hub for some products whose exports to Belarus are banned. Since the model cannot route these products through Belarus, it can match Belarus's share only through its other products.

[68] For zero bilateral trade shares, we replace the relative share term in parentheses by 10^{-12}, which implies a gravity barrier of $\tau_{ei}^{k} = 10^{12/\theta^{k}}$ before the TI adjustment described next.

[69] The algorithm starts by setting the trade barriers that we obtain from equation (31) to at least one. Then, it verifies the TIs, and if a TI is violated, it sets the updated trade cost equal to the minimum indirect cost. This procedure is repeated until there are no more TI violations. The wedge between the initial value of trade barriers and the final value of trade costs can be interpreted as a bilateral preference shifter through the lens of standard gravity theory (cf. Foellmi et al., 2024). Because exact hat algebra conditions on the observed baseline trade shares, this residual need not be recovered separately. The levels τ_{ei}^{k} are needed only to determine rerouting opportunities and the corresponding trade-cost changes.

[70] Counting a hub when it accounts for at least 1% of the imports of an origin-product cell, instead of at least USD 1,000, yields nearly the same shares, with a correlation of 0.999.

Relative wedges. We then choose the relative wedges such that the model's hub shares match the observed ones as closely as possible. Specifically, the relative wedges minimize $\sum_h (s_h - s_h^{\text{data}})^2 + \lambda \sum_h (\log \widetilde{\rho}_h)^2$, where s_h and s_h^{data} denote hub h's share in the model and in the data, respectively. The penalty term, with the small weight $\lambda = 10^{-4}$, keeps the wedges of countries that rarely serve as hubs close to the common level, since their shares carry little information about their wedges.

Common level. By the gravity equation (11), the direct effect of a full ban equals $(m^k_{(1),eR}/\tau^k_{eR})^{-\theta^k}$ for Russia's imports of product k from origin e. We choose a such that

$$\frac{\sum_{(e,k)\in\mathcal{F}} X^k_{eR}\left(m^k_{(1),eR}/\tau^k_{eR}\right)^{-\theta^k}}{\sum_{(e,k)\in\mathcal{F}} X^k_{eR}} = \exp\left(\hat{\beta}_F\right), \tag{33}$$

where $\hat{\beta}_F$ is our estimate of the effect of full bans in Section 3.1 and $\mathcal{F}$ is the set of origin-product cells of the EU and the mirroring countries that are fully banned at the end of 2024 and have positive exports to Russia in 2019.[71] This yields $a = 1.34$, so rerouting through a hub with a relative wedge of one costs 1.34 times as much as in the TI benchmark.

Partial-ban cost increase. We calibrate δ_P to the estimated effect of the partial bans, holding the hub wedges at their calibrated values. To estimate this effect, we rerun the triple-DiD specification in equation (2) with products that remain partially banned through December 2024 as the treated group, so that later upgrades to full bans do not contaminate the estimate. Figure D.1 shows the resulting event study. Relative to never-sanctioned products, imports of partially banned EU products fall by 47% on average after the bans. We then choose δ_P such that the model's average direct effect of the partial bans equals this estimate. The average is taken over the partially banned origin-product cells of the EU and the mirroring countries with positive exports to Russia in 2019, weighted by their 2019 values. For each cell, the direct effect uses the cost in equation (17), the lower of δ_P times the pre-war direct cost and the cost of the cheapest hub route. The result is $\delta_P = 1.100$.

D.5 Untargeted Fit

The relative wedges target only the aggregate hub shares of the EU and the countries that mirror its sanctions. The routing of the other coalition origins, the distribution of hubs within individual origins, the value-weighted hub shares, and the variation across product

[71] Since $\rho_h = a\widetilde{\rho}_h$ cannot fall below one, no relative wedge can be lower than $1/a$. The relative wedges that best match the hub shares can therefore depend on a, and we calibrate the two jointly.

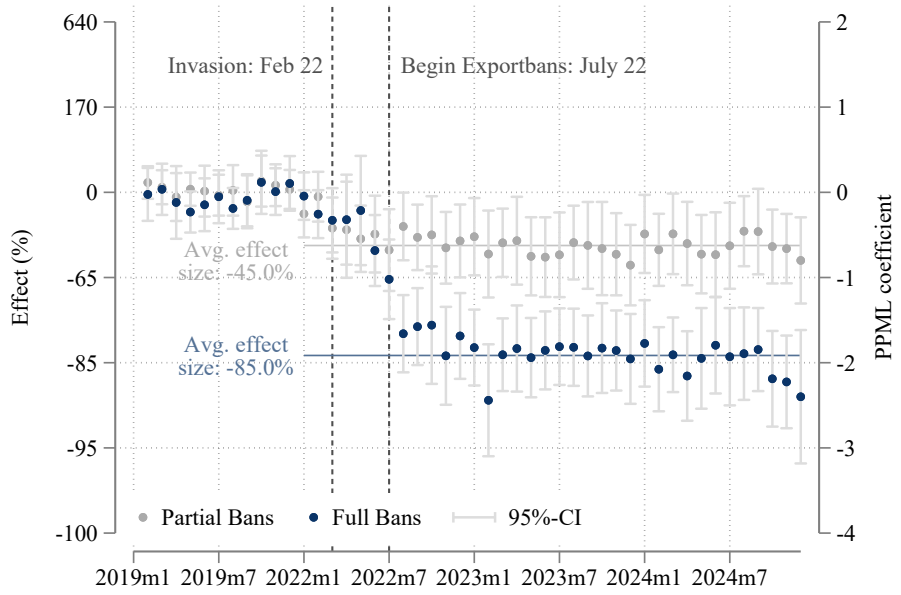
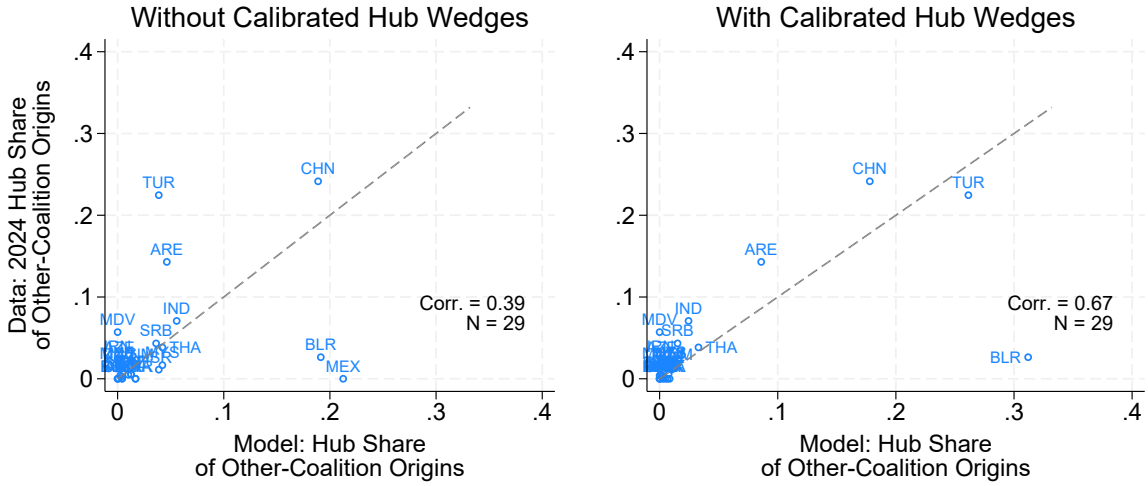


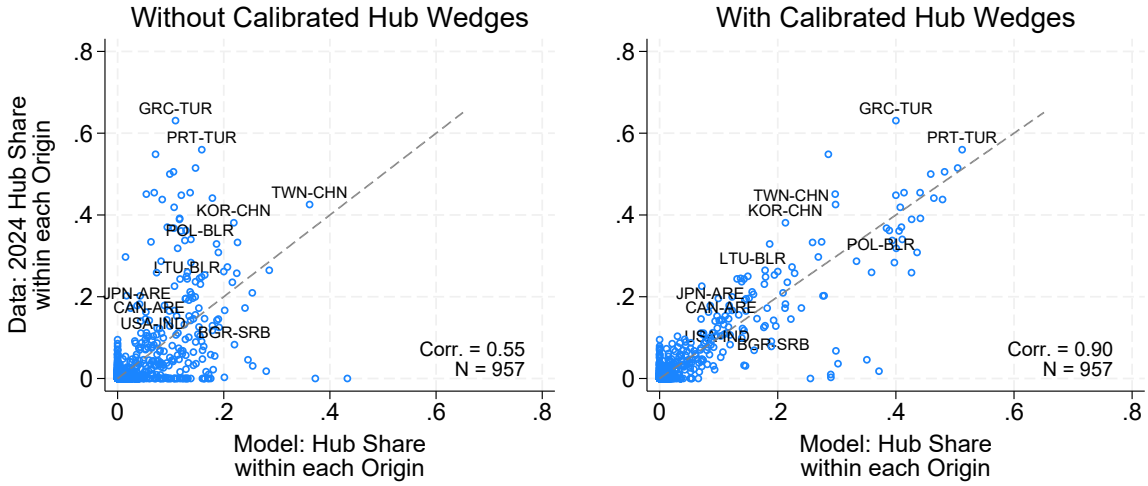
Figure D.1. Event Study: Partial Export Bans and Russian Imports

Notes: The figure plots monthly PPML coefficients $\hat{\beta}_m^P$ of equation (2) for Russian imports of products that remain partially banned through December 2024, with never-sanctioned products as controls. Coefficients are relative to January 2019 (right axis); the left axis shows implied trade-flow changes, $(e^{\hat{\beta}_m^P} - 1) \times 100\%$. The horizontal line marks the average post-ban effect. Bars show 95% confidence intervals clustered by product and origin; vertical lines mark the invasion (February 2022) and the export bans (July 2022).

sectors are therefore untargeted. For the remaining coalition origins, the correlation between the model's and the observed hub shares rises from 0.39 in the TI benchmark to 0.67 with the calibrated wedges (Figure D.2a). For hub shares computed within each coalition origin, the correlation across origin-hub pairs rises from 0.55 to 0.90 (Figure D.2b). The fit also improves for value-weighted hub shares and for hub shares within HS2 chapters (Figure D.3). These comparisons use the same 2024 customs data as the calibration target and are therefore untargeted rather than out-of-sample.



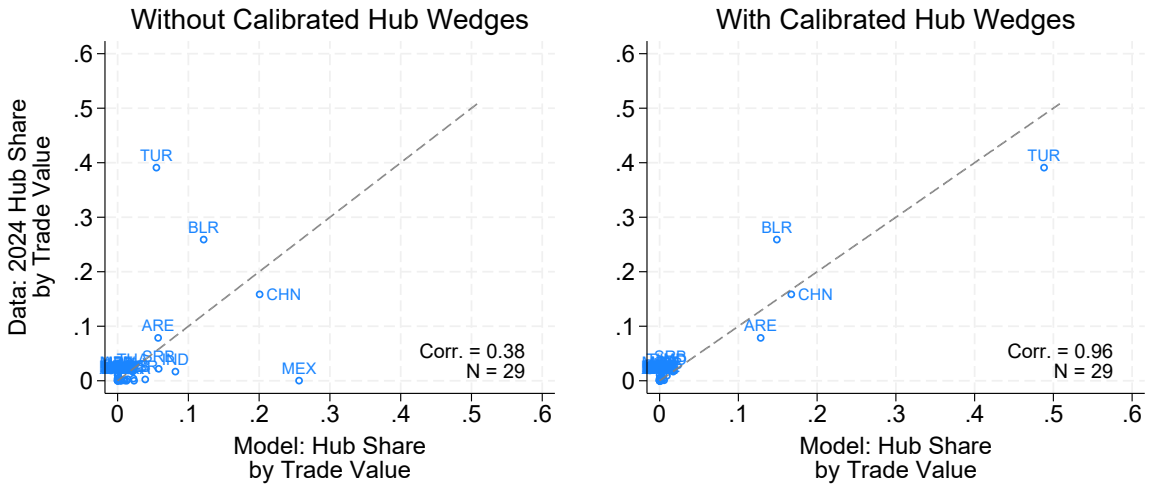
(A) Hub Shares of the Other-Coalition Origins



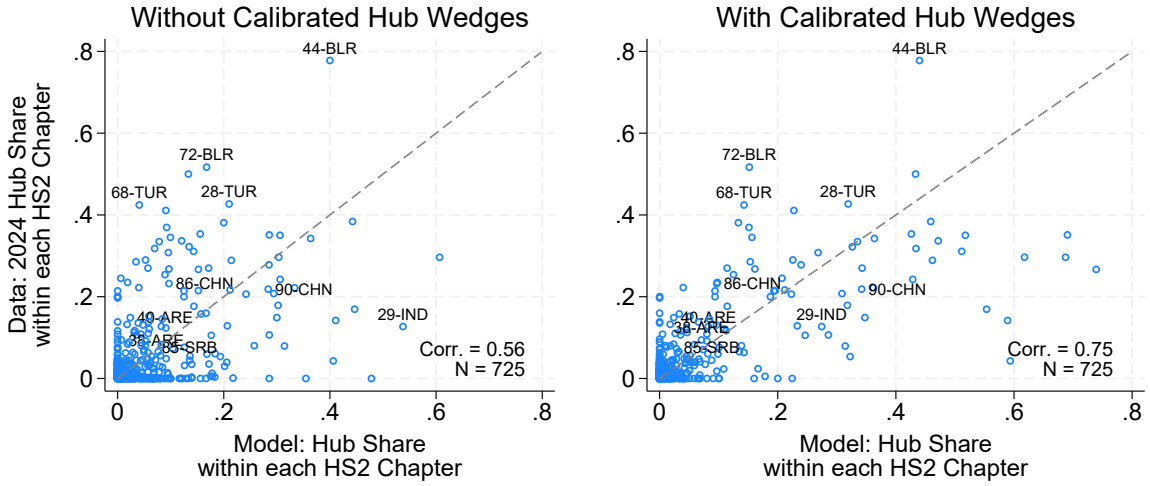
(B) Hub Shares within Each Origin, by Origin-Hub Pair

Figure D.2. Untargeted Fit of the Calibrated Hub Wedges

Note: This figure compares the hub shares of fully banned goods in the Russian customs data for May to December 2024 (vertical axis) with those in the model (horizontal axis), without the calibrated wedges in the left panels (the TI benchmark) and with them in the right panels. Panel D.2a shows the hub shares of the coalition origins outside the EU and the mirroring countries. Panel D.2b shows the hub shares within each coalition origin, for the 33 origins with at least 25 origin-product cells that are rerouted in both the model and the data. Labels identify ten origin-hub pairs with high shares. The dashed line is the 45°-line. "Corr." is the correlation across the plotted points, and "N" is the number of points.



(A) Hub Shares by Trade Value, All Coalition Origins



(B) Hub Shares within Each HS2 Chapter, by Chapter-Hub Pair

Figure D.3. Untargeted Fit of the Calibrated Hub Wedges: Values and Chapters

Note: Like Figure D.2, this figure compares the hub shares of fully banned goods in the Russian customs data for May to December 2024 (vertical axis) with those in the model (horizontal axis), without the calibrated wedges in the left panels (the TI benchmark) and with them in the right panels. Panel D.3a shows the hub shares of all coalition origins measured by trade value. Panel D.3b shows the hub shares of all coalition origins within each HS2 chapter, measured as in Figure D.2, for the 25 chapters with at least 25 origin-product cells that are rerouted in both the model and the data. Labels identify ten chapter-hub pairs with high shares, with each chapter given by its two-digit HS code. The dashed line is the 45°-line. "Corr." is the correlation across the plotted points, and "N" is the number of points.

E Modeling Hub Rents

In the thought experiment of Section 5, potential hubs compete to provide the intermediation service. Let $m^k_{(1),eR}$ denote the lowest route cost across the countries that can serve as intermediaries, with route costs as in equation (15), and let $m^k_{(2),eR}$ denote the cost of the cheapest competing route. The country with the lowest route cost is selected, while the competing route limits the markup that it can charge without losing the trade flow. This introduces a Bertrand-like pricing structure.[72] The gross markup charged by the selected hub is

$$\kappa^k_{eR} = 1 + \min\left\{\frac{m^k_{(2),eR}}{m^k_{(1),eR}} - 1,\ \frac{1}{\theta^k}\right\}. \tag{34}$$

The first term inside the minimum limits the markup by the cost of the competing route. For a fully banned flow, this is the second-cheapest hub route, and we set $m^k_{(2),eR} = \infty$ if only one country can serve as an intermediary for this flow. For a partially banned flow, the direct route also competes with the selected hub, so $m^k_{(2),eR}$ is the lower of the second-cheapest hub route cost and the direct cost $\delta_P \tau^k_{eR}$. The second term is the markup that maximizes the hub's revenue. Where the competing route would allow a higher markup, the hub still charges this one, because a higher markup would reduce Russian demand for the rerouted flow so much that its revenue falls.[73]

The trade cost of a rerouted flow is $m^k_{(1),eR}\kappa^k_{eR}$. Let $X^{k\prime}_{ei}$ denote importer i's gross expenditure on product k from origin e in the counterfactual equilibrium. For a flow that is not rerouted, $\kappa^k_{ei} = 1$, and the exporter receives the full amount. For a rerouted flow, the original exporter receives $X^{k\prime}_{eR}/\kappa^k_{eR}$, while the selected hub receives $\left(1 - 1/\kappa^k_{eR}\right) X^{k\prime}_{eR}$. We treat the markup as pure rent, so it reallocates income between the exporter and the hub rather than using additional resources. By contrast, the wedge ρ_h is an iceberg cost of rerouting and generates no rents for the hub. Let $h^\star(e,k)$ denote the hub selected for exports of product k from origin e to Russia. The rents of hub country h are

$$R'_h = \sum_{e,k:\, h^\star(e,k)=h} \left(1 - \frac{1}{\kappa^k_{eR}}\right) X^{k\prime}_{eR}. \tag{35}$$

We assume that this income is rebated to the representative household of the hub country. For intuition, note that the rents are analogous to tariff revenue in a standard quantitative

[72] This follows the Bertrand-pricing logic in Bernard et al. (2003), where the lowest-cost supplier serves the market, while the cost of the second-best supplier constrains the price it can charge.

[73] To derive this markup, hold Russian expenditure on product k, wages, and competing origins' trade costs fixed, and let the hub take the Russian product price index as given. From the gravity equation (11), multiplying its trade cost by κ then implies that gross bilateral expenditure satisfies $X^k_{eR}(\kappa) \propto \kappa^{-\theta^k}$. The hub retains the fraction $1 - 1/\kappa$ of this expenditure, so its revenue is proportional to $(1 - 1/\kappa)\kappa^{-\theta^k}$. The derivative of this expression with respect to κ is $\kappa^{-(\theta^k+2)}\left[(\theta^k+1) - \theta^k\kappa\right]$, which is positive below and negative above $\kappa^\star = 1 + 1/\theta^k$, so revenue is highest at the proportional markup $\kappa^\star - 1 = 1/\theta^k$.

trade model such as Caliendo and Parro (2015). With a gross tariff factor $\kappa = 1 + t$, importer expenditure is split into exporter income $X/(1+t) = X/\kappa$ and tariff revenue $tX/(1+t) = (1 - 1/\kappa)X$. Here, this revenue accrues to the intermediary country rather than to the importing government.

Because labor is the only production input, the wage bill in exporter e equals its sales net of hub markups,

$$w'_e L_e = \sum_{i=1}^{N} \sum_{k=1}^{K} \frac{X_{ei}^{k\prime}}{\kappa_{ei}^{k}}, \tag{36}$$

and total expenditure in country i is labor income plus any rents earned as a hub,

$$X'_i = w'_i L_i + R'_i. \tag{37}$$

In the main specification, $\kappa_{ei}^{k} = 1$ and $R'_i = 0$, so these conditions reduce to equation (18).

With these markups, we recalibrate the hub wedges and the partial-ban cost increase so that the model still matches the observed hubs and the estimated effects of the full and partial bans. Since each hub charges the maximum markup it can, the resulting rents are an upper bound on what the hubs can earn from rerouting.[74] Except for Türkiye, the real wages of the hubs in Table E.1 change by about as much as their real income does in the main specification. For these hubs, the rents therefore come on top of what they gain or lose from the sanctions without markups.

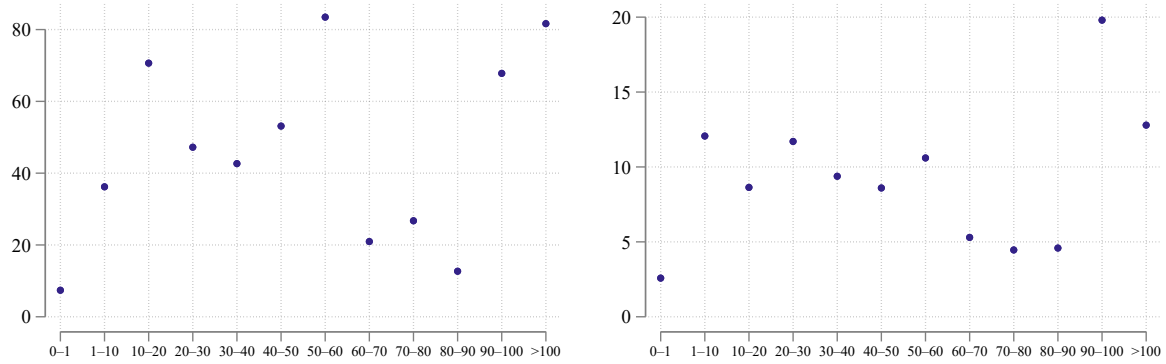
[74] Strictly speaking, this holds for given route costs, which change when we recalibrate the model.

Table E.1. Hub Rents in the Thought Experiment

Hub	Hub-Use Share (%)	Hub Rents (USD in M)	Export Gain (USD in M)	Change in Real Income (%)			
				With Hub Rents			Main Specification
				Total	Real Wages	Rents	
TUR	30.50%	1,028.5	1,799.6	0.189%	+0.021%	+0.168%	0.012%
BLR	19.56%	332.2	2,309.7	-0.570%	-0.979%	+0.409%	-0.976%
CHN	13.21%	265.3	16,345.5	0.006%	+0.005%	+0.001%	0.005%
ARE	7.82%	186.2	424.6	0.090%	+0.039%	+0.051%	0.038%
SRB	6.24%	41.5	485.9	0.159%	+0.073%	+0.086%	0.077%
IND	5.56%	58.2	1,617.5	0.006%	+0.003%	+0.002%	0.003%
THA	1.96%	9.0	788.8	0.009%	+0.008%	+0.001%	0.008%
ISR	1.87%	10.0	452.9	0.023%	+0.018%	+0.005%	0.019%
MYS	1.60%	1.9	602.6	0.007%	+0.007%	+0.000%	0.007%
MAR	1.54%	13.5	128.0	0.023%	+0.012%	+0.011%	0.012%

Notes. This table reports results from the thought experiment of Section 5, in which each hub charges the highest markup it can without losing the trade to a competing route, subject to the cap in equation (34), and the model is recalibrated so that it still matches the observed hubs and the estimated effects of the bans. All results refer to observed transshipment. Rows show the ten countries that most often serve as hubs in the thought experiment. "Hub-Use Share" is a country's hub share in the thought experiment, measured as in Section 4.3. Rents and export gains are in millions of 2019 USD. Export gains are the change in each hub's own exports to Russia relative to the baseline without sanctions, summed across all products. These goods originate in the hub itself, whereas rerouted coalition goods keep their coalition origin and are not included in this column. The columns under "With Hub Rents" report the change in real income, $(\hat{W}_h - 1) \times 100$, and split it into the change in real wages and the contribution of the rents, $100\,\hat{W}_h R'_h / X'_h$ percentage points, where X'_h is the hub's counterfactual expenditure. The split is exact within the model, as baseline rents are zero. The real-wage component still reflects the equilibrium effects of spending the rents. The last column reports the real-income change in the main specification, in which hubs earn no rents. Belarus is itself sanctioned throughout, which explains its real-income loss. The results are discussed in Section 5 and Appendix E.

F Additional Figures



(A) Unit Values (USD/kg) (B) Avg. Nr. Oth. HS6-Prod. per Shipment

Figure F.1. Evasion and Pre-War Characteristics of Export-Banned Products

Note: Bins are constructed over an evasion measure defined for each HS6 product as the ratio of its average monthly Russian imports of EU-origin products in the post–export-ban period (August 2022–December 2024) to the corresponding average in 2019. The sample consists of the 668 HS6 products fully subject to EU export bans by July 2022. Each point reports the unweighted mean of the characteristic shown on the y-axis within a bin of the evasion measure, except for unit values, which are reported as medians within bins. All product characteristics refer to 2019.

G Additional Tables

Table G.1. Robustness of the Main Results

Specification	Real-Income Loss		Relative Transshipment Gain	Decline in Fully Banned Imports
	OT	NT		
Main specification	1.26%	1.66%	32%	76%
$\nu = 0.5$	1.26%	1.67%	32%	76%
$\nu = 0.9$	1.26%	1.66%	32%	76%
$\nu = 2.2$	1.25%	1.66%	32%	76%
$\sigma_M = 1.2$	1.26%	1.67%	32%	76%
Home-share floor 5%	1.24%	1.70%	37%	75%
Hub shares from re-exports	1.28%	1.67%	31%	76%
Wartime demand ($\hat{\alpha}_R^M = 3$)	1.32%	1.72%	31%	78%
Trade elasticities halved	2.29%	2.92%	28%	78%

Notes. This table compares the main results with alternative parameter choices and an alternative hub-share target. The first two columns report Russia's real-income loss in percent under observed transshipment (OT) and no transshipment (NT), and the third column the increase in the NT loss in percent of the OT loss (the relative transshipment gain). The last column reports the decline in Russia's imports of fully banned coalition-origin products under OT, measured as the percentage change in their share of world expenditure. The main specification sets $\nu = 1.1$, $\sigma_g = 2.2$ for all groups, and a 10% floor on home shares. Except for the wartime-demand exercise, each specification recalibrates the hub wedges and the partial-ban cost increase, as in Section 4.3. "Hub shares from re-exports" calibrates the relative hub wedges to re-exports only, whose hub is the recorded dispatch country. "Wartime demand" triples Russia's demand weight for the military-relevant group, holding the calibrated hub wedges and the partial-ban cost increase fixed. Its losses are measured against the no-sanctions equilibrium of this economy. "Trade elasticities halved" scales the trade elasticities θ^k by one half, leaving the calibrated demand system unchanged. To keep every θ^k above $\sigma_{g(k)} - 1$ (Appendix D.1), the halved elasticities are floored at $(\sigma_{g(k)} - 1) + 0.1$, which binds for 227 products. The results are discussed in Section 5.

Table G.2. Robustness of Group-Level Real Absorption

	Decline in Real Absorption (%)					
	Observed Transshipment			No Transshipment		
Specification	M	C	O	M	C	O
Main specification	3.6%	2.0%	0.9%	4.0%	2.7%	1.1%
$\nu = 0.5$	2.4%	1.6%	1.1%	2.8%	2.1%	1.4%
$\nu = 0.9$	3.2%	1.8%	1.0%	3.6%	2.5%	1.2%
$\nu = 2.2$	6.0%	2.6%	0.5%	6.4%	3.7%	0.6%
$\sigma_M = 1.2$	3.7%	2.0%	0.9%	4.2%	2.7%	1.1%
Home-share floor 5%	3.6%	1.9%	0.9%	4.1%	2.7%	1.2%
Hub shares from re-exports	3.7%	2.0%	0.9%	4.0%	2.7%	1.1%
Wartime demand ($\hat{\alpha}_R^M = 3$)	3.6%	1.9%	0.9%	4.0%	2.7%	1.1%
Trade elasticities halved	6.6%	3.5%	1.6%	7.7%	4.6%	2.0%

Notes. This table reports the decline in Russia's real absorption, $(1 - \hat{Q}_R^g) \times 100$, of military-relevant ($M$), other critical ($C$), and remaining goods ($O$), under observed transshipment and without transshipment, for every specification of Table G.1. Real absorption includes domestic supply. The specifications are described in the notes to that table. Group-level real absorption is defined in Section 4.2.4. The results are discussed in Section 5.

Table G.3. The Effects of the Sanctions on EU Member States

Country	Baseline Exports of Fully Banned Products (USD in M)	Change in Exports to Russia (%)						Change in Real Income (%)	
		Full		Partial		Total			
		OT	NT	OT	NT	OT	NT	OT	NT
EU27	58,838	-76%	-100%	-27%	-23%	-39%	-48%	-0.036%	-0.048%
AUT	1,656	-79%	-100%	-35%	-28%	-38%	-44%	-0.029%	-0.032%
BEL	2,140	-74%	-100%	-40%	-37%	-37%	-47%	-0.019%	-0.025%
BGR	298	-76%	-100%	-33%	-32%	-26%	-32%	-0.041%	-0.051%
CYP	39	-92%	-100%	-39%	-45%	-37%	-41%	-0.024%	-0.026%
CZE	2,930	-74%	-100%	-30%	-28%	-48%	-61%	-0.092%	-0.115%
DEU	16,385	-73%	-100%	-24%	-19%	-40%	-51%	-0.043%	-0.054%
DNK	583	-78%	-100%	-21%	-18%	-30%	-37%	-0.017%	-0.021%
ESP	1,718	-72%	-100%	-28%	-27%	-33%	-41%	-0.014%	-0.018%
EST	1,149	-88%	-100%	-31%	-29%	-52%	-57%	-0.326%	-0.361%
FIN	3,470	-80%	-100%	-30%	-26%	-57%	-69%	-0.144%	-0.175%
FRA	5,768	-80%	-100%	-27%	-24%	-43%	-52%	-0.023%	-0.028%
GRC	227	-61%	-100%	-22%	-22%	-25%	-39%	-0.019%	-0.026%
HRV	78	-80%	-100%	-30%	-28%	-11%	-13%	-0.009%	-0.008%
HUN	1,167	-75%	-100%	-29%	-27%	-35%	-44%	-0.048%	-0.062%
IRL	142	-82%	-100%	-35%	-32%	-17%	-17%	-0.003%	-0.003%
ITA	5,226	-72%	-100%	-26%	-25%	-36%	-46%	-0.036%	-0.045%
LTU	2,420	-83%	-100%	-24%	-21%	-40%	-46%	-0.458%	-0.514%
LUX	237	-73%	-100%	-30%	-31%	-46%	-63%	-0.027%	-0.036%
LVA	634	-83%	-100%	-17%	-15%	-30%	-35%	-0.178%	-0.209%
MLT	25	-94%	-100%	-60%	-60%	-22%	-23%	-0.119%	-0.146%
NLD	4,294	-77%	-100%	-32%	-30%	-36%	-45%	-0.069%	-0.085%
POL	4,265	-74%	-100%	-29%	-28%	-37%	-47%	-0.080%	-0.098%
PRT	245	-81%	-100%	-33%	-34%	-36%	-42%	-0.008%	-0.009%
ROU	783	-64%	-100%	-27%	-27%	-33%	-45%	-0.036%	-0.048%
SVK	679	-68%	-100%	-17%	-6%	-26%	-26%	-0.056%	-0.055%
SVN	549	-81%	-100%	-33%	-32%	-30%	-36%	-0.077%	-0.090%
SWE	1,731	-74%	-100%	-31%	-26%	-46%	-58%	-0.023%	-0.031%

Notes. This table extends Table 3 to the individual member states. The first column reports baseline exports of fully banned products to Russia in millions of 2019 USD. Export changes are relative to the corresponding baseline flows of fully banned (Full), partially banned (Partial), and all products (Total), under observed transshipment (OT) and no transshipment (NT). Real-income changes are $(\hat{W} - 1) \times 100$. In the EU27 row, the export changes refer to flows summed over member states, while the real-income entries are medians across member states, as in Table 3. The results are discussed in Section 5.