Export Sanctions: Rerouting, Disruption, and the Reach of Economic Warfare*

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Abstract

To what extent are trade sanctions neutralized by rerouting through third countries? Do they nevertheless disrupt production and supply chains in a targeted economy? We study the large-scale export sanctions imposed on Russia after February 2022, which covered 36% of Russia's prewar import value. We combine newly collected sanctions records with Russian customs data, firm balance sheets, domestic railway shipments, and government procurement contracts. We find that sanctions sharply reduced directly targeted country-product imports. Imports of the sanctioned products from friendly third countries increased substantially. Using records of both the country of shipment and the country of production for each transaction, we show that this increase was driven primarily by rerouting of goods produced in sanctioning countries. This adjustment offset about two-thirds of the direct import decline, but not fully. Firms that had relied on soon-to-be-sanctioned imports experienced a persistent 12% decline in output, with no offsetting expansion by competitors or entrants. These losses extended to manufacturing and technology firms, firms along the military supply chain, and firms indirectly exposed through trading partners. Affected firms also lost government procurement sales. The results show that export sanctions can impose substantial real costs even when rerouting absorbs a large share of the direct trade shock.

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1 Introduction

Trade sanctions have become a central instrument of geoeconomic statecraft. A growing theoretical literature models them as threats that can coerce rivals or reshape the economic and political options available to them (Clayton, Maggiori, and Schreger, 2026). Whether such threats bind in practice, however, remains an open empirical question: do large-scale trade restrictions meaningfully constrain the target economy, or are they largely neutralized by rerouting through third countries and other margins of adjustment?

Governments typically impose trade sanctions for two related but conceptually distinct purposes. The first is *economic coercion*: inducing the target country, or others observing its fate, to change their political behavior. Because political concessions may take years to materialize and depend on many non-economic factors, evaluating sanctions on these grounds alone can be empirically elusive. The second, more direct objective is *economic warfare*: disrupting the target's productive capacity and thereby eroding its industrial base, technological potential, and military capabilities. Export sanctions—restrictions on exports *to* the target country—are the natural instrument for this second objective, as they aim to deprive the target economy of foreign inputs.[1,2]

How effective are export sanctions at achieving this objective? Ex ante, the answer is ambiguous. On one hand, if firms cannot easily replace foreign inputs, restrictions on imported intermediates and capital goods should reduce output. This logic is especially compelling for high-tech or specialized inputs, where substitution may be slow, costly, or infeasible. On the other hand, if restricted goods can be rerouted through third countries or replaced by similar goods produced elsewhere, export sanctions may have limited effects on imports and downstream production.

The export sanctions imposed on Russia after its February 2022 invasion of Ukraine provide a large-scale test of these competing forces: the campaign covered more than one-third of Russia's

[1] This logic was explicit in the EU's justification for its post-2022 sanctions on Russia, which aimed at "weakening Russia's economic base, depriving it of critical technologies and markets, and significantly curtailing its ability to wage war" (European Commission, 2022).

[2] These two objectives are not mutually exclusive: targeted disruptions can simultaneously degrade technological and military capacity and raise the economic cost of noncompliance, thereby reinforcing the coercive function. See Mastanduno (2025) on the recent shift from economic coercion to economic warfare in debates on sanctions' effectiveness, and Lindsay (1986) for a broader typology of sanctions' purposes, including symbolic signaling.

prewar import value and targeted many inputs central to industrial and military production.[3] Skepticism about its effectiveness has nonetheless been widespread. In a 2024 U.S. Senate hearing, Senator Richard Blumenthal argued that *"our export control regime is lethally ineffective,"* noting that Russia's imports of critical battlefield goods had nearly recovered to pre-invasion levels (Blumenthal, 2024). Senator Ron Johnson similarly stated that *"U.S. sanctions on Russia have failed spectacularly,"* arguing that they had neither denied Russia access to advanced weapons technology nor derailed the broader economy (Johnson, 2024). These claims crystallize our research questions. Did rerouting and substitution neutralize export sanctions—and can the two channels be separated empirically? Or did the restrictions nevertheless reduce Russia's access to targeted inputs and disrupt domestic production, including among firms in strategically important sectors?

Despite intense theoretical interest in sanctions as instruments of geoeconomic influence, granular causal estimates of their effects on a target country's imports, firm performance, and circumvention margins remain scarce. Credible answers require an unusual combination of ingredients. Researchers need detailed customs records that not only identify firms importing sanctioned products but also separate rerouting from genuine substitution toward alternative suppliers. They also need firm-level accounting data to link import behavior to economic performance. Such data are rarely available for countries historically subject to sanctions, such as Cuba or Iran. Strong causal identification further requires variation in both the timing and coverage of export sanctions, another condition seldom met in practice: such sanctions are often imposed all at once, alongside other restrictive measures, and tend to cover narrow product sets or be issued by few countries.

We overcome these challenges by studying the post-2022 export sanctions on Russia—a setting uniquely suited to the question. The campaign was one of the most extensive sanctions efforts in history and was directed at one of the world's largest economies.[4] It therefore tests the limits of sanctions' effectiveness, especially because Russia borders large trading partners that remained

[3]Export sanctions were not the only measures imposed on Russia: the broader post-2022 sanctions regime also included financial sanctions, blocking sanctions targeting specific firms and individuals, restrictions on imports from Russia, and the exit of foreign firms and banks. We focus on export sanctions because they aimed directly at Russia's productive capacity by cutting off access to inputs, machinery, and technology that sustain its industry and military. Our empirical analysis accounts for these concurrent shocks when estimating the effect of export sanctions.

[4]As of 2021, Russia ranked as the fourth-largest economy globally in terms of PPP-based GDP and tenth-largest in terms of nominal GDP, according to World Bank (2023).

neutral or friendly after the invasion and were well positioned to facilitate trade diversion. The sanctions were also imposed by multiple countries, at different times, on product categories defined down to the ten-digit level, generating rich variation for identification. Finally, Russia offers an unusually data-rich environment: customs records report both country of shipment and country of production for each transaction, allowing us to distinguish rerouting from substitution, and can be linked to firm-level financials, domestic railway shipments, and government procurement contracts. We combine these sources with a novel, manually assembled dataset on export sanctions covering roughly 6,000 ten-digit product codes in Russian customs data and some 72,000 sanctioned country-product varieties with 50 distinct imposition dates. Together, these data allow us to trace the pass-through of export sanctions at a previously unattainable level of detail.

Our analysis proceeds in three steps. We first ask whether export sanctions restricted imports into Russia. We then ask whether these restrictions disrupted production and supply chains within the Russian economy, using firm-level data. Third, we aggregate both sets of estimates into economy-wide dollar and welfare magnitudes via standard back-of-the-envelope counterfactuals.

We begin by jointly estimating the decline in sanctioned country-product imports and the compensating flows from countries that remained relatively friendly to the Russian regime, such as China and Turkey. We pursue two complementary empirical strategies: a simple pre-post difference-in-differences (DiD) approach that compares sanctioned and nonsanctioned country-product import flows before and after the war's onset, and a staggered DiD strategy that compares newly sanctioned imports with those not (or not yet) subject to sanctions. While the former approach is simple, transparent, and well-suited to our context, the latter allows us to further disentangle the effects of trade sanctions from possible heterogeneous effects of broader wartime disruptions.[5] In both specifications, granular ten-digit product-by-time fixed effects absorb product-specific shocks, such as surges in demand for military-related goods, while country-time fixed effects capture country-specific shocks, such as other restrictions on doing business with Russia.

The results reveal two opposing forces. Directly sanctioned country-product imports collapsed:

[5] Recent research highlights potential biases in staggered DiD designs when treatment effects vary substantially across units and over time (see Arkhangelsky and Imbens, 2024 for a review). Following the guidance of Rios-Avila, Nagengast, and Yotov (2024), we address these concerns by employing the ETWFE estimator from Wooldridge (2021), which is particularly well-suited for estimating large-scale gravity models.

among flows that remained positive, imports were nearly 60% lower by the end of 2023, and the probability of positive imports in a given quarter fell by about 10 percentage points. Meanwhile, imports of sanctioned products from friendly countries rose substantially: positive flows roughly doubled, and the probability of positive quarterly imports increased by 6–8 percentage points.

To determine whether the surge of sanctioned-product imports from friendly countries reflects rerouting or substitution, we exploit a unique feature of Russian customs data: each transaction records both the country of shipment and the country of production. Using this information, we find that the surge in imports of sanctioned products from friendly countries was almost entirely driven by rerouted shipments. Moreover, more than two-thirds of this increase reflects *rerouting specifically from sanctioning countries*—that is, sanctioned goods produced in sanctioning countries but shipped through friendly intermediaries, likely in violation of export controls. In contrast, genuine substitution toward goods manufactured in friendly countries has been much more muted.

These adjustments, however, did not fully offset the import shock. Estimating our DiD specifications at the product level—aggregating across all countries of shipment—we find that total imports of sanctioned products declined relative to nonsanctioned products. The effect comes with no pretrends, persists over time, and is similar under the staggered DiD design. Replicating the analysis using mirror-export data from UN Comtrade, available only at the HS6 level, yields similar declines, helping address concerns about spillovers within HS6 codes, such as relabeling, and potential omissions in Russian customs data. Our back-of-the-envelope aggregate accounting implies that *increased sanctioned-product shipments from friendly countries offset roughly two-thirds of the direct sanctions-induced decline*, but did not eliminate it.[6]

Having established that export sanctions reduced Russia's access to targeted imports despite substantial rerouting through third countries, we next ask whether these trade disruptions translated into lower domestic production. Such effects need not follow: firms may have substituted toward domestic inputs, received compensating government support, or obtained sanctioned products through unobserved informal channels. To distinguish among these possibilities, we combine the trade data with balance-sheet records for more than 2 million Russian firms and examine the

[6]Firm-product-level estimates controlling for firm-by-year fixed effects confirm a significant average decline in imports of sanctioned products, reinforcing our main findings and providing the bridge to our firm-level analysis.

effects of export-sanctions exposure on firm performance and domestic supply chains.

First, we investigate whether export sanctions had a negative impact on the performance of Russian firms that were exposed to these restrictions. To this end, we estimate a DiD specification comparing firms that imported country-product varieties subject to export sanctions with firms that did not, before and after the invasion. The specification includes firm fixed effects and allows firms with different prewar characteristics and exposure to other sanctions-related shocks to follow flexible year-specific paths. Specifically, we control for year fixed effects interacted with prewar importer and exporter status, two-digit industry, exposure to targeted firm sanctions, foreign restrictions on imports from Russia, financial sanctions, and the exit of foreign-owned banks. These controls assuage the concern that exposed firms were more internationally oriented, operated in industries differentially affected by the war, or were simultaneously exposed to other components of the sanctions regime and associated financial disruptions.

We find that firms that had imported soon-to-be-sanctioned country-product varieties experienced an average 11.9% decline in sales after the invasion. The effect remains similar in magnitude in every year from 2022 through 2024, with no evidence of recovery over the sample period. Its persistence suggests that adjustment through rerouting, supplier substitution, inventories, or government support was insufficient to restore production. This result also provides an independent validation of the trade evidence: large and persistent output declines would be difficult to reconcile with sanctioned inputs continuing to reach exposed firms at scale through unobserved channels.

Consistent with the decline in sales reflecting a contraction in output, we find similarly sized effects on total cost of goods sold (-12.5%), gross profits (-10.6%), and value added (-9.2%). Capital, labor, and material expenditures decline by 9.0%, 9.4%, and 13.3%, respectively, indicating a broad contraction in production and input use. The estimates are also robust to restricting the sample to a fully balanced panel, suggesting that they are not driven by changes in sample composition associated with differential firm entry, exit, or changes in reporting behavior.

The negative effects extend to manufacturing firms and are especially pronounced in the science-and-technology sector, where sales decline by approximately 20%. We also find *little evidence that exposed military-related firms or firms designated as strategically important were insulated from the shock*. These patterns are consistent with the *economic warfare* objective of export sanctions:

restricting access to foreign inputs disrupted production, including among firms central to Russia's technological and military capabilities.

The losses among exposed firms were not offset by gains among non-exposed firms or competitors. The estimated declines persist after excluding close competitors from the comparison group and remain negative and statistically significant when the analysis is aggregated to the five-digit industry level. These results indicate that reallocation within narrowly defined industries was insufficient to replace the output lost by exposed firms.

We next examine how export-sanctions exposure affected firms' procurement relationships with the Russian state. The effect is ex ante ambiguous: the government could redirect contracts toward exposed firms to compensate for sanctions-related losses, but impaired productive capacity could make these firms less able to supply the state. We find the latter: exposed firms became 2.4 percentage points less likely to win a government contract in a given year. Thus, rather than cushioning the shock, government procurement reveals an additional margin of disruption, with export sanctions reducing exposed firms' participation in supplying the Russian state.

We use firm-to-firm railway shipment data to examine domestic supply-chain propagation and adjustment. Firms whose suppliers were exposed to export sanctions experienced declines in their own sales, even conditional on their direct exposure. Directly exposed firms also reduced their incoming domestic shipments, providing little evidence that they replaced sanctioned foreign inputs through increased sourcing from domestic suppliers. Export-sanctions shocks therefore amplified through domestic production networks beyond the firms directly exposed.

Finally, we explore whether our micro-level estimates translate into economically significant aggregate magnitudes through standard back-of-the-envelope calculations. On the trade side, although increased shipments through friendly countries offset roughly two-thirds of the direct decline, the remaining import shortfall implies a welfare-equivalent loss of approximately 0.5% of real income per year under the sufficient-statistic formula of Arkolakis, Costinot, and Rodríguez-Clare (2012). This magnitude is sizable relative to the corresponding full-import-autarky benchmark of 3.6%. On the firm side, the estimated production effects imply cumulative value-added losses equal to 2.8% of counterfactual firm value added, or roughly 1.3% of cumulative Russian GDP. Despite relying on distinct data and aggregation strategies, both exercises indicate that the micro-level disruptions were economically meaningful in the aggregate.

Overall, our findings establish both the reach and the limits of export sanctions as an instrument of economic warfare. Rerouting and substitution absorbed much of the direct trade shock but did not restore full access to targeted foreign inputs. The remaining disruption generated persistent production losses, including among strategically important firms; reduced exposed firms' ability to supply the state; and propagated through domestic production networks. Thus, even when circumvention is extensive and political concessions do not materialize, export sanctions can still serve a distinct function by constraining the target economy's productive capacity.

Related Literature. We add to the growing economics literature on *geoeconomics*: the use of international economic linkages, including international trade, as instruments of geopolitical power.

Theoretically, researchers have explored the rationale behind imposing sanctions on other nations. Most existing frameworks consider trade policy and the threat of trade sanctions as instruments of *economic coercion* (Eaton and Engers, 1992; Clayton, Maggiori, and Schreger, 2024; Clayton et al., 2026; Becko, 2024; Becko and O'Connor, 2024; Bianchi and Sosa-Padilla, 2024; Broner, Martin, Meyer, and Trebesch, 2024; Liu and Yang, 2024; Mayer, Mejean, and Thoenig, 2024). Our paper contributes to this ongoing discussion by demonstrating empirically that trade sanctions fulfill a complementary purpose of *economic warfare*: they can disrupt production and supply chains within the target economy and, ultimately, may serve to weaken its technological and military capabilities—core foundations of geopolitical power. This channel has been explored only theoretically in Kooi (2024) and is an underlying premise in Alekseev and Lin (2024). More broadly, we provide an empirical assessment of the credibility and limits of geoeconomic influence: how effective is the threat of the United States and its allies in constraining a targeted country's industrial base, and to what extent is that leverage diluted by rerouting through and substitution to third countries? The empirical moments we document—the direct trade shock, the rerouting offset, the firm-level pass-through, and the implied welfare loss—offer a set of targets for future theoretical work on geoeconomic influence to match.

In terms of the empirical literature, we contribute to the studies of sanctions in three main ways.

First, our paper offers the most detailed empirical assessment of the economic impact of export sanctions and controls on a target country—an area highlighted by Mohr and Trebesch (2025) as heavily understudied.[7] The level of detail is critical for understanding the causal impact of export sanctions on the targeted economy. Measuring effects with trade data alone would not account for domestic substitution or illicit flows. Likewise, domestic firm data alone cannot identify which businesses were affected by the inability to import certain country-product varieties, and thus may not identify an impact on firms stemming specifically from export sanctions. Only combining transaction-level customs data with firm-level information allows us to trace the full causal chain from export sanctions to the target country's import flows and, ultimately, to firm output and supply chains. Incorporating micro-level data on firms in strategic sectors such as technology and defense further allows us to evaluate the economic warfare rationale underlying export sanctions.

Second, we distinguish and quantify two central mechanisms of sanctions evasion, rerouting and substitution, that have been widely discussed but rarely measured separately. Several studies have documented evidence of trade rerouting in response to trade shocks (Chupilkin, Javorcik, and Plekhanov, 2023; Iyoha, Malesky, Wen, Wu, and Feng, 2024; Fisman, Marcolongo, and Wu, 2025; Sagyndykova et al., 2025; Scheckenhofer, Teti, and Wanner, 2025). The measures employed in this literature generally rely on shipping flows in which the country of production is not observed.[8] While such flows can provide compelling evidence of rerouting in specific settings, they do not allow the compensating response to be decomposed systematically into rerouting and substitution—a

[7]Most existing studies analyze either *targeted sanctions*, which limit all transactions for select firms (Ahn and Ludema, 2020; Nigmatulina, 2021; Draca, Garred, Stickland, and Warrinnier, 2023), *financial sanctions* (Efing, Goldbach, and Nitsch, 2023; Jiao and Wei, 2025), or *import sanctions* that restrict imports from, rather than exports to a particular country (Haidar, 2017; De Souza, Hu, Li, and Mei, 2024), including oil embargoes and price caps (Hilgenstock, Ribakova, Shapoval, Babina, Itskhoki, and Mironov, 2023; Johnson, Rachel, and Wolfram, 2026, 2023; Kilian, Rapson, and Schipper, 2024; Spiro, Wachtmeister, and Gars, 2024; Bai, Fernández-Villaverde, Li, Xu, and Zanetti, 2025). Other studies focus on private sanctions and the exit of multinational enterprises (Hart, Thesmar, and Zingales, 2024; Chupilkin, Javorcik, Peeva, and Plekhanov, 2025), the consequences for sanctioning countries (Hinz and Monastyrenko, 2022; Crosignani, Han, Macchiavelli, and Silva, 2024; Görg, Jacobs, and Meuchelböck, 2024; Gao, Shroff, and Zhang, 2025) and countries-intermediaries (Corsetti, Demir, and Javorcik, 2024; Li, Li, Park, Wang, and Wu, 2024), implications for the exchange rate (Itskhoki and Mukhin, 2025) and the use of the U.S. dollar in trade invoicing (Berthou, 2022; Chupilkin, Javorcik, Peeva, and Plekhanov, 2023). See Morgan, Syropoulos, and Yotov (2023) and Itskhoki and Ribakova (2024) for reviews. Closest to our focus, Kim, Kim, Park, and Sun (2023) study the effect of export sanctions on nighttime luminosity in North Korea, while Liu, Liu, Makarin, and Wen (2025) show that export controls spurred innovation among affected Chinese firms and their suppliers.

[8]A notable exception is contemporaneous work by Chupilkin et al. (2025), who focus on the rerouting of privately sanctioned Western trademarks. We complement their analysis by offering a comprehensive assessment of the circumvention of state-imposed export sanctions—a key instrument in governments' geoeconomic toolkit.

distinction that is especially important when intermediary countries may also produce close substitutes. We leverage a unique feature of Russian customs data, which record both the country of shipment and the country of production, to identify these margins *directly*. Our results reveal that *rerouting specifically from sanctioning countries* accounted for most of the observed adjustment, highlighting that effective trade sanctions depend critically on the credible enforcement of secondary sanctions on intermediaries.

Third, by leveraging highly granular variation in export sanctions against Russia—at the ten-digit product-by-country-by-month level—we are able to provide particularly rigorous estimates of the causal impact of trade sanctions. Granularity and time variation of sanctions data is crucial, because it allows us to separate the inclusion of a 10-digit HS product to the sanction list from concurrent macroeconomic shocks, policy changes, and other country- or product-specific demand and supply factors, many of which occurred in the very first month of the 2022 conflict. Our analysis thus complements existing work that often focuses on a single sanctioning country, narrower product sets, or a single implementation date (e.g., Liu, Liu, Makarin, and Wen, 2025).[9]

The rest of this paper is organized as follows. Section 2 provides the background on the Russian invasion of Ukraine in February 2022, and the sanctions that followed. Section 3 describes the data. Section 4 presents the stylized facts. Section 5 analyzes the sanctions' impact on import flows. Section 6 examines the sanctions' impact on exposed firms, including heterogeneity along firm characteristics and military-related dimensions. Section 7 examines spillovers via domestic linkages, including government procurement and railway shipments. Section 8 provides back-of-the-envelope aggregate effects implied by our micro-level estimates. Section 9 concludes.

2 Background

Following the Russian invasion of Ukraine in February 2022, Western countries imposed an unprecedented level of sanction measures against Russia—more than 19,000, making Russia one of the most sanctioned countries in world history (Trefanenko, 2025). In fact, as of the time of this

[9] We also add to the literature on wars and trade. This literature has documented the negative impact of conflicts on international trade as well as the peace-inducing effects of trade integration (Martin, Mayer, and Thoenig, 2008a,b; Thoenig, 2023; see also Kleinman, Liu, and Redding, 2024). Closely related to our context, Korovkin and Makarin (2023) and Korovkin, Makarin, and Miyauchi (2025) examine, respectively, the negative impact of the 2014 Russia-Ukraine conflict on their bilateral trade and the disruption and reorganization of production networks within Ukraine.

writing, this figure exceeds the total number of sanctions imposed on Iran, Venezuela, Myanmar, and Cuba combined (Statbase, 2026).

These international sanctions against Russia were not the first. Sanctions were also imposed several years earlier, after Russia's annexation of Crimea in 2014 and the start of the Donbas War. However, they were much more limited in scope and primarily targeted politically connected and state-owned firms. On the contrary, the post-2022 sanctions were much more comprehensive.

The post-2022 sanctions included measures that targeted Russia's financial system, such as the freezing of more than $300 billion of the Russian Central Bank's reserves and the exclusion of key Russian banks from the SWIFT international payment system. Sanctions have also been levied against individuals, freezing assets and imposing travel bans on Russian elites and government officials. Western companies have been barred from providing Russia with services in the IT, consulting, and legal fields, with many large multinational companies exiting Russia voluntarily. Russian airlines and shipping companies have faced transportation bans, further isolating the country from global supply chains.

While the above sanctions are important and deserve to be studied separately, this paper will focus on post-2022 trade sanctions, which were of two types: against exports to Russia and against imports from Russia. Sanctions targeting exports to Russia (our *export sanctions*) began almost immediately after the invasion, while sanctions against imports from Russia (*import sanctions*) came later, toward the end of 2022. The latter included a ban on exporting maritime oil from Russia to G7 countries and the EU, along with a price cap on exports to all other countries (Johnson et al., 2023). Similar restrictions were applied to other raw materials. In this paper, however, we focus exclusively on the impact of export sanctions, with the goal of understanding whether restricted access to banned inputs has disrupted the production processes and supply chains of Russian firms.

Export sanctions have significantly restricted Russia's access to Western high-tech inputs, particularly in sectors such as semiconductors, aerospace, and energy, but have also targeted a broader range of industries. In the words of official EU sources, they included bans on the exports of:

> "cutting-edge technology (e.g. quantum computers and advanced semiconductors, electronic components and software); specific goods and technology needed for oil

> refining; energy industry equipment, technology and services; aviation and space industry goods and technology (e.g. aircraft, aircraft engines, spare parts or any kind of equipment for planes and helicopters, jet fuel); maritime navigation goods and radio communication technology; a number of dual-use goods (goods that could be used for both civil and military purposes), such as drones and software for drones or encryption devices; luxury goods (e.g. luxury cars, watches, jewellery); arms and related materiel of all types, including civilian firearms and their parts; chemicals, generators and thermostats; IT, electronic and optical components; cameras, lenses, toy drones, laptops and hard drives; and other goods which could enhance Russian industrial capacities" (Council of the European Union, 2024).

We provide additional details in Section 4 on the scope of these sanctions and the products targeted.

The impact of these export sanctions on the Russian economy remains highly debated. Some observers argue that they have imposed lasting costs by restricting access to critical technologies and foreign capital, raising the price of imported components, and increasing Russia's dependence on a narrower set of trading partners (Luck, 2025). Others emphasize Russia's apparent resilience, pointing to redirected trade through Turkey, China, and other "friendly" or neutral countries as evidence that alternative routes have mitigated, or even offset, the initial supply shock (Krueger, 2024). The resulting environment is often described as a "cat-and-mouse" dynamic, in which export controls are met by transshipment through intermediaries and other forms of adaptation.

This skepticism has also been prominent in policy debates. In 2024, Senator Richard Blumenthal argued that "*Our export control regime is lethally ineffective*. [...] Russia has been so successful in evading U.S. export controls that its ability to import critical battlefield goods has nearly recovered to levels seen before the invasion of Ukraine" (Blumenthal, 2024). Similarly, Senator Ron Johnson stated that "*U.S. sanctions on Russia have failed spectacularly*. They have neither denied Russia the technology needed to produce advanced weapons nor derailed the Russian economy" (Johnson, 2024). These claims highlight the central empirical questions: whether circumvention fully neutralized export sanctions; whether the observed adjustment reflected rerouting through intermediaries—a margin potentially addressable through stronger enforcement and secondary sanctions—or genuine substitution toward alternative suppliers; and whether the restrictions nevertheless reduced Russia's access to targeted inputs and disrupted domestic production, including among strategic and military-adjacent firms. The remainder of the paper addresses these questions by combining detailed sanctions data with transaction-level customs records and firm-level information on production and supply chains.[10]

3 Data

Data on the Sanctions Against Russia's Imports. One of our key challenges is the absence of readily available data detailing which countries imposed export sanctions on what specific product codes and when these sanctions were enacted. To address this gap, we manually compile a novel dataset on export sanctions imposed by nine major trading partners of Russia following February 2022: Australia, Canada, the European Union, Japan, South Korea, Switzerland, Taiwan, the United Kingdom, and the United States (a total of 35 countries).

As a starting point for our dataset, we used the records available on the online platform Alta.ru, where the experts in the industry provide detailed information on the sanctioned products and their description, the sanctioning countries, and the type of trade flow being sanctioned: Russian exports, Russian imports, reexports to Russia, or transit through Russia (Alta, 2025). We methodically cross-referenced and supplemented this dataset with the information we extracted from official legal documents from the sanctioning countries. Most crucially, we carefully identified the dates when each restriction was imposed and added export sanction information for Taiwan.

Many sanctions were imposed based solely on the textual description of products, with product codes provided only for general reference. In such cases, Alta.ru supplied the corresponding ten-digit product codes from the Russian classification system that, in their expert judgment, best matched each description. Likewise, when sanctions were issued at the ten-digit level in foreign classification systems, Alta.ru reported the most likely Russian ten-digit equivalents. In addition, some sanctions included further textual conditions. For instance, Swiss sanctions on luxury wrist-

[10] While rigorous causal estimates of the pass-through of export sanctions to the Russian economy remain limited, important descriptive evidence comes from Simachev et al. (2023), who surveyed over 1,800 Russian firms and found that nearly two-thirds reported negative effects from sanctions in the first year of the war. Among importers, 30% of surveyed firms reported difficulties importing necessary goods and services, and 17% reported difficulties importing or servicing essential machinery. Yet it remains unclear whether these self-reported effects align with objective customs data, and whether such disruptions translated into declines in firm output—questions that this paper seeks to address.

watches applied only to models above a certain price threshold. Because we do not observe actual prices (which we can only approximate through unit values), we disregard such conditional information and treat all items within the affected ten-digit category as "sanctioned," even though some may be formally exempt. In this sense, our classification method likely overstates the set of sanctioned trade flows, implying that our estimated effects should be interpreted as a conservative lower bound on the true impact of export sanctions.

Overall, we have identified around 72,000 distinct country-product sanctioned varieties with 50 unique dates of sanction imposition. Partly to minimize the noise in the process of pinpointing precise sanction dates, in addition to a staggered DiD approach, we will also employ a simple pre-post DiD comparing country-product imports before and after the start of the war.

Customs Data. To study the impact of sanctions on trade flows, we rely on a transaction-level dataset of international shipments as recorded by the Federal Customs Service of Russia. For each transaction, the dataset contains the country of shipment, the country of production, the ten-digit product code (where the first six digits match the Harmonized System [HS] product classification), the product description, information on the sending and buying firms (including the tax ID for the firms located in Russia), the total weight of each shipment, and its total contract value.

To assess the completeness of this dataset, Figure A.1 compares the total value of all imports recorded in these data (in blue)[11] to several benchmarks: mirror export data from UN Comtrade reported by other countries (yellow), data from the World Trade Organization (WTO; green), and the official records from the Russian Statistics Service (red), which ceased publication shortly before the invasion. When aggregated, our data match almost exactly the Russian official import statistics and closely match the UN Comtrade's mirror exports to Russia and the WTO-reported Russian imports. The persistent level difference between our data and mirror exports likely stems from differences in the treatment of insurance and freight costs (CIF vs. FOB valuation). Overall, these estimates suggest that our data correctly reflect the volume and evolution of Russian imports. This is in line with Babina et al. (2023), Chupilkin et al. (2023), and Jiao and Wei (2025), who also

[11]Throughout this paper, including this figure, we exclude imports of physical cash.

find that the quality of the Russian customs data was not severely affected by the start of the war.[12]

When merging the customs data with our export sanctions dataset, we account for changes in classification of HS product codes introduced in January 2022. Following Pierce and Schott (2012), we retire the actual HS product codes and replace them with synthetic ones that remain consistent throughout our study period. Specifically, for cases where product codes split or merged during the classification transition, synthetic codes represent the connected set of altered codes. Throughout, we define each product's HS2 or HS3 codes based on the modal HS2 or HS3 codes within its respective connected set.

Firm Accounting Data. We use annual financial statements for the universe of Russian reporting firms from 2017 through 2024. These data are collected and made available by the Federal Tax Service (FTS).[13] The statements report annual revenues, profits, book capital, material expenditures, labor expenditures, and other firm-level variables. Submitted statements are subject to FTS validation, and Russia's VAT system provides an additional cross-firm check on reported sales through invoice-level matching of purchases and sales across buyers and sellers. Gross accounting violations are subject to statutory penalties, especially when misreporting understates the tax base. We restrict the sample to firms with positive book capital in at least one year, which helps exclude shell entities and firms without recorded productive assets. We merge the accounting data to import transactions using the buyer's firm tax identifier, or INN.

Data on Domestic Railway Shipments. We also use data on the universe of firm-to-firm railway shipments available for years from 2017 through 2023, collected by the state-owned monopolist. Railway shipments are central to freight transportation in Russia, accounting for 87% of total non-pipeline freight turnover in ton-kilometers (Federal State Statistics Service, 2026). For each

[12]A potential limitation of the Russian customs data are its incomplete coverage of shipments within the Eurasian Economic Union (EAEU). To verify that this omission does not drive our results, we replicate our main trade estimates using mirror export statistics from UN Comtrade, which include these flows. See Online Appendix B.5.

[13]Under Federal Law No. 402-FZ, Russian organizations are generally required to submit annual accounting statements to the tax authority within three months of the end of the reporting year. The requirement is broad: small enterprises and non-commercial organizations may file simplified forms, but are not exempt from filing. The main exemptions are budget-sector organizations (but not state-owned commercial firms), the Central Bank of Russia, organizations that report to the Central Bank, religious organizations, and organizations whose statements contain state secrets. We observe no significant post-invasion decline in the number of reporting firms, with counts fluctuating between 2.2 and 2.3 million in 2019–2024. To address the possibility of changes in filing behavior, including increased use of state-secrecy exemptions, we also replicate the firm-level analysis using a balanced panel of firms.

shipment, the dataset records its weight, product code and description, buyer and seller information, and the nature of the shipment (import, export, or domestic shipment). In our context, railway shipment data are helpful because, for a subset of firms, they offer granular proxy measures for the quantity of their domestic outgoing and incoming shipments and provide insight into the structure of their domestic supply chain network. As such, we restrict our attention to domestic shipments.

Government Procurement Data. We extract data on procurement purchases from the Marker database, which compiles publicly available records of purchases by government and state-owned entities from *zakupki.gov.ru* for the years 2012 to 2023. In principle, all domestic purchases of goods and services by public entities are required to be reported in this database. In 2023, the total volume of such purchases amounted to approximately 18% of Russian GDP. To identify military-related procurement, we search for a set of relevant keywords appearing in contract titles or descriptions, such as "GOZ" or "gosoboronzakaz." Each contract record provides the seller's name and, in most cases (unless classified), that of the buyer. Using this approach, we identify 46,299 firms that acted as buyers or suppliers in military procurement contracts at any point.

Summary Statistics. Tables A.1 and A.2 display the summary statistics for Russian imports and firms, respectively. Table A.1 describes quarterly import flows between 2019Q1 and 2023Q4, showing significant variation in import values, transaction counts, and weights. Notably, 28% of country-product-quarter observations correspond to flows ever subject to sanctions, with 7% under active sanctions in a given quarter. Table A.2 presents firm-level statistics for Russian enterprises from 2017 to 2023, highlighting substantial heterogeneity in their sales, capital, and profitability. Only 2.4% of firms were directly exposed to export sanctions; that is, they imported soon-to-be-sanctioned country-product varieties before the war. About 9.8% and 9.1% of all firms are in the manufacturing and science and technology sectors, respectively. Additional data on railway shipments in Panel C of Table A.2 highlight the firms' extensive domestic logistical networks, showing substantial variation in shipment weights and the number of trading partners.[14]

[14]For summary statistics in Panels A and B of Table A.2 and throughout the rest of this paper, we exclude one firm with an abnormally high reported revenue of 30 trillion rubles—an amount exceeding the entire Russian federal budget. The exclusion of this outlier does not affect our results.

4 Stylized Facts

Using our comprehensive data, we first establish several stylized facts about the export sanctions imposed on Russia after February 2022. These patterns highlight substantial variation in these restrictions across countries, products, and time, enabling our granular empirical analysis.[15]

Magnitude and Evolution of Export Sanctions. First, we examine the size of imposed export sanctions as well as how it varies with the timeline of the sanctions' introduction.

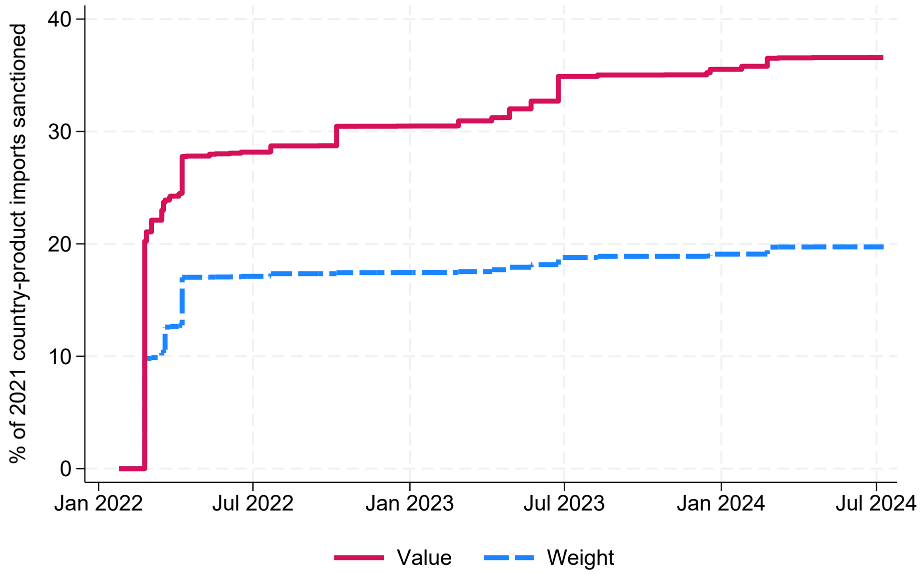
Figure 1 depicts the cumulative shares of all sanctioned country-product imports over time. More than 36% of all country-product imports to Russia in prewar value had been sanctioned by July 2024. At the product level, more than 80% of all imports in prewar value had been sanctioned by at least one country by July 2024 (Figure A.2).

The timeline of sanction impositions informs our empirical strategy for assessing the impact on imports. Nearly two-thirds of sanctions were introduced within the first few months of the war, making a simple pre-post DiD approach—comparing sanctioned and nonsanctioned import flows before and after the war's onset—a suitable baseline. However, since there was still substantial variation in sanction impositions between July 2022 and December 2023, a staggered DiD offers an additional layer of rigor, allowing us to leverage this timing variation to strengthen identification.

Most-Sanctioned Products. Figure A.3a lists the 20 most-sanctioned two-digit product categories, ranked by the share of their 2021 import value to Russia that was later prohibited. Consistent with the economic warfare goal of the sanctions, the most heavily targeted categories fall under HS2 codes 84, 85, and 87, which include technologically sophisticated goods, such as electronics, drones, vehicles, and microchips. At the same time, sanctions extend well beyond the high-tech sectors. Notably, across all the sanctioned product categories, nonsanctioned imports still account for a substantial share of prewar import value—often more than half. This rich variation enables us to identify the effects of sanctions on import flows even within broad product categories.

[15] See Egorov, Korovkin, Makarin, and Nigmatulina (2025) for an extended discussion. Note, however, that their figures may differ slightly from those reported here, as they rely on trade data coming from aggregated UN Comtrade rather than the granular Russian customs records used in this paper.

Figure 1: Timing and Magnitude of Export Sanctions Imposed on Russia, as a Share of 2021 Russian Total Import Volume



Notes: This figure displays the timing and scope of export sanctions against Russia at the country-product level. For each date from February 2022 to July 2024, it plots the share of 2021 total Russian imports covered by country-product varieties that had been sanctioned as of that date. Shares are measured by value (red solid line) and by weight (blue long-dashed line). Figure A.2 in Online Appendix A presents the corresponding product-level analogue.

Most-Sanctioning Countries. Figure A.3b ranks countries by the volume of their sanctioned 2021 exports to Russia while also showing their total prewar exports to Russia. Germany stands out as the country that contributed the most to these sanctions in absolute terms, banning around $26 billion of its own 2021 exports to Russia and leaving only $7 billion untouched. Notably, however, for nearly all sanctioning countries, some portion of exports remained nonsanctioned—providing variation to distinguish the effects of export sanctions from broader country-specific shocks.

Not All Countries Sanctioned the Same Products. Table A.3 reports the pairwise correlations between the lists of sanctioned products across countries. While some country pairs, such as the EU and the United Kingdom, exhibit a high degree of alignment in their sanctioned product lists, coordination appears significantly weaker among other country pairs. Notably, there is minimal overlap between the EU's list and those of Australia, Canada, or Taiwan. These gaps in coordination further assure us that variation exists even in sanctioned products across sanctioning countries, i.e., at the *country-product* level, further strengthening our identification strategy.

Descriptive Aggregate Trends. Online Appendix A.3 presents aggregate time-series evidence showing that, after the invasion, Russian imports shifted sharply away from sanctioning countries and toward nonsanctioning countries, including through routes consistent with rerouting. Online Appendix A.4 complements these aggregate patterns by zooming in on two product categories crucial during wartime: semiconductors and critical components. For both categories, and especially for semiconductors, it documents a sizable post-February 2022 increase in shipments of goods produced elsewhere through friendly countries. These exercises underscore the richness of our data, but also illustrate the limitations of raw trends alone: contemporaneous shocks, such as surging wartime demand, can obscure the causal effects of export sanctions.

All these facts show that export sanctions against Russia were broad but far from uniform: they varied substantially across products, sanctioning countries, and time. This variation is central to our empirical strategy. We next turn to an econometric framework that uses the country-product-level variation in sanctions to isolate their causal impact on Russian imports. We then examine whether these trade disruptions translated into firm- and industry-level effects consistent with the economic-warfare objective of constraining Russia's productive capacity.

5 Trade Results: Direct Effects, Rerouting, and Net Import Losses

We begin by estimating the causal impact of export sanctions on Russian imports. We ask three questions. First, did export bans reduce targeted country-product flows? Second, to what extent did sanctioned products re-enter Russia through friendly countries, and was this adjustment driven by rerouting or substitution? Third, after allowing for these adjustment margins, did total Russian imports of sanctioned products decline? These trade effects are important in their own right: they quantify the ability of export sanctions to constrain imports and the extent to which rerouting attenuates their impact. They also discipline the firm-level analysis that follows, since export sanctions can disrupt production only if they reduce firms' access to targeted foreign inputs after accounting for rerouting and substitution.

5.1 Direct Effects and Friendly-Country Adjustment

First, we jointly estimate the decline in sanctioned country-product imports and the compensating increase from countries that remained friendly to Russia after the invasion.

As our baseline empirical strategy, we estimate the following dynamic pre-post DiD equation on the full sample of country-product import flows:

$$\begin{aligned} y_{gct} = &\sum_{s \neq 2021\text{Q4}} \theta_s \, Sanctioned_{gc} \times \mathbb{1}\{t = s\} \\ &+ \sum_{s \neq 2021\text{Q4}} \gamma_s \, (Sanctioned_g \times Friendly_c) \times \mathbb{1}\{t = s\} + \tau_{gc} + \eta_{gt} + \omega_{ct} + \zeta_{gct}. \end{aligned} \tag{1}$$

Here, y_{gct} denotes imports of ten-digit product g from country c to Russia in quarter t, where c refers to the country of *shipment*. In intensive-margin specifications, y_{gct} is log import value (or weight) conditional on positive imports in the corresponding country-product-quarter. In extensive-margin specifications, it is an indicator equal to one if the corresponding country-product-quarter import flow is positive. $Sanctioned_{gc}$ is an indicator equal to one if the country-product variety (g, c) is ever subject to export sanctions, while $Sanctioned_g$ indicates whether product g is ever sanctioned by any country. $Friendly_c$ indicates whether country c is classified as friendly to Russia.[16] The terms τ_{gc}, η_{gt}, and ω_{ct} denote product-country, product-quarter, and country-quarter fixed effects, respectively. Standard errors are clustered two-way by country and product.

The coefficients θ_s provide the empirical first stage for the rest of the paper, tracing the dynamic effect of export sanctions on *directly targeted country-product flows*. The coefficients γ_s trace the differential evolution of imports of sanctioned products from friendly countries, capturing the *compensating response through potential rerouting or substitution*. The omitted category consists of flows for which $Sanctioned_{gc} = 0$ and $Sanctioned_g \times Friendly_c = 0$: imports of nonsanctioned products from any country, as well as imports of sanctioned products from non-friendly countries that did not impose sanctions on the corresponding product. The identifying

[16] We define friendly countries as Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE. This classification is based on journalistic accounts documenting these countries as common rerouting hubs for Russian imports. Our results are robust to alternative classifications, including extending the list to all BRICS members (Online Appendix B.4).

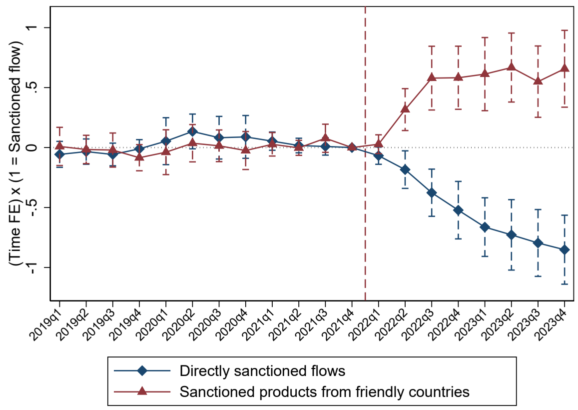
assumption is that, absent sanctions, directly sanctioned flows and friendly-country flows of sanctioned products would have evolved similarly to their respective comparison flows, conditional on the included fixed effects. Product-by-quarter fixed effects absorb time-varying shocks common to each ten-digit product, such as surging demand for war-related inputs or reduced demand for luxury products, while country-by-quarter fixed effects absorb time-varying shocks common to each source country, including boycotts, policy changes, payment frictions, and shifts in trade logistics.

As a complementary design, we also exploit the staggered monthly timing of sanctions across country-product pairs. For directly sanctioned flows, treatment begins in the month when a country-product variety becomes subject to export sanctions; for friendly-country flows, treatment begins when the product is first sanctioned by any country. The design compares import flows around these treatment dates to not-yet-treated and never-treated flows, while retaining the fixed effect structure in Equation (1). This timing-based comparison helps address the concern that the pre-post estimates may partly capture country-product-specific shocks coinciding with the invasion rather than the effect of export sanctions themselves. We implement the design using the ETWFE estimator of Wooldridge (2021), which accommodates treatment-effect heterogeneity in staggered settings; Online Appendix B.2 provides the full specification and implementation details.

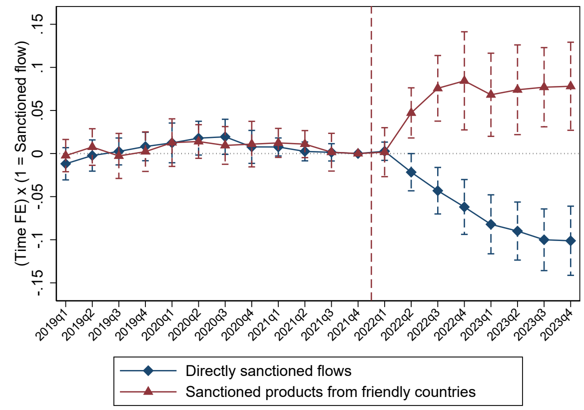
Figure 2 presents the results. The top row reports the pre-post DiD estimates, while the bottom row reports the staggered-DiD estimates averaged across cohorts. In each row, the left panel shows intensive-margin effects on log import value, and the right panel shows extensive-margin effects on the probability of observing a positive country-product import flow.

The results reveal two sharp and opposing forces. Prior to the invasion, sanctioned and non-sanctioned import flows evolved similarly for both treatment arms, providing little evidence of anticipatory adjustment before the war and sanctions. After the invasion, *directly sanctioned country-product flows declined sharply*. In the pre-post specifications in Panels A and B, the intensive-margin decline grows steadily through 2023, reaching -0.85 log points by the end of the sample, or about a 57% decline, while the extensive-margin effect reaches roughly -10 percentage points. Thus, sanctions reduced imports both by eliminating some country-product flows

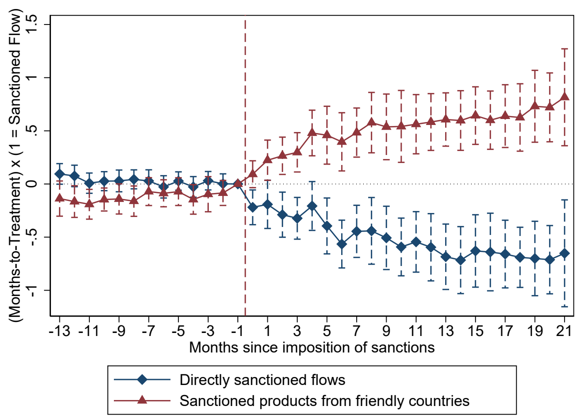
Figure 2: Direct Effects of Export Sanctions and Adjustment Through Friendly Countries



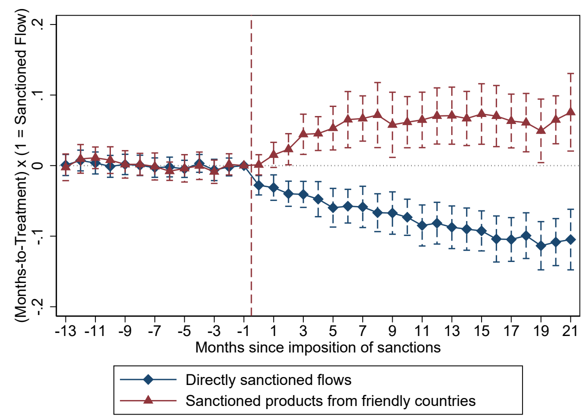
(a) Intensive Margin: Pre-Post DiD



(b) Extensive Margin: Pre-Post DiD



(c) Intensive Margin: Staggered DiD



(d) Extensive Margin: Staggered DiD

Notes: This figure reports the direct effect of export sanctions on Russian imports and the compensating adjustment through friendly countries. *Friendly* countries are Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE. The top row reports quarterly pre-post DiD estimates from Equation (1), with 2021Q4 as the omitted period. The bottom row reports monthly staggered-DiD estimates, aggregated across cohorts by event time. For these estimates, the direct-sanctions arm (blue) and friendly-country adjustment arm (red) are estimated separately for computational feasibility; for details, see Online Appendix B.2. The left column reports intensive-margin estimates from log specifications restricted to positive import flows; the right column reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The vertical red line in the top row marks the start of the war; in the bottom row, it marks the month of sanction imposition for the relevant treated group. Bars represent 95% confidence intervals. Standard errors are two-way clustered by country and product. Pre-post sample: 5,076,220 observations, 9,486 products, 214 countries; staggered-DiD sample: 9,256,464 observations, 8,838 products, 197 countries.

altogether and by sharply reducing the value of flows that remained positive.[17]

At the same time, *sanctioned products increasingly entered Russia through friendly countries*.

[17]Imports of some country-product varieties may remain positive despite sanctions because of exemptions, enforcement lags, noncompliance, or measurement imperfections.

In the pre-post event study, the value of these imports rises by roughly 0.6–0.7 log points by late 2023, corresponding to an increase of about 80%–100%, while the probability of observing a positive flow increases by about 7–8 percentage points.[18] These estimates point to a large compensating response via either rerouting or substitution, two channels we disentangle in the next section.

The staggered-DiD estimates in the bottom row closely mirror these patterns: directly sanctioned flows decline sharply in the month sanctions are imposed, with no differential pre-trends, while the offsetting increase through friendly countries emerges somewhat more gradually.

Online Appendices B.3 and B.4 further show that these patterns are robust to using import weight instead of value, broadening the set of "friendly" countries, accounting for countries with missing sanctions data, excluding the earliest sanction cohorts, and redefining the reference period in the staggered design to address possible anticipation of postinvasion sanctions.

Taken together, these estimates reveal two large and opposing responses: directly sanctioned imports fall quickly and by large amounts, while imports of sanctioned products from friendly countries rise markedly. The increase from friendly countries should not be interpreted as a full offset, however, because it is measured relative to a much smaller prewar base. We therefore next decompose the friendly-country response into rerouting and substitution, and then assess whether these adjustment margins fully offset the direct decline at the product level. We return to these estimates in the back-of-the-envelope aggregation in Section 8, where we quantify the overall import shortfall and the share of the direct sanctions-induced decline offset by rerouting and substitution.

5.2 Rerouting versus Substitution

We now decompose the compensating response through friendly countries into rerouting and substitution. A key advantage of the Russian customs data is that each transaction reports both the country of shipment and the country of production. This transaction-level distinction allows us to *directly separate goods produced in friendly countries from goods transshipped through them*, rather than inferring rerouting from aggregate bilateral flows under additional assumptions.

We partition each import flow of sanctioned products arriving from friendly countries by the product's country of production: (i) goods produced in the country of shipment (*substitution*); (ii)

[18] Columns (1)–(3) of Table B.1 report the corresponding static estimates for these margins of adjustment.

goods produced in a sanctioning country (*rerouting from sanctioning countries*); and (iii) goods produced in another nonsanctioning country (*rerouting from other countries*). We then reestimate the pre-post specification underlying Figure 2, replacing the aggregate friendly-country response with these three disaggregated flows. Because this exercise focuses on the composition of that response, directly sanctioned import flows are excluded and the θ_t terms are no longer estimated.

Figure 3 presents the results.[19] The postinvasion increase in imports of sanctioned products from friendly countries (red lines in Figure 2) is driven primarily by rerouting, while substitution plays only a limited role, on average. Moreover, roughly two-thirds of the compensating response through friendly countries reflects *rerouting specifically from sanctioning countries*. If anything, incentives to conceal the origin of sanctioned products would tend to attenuate these estimates, making them a lower bound on rerouting from sanctioning countries.

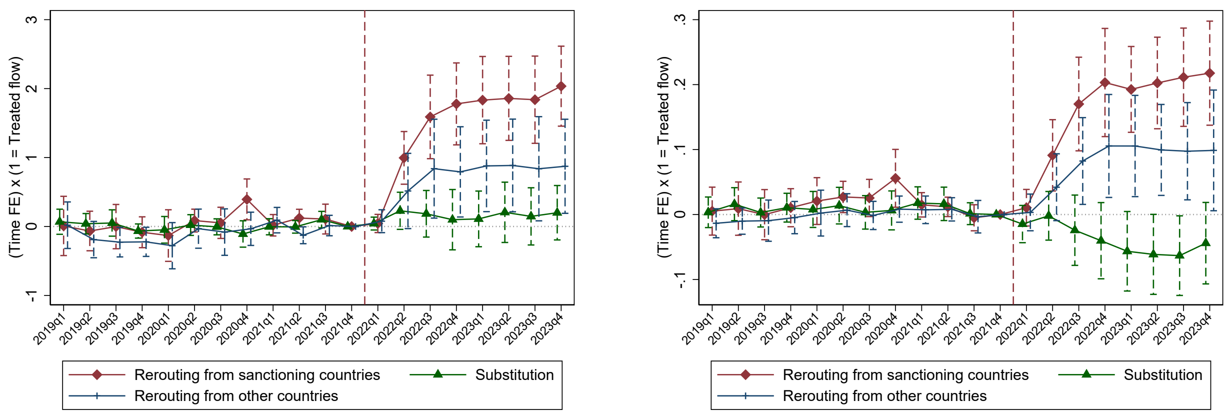
This pattern holds on both the intensive and extensive margins. On the intensive margin (Panel A), rerouting from sanctioning countries rises by about 2 log points by the end of the sample, implying that these flows become more than *seven times* as large as before the war. Rerouting from other countries also increases, but by a smaller 0.8–0.9 log points, corresponding to an increase of about 125%–145%, while substitution remains much more limited. The extensive-margin estimates (Panel B) show the same ordering: the probability of observing rerouted imports from sanctioning countries increases by about 20–22 percentage points, compared with roughly 10 percentage points for rerouting from other countries and no sustained increase for substitution.

5.3 Did Rerouting Fully Offset the Import Shock?

We now ask whether the adjustment margins documented above fully offset the decline in directly sanctioned imports. To do so, we aggregate across countries of shipment and production and examine total Russian imports of each ten-digit product. This exercise captures the net effect of export sanctions on access to sanctioned products after allowing for rerouting and substitution.

[19] Figure B.1 reports the staggered-DiD analogue. Figure B.4 reports the corresponding decomposition using import weight instead of import value. Results are qualitatively and quantitatively similar in both cases.

Figure 3: Decomposing Rerouting and Substitution Through Friendly Countries



(a) Intensive Margin

(b) Extensive Margin

Notes: This figure decomposes the rise in Russian imports of sanctioned products from friendly countries into rerouting and substitution. We separate each import flow of the sanctioned products shipped from friendly countries into three flows: those produced within the same friendly country (*in green*), those produced in sanctioning countries (*in red*), and those produced elsewhere (*in blue*). The impact of export sanctions is then estimated on each of these flow's value, with the nonsanctioned imports from third countries serving as a control group. Directly sanctioned flows from sanctioning countries are excluded from the estimation sample. *Friendly countries* are defined as Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE. Panel A reports intensive-margin estimates from a log specification restricted to country-product-quarters with positive imports; Panel B reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The data use quarterly frequency, with 2021Q4 as the omitted period. The red vertical line marks the start of the war. The bars represent 95% confidence intervals. Standard errors are clustered two-way by country and product. Total observations: 3,669,220 across 8,770 products and 205 countries. For the staggered DiD analogue, see Figure B.1 in Online Appendix B. For the weight-based analogue, see Figure B.4.

We first estimate a product-level analogue of Equation (1):

$$y_{gt} = \sum_{s \neq 2021\text{Q4}} \lambda_s \, Sanctioned_g \times \mathbb{1}\{t = s\} + \omega_{h(g)t} + \tau_g + \eta_t + \zeta_{gt}. \tag{2}$$

Here, y_{gt} denotes imports of product g into Russia in quarter t, measured either as log import value conditional on positive imports or as an indicator for whether the product is imported. $Sanctioned_g$ is an indicator equal to one if product g is ever sanctioned by any country. The terms τ_g and η_t denote ten-digit product and quarter fixed effects, while $\omega_{h(g)t}$ denotes higher-level product-category-by-quarter fixed effects, defined at the three-digit level in our baseline specification, which absorb time-varying shocks common to broader product groups, such as wartime demand shifts for electronics or machinery. Standard errors are clustered by product.

As a complementary design, we also estimate a staggered DiD in which treatment begins in the month when product g is first sanctioned by any country. This timing-based comparison uses not-yet-sanctioned and never-sanctioned products as controls and helps further separate the effect of export sanctions from broader war-related shocks that may differentially affect specific ten-digit products. Online Appendix B.2 provides the full specification and implementation details.

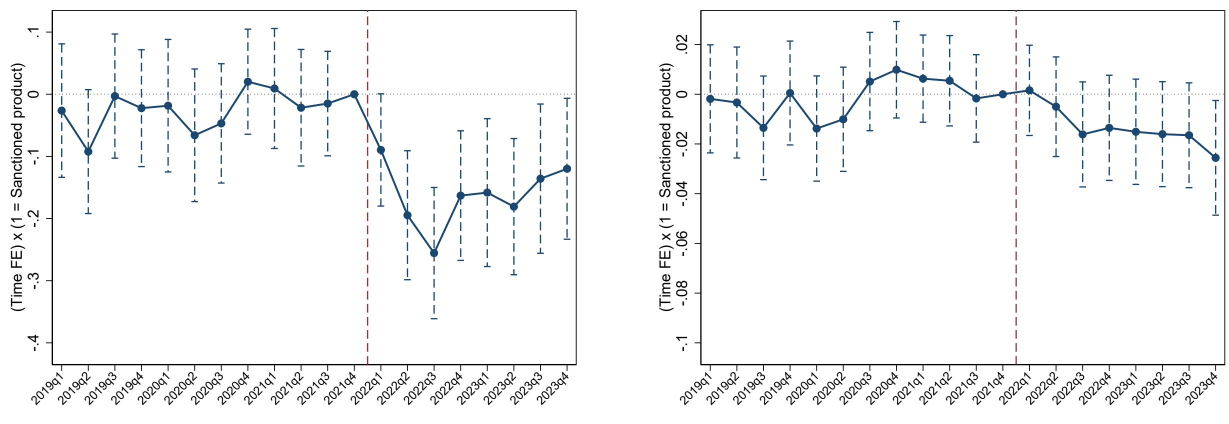
Figure 4 presents the results. Total Russian imports of sanctioned products declined after the invasion, even after aggregating across all countries of shipment. In the pre-post specification, the intensive-margin effect turns negative immediately and reaches roughly -0.2 to -0.3 log points before partially rebounding by the end of 2023. The corresponding nondynamic estimate in column (5) of Table B.1 implies an average decline of 12.9% ($= \exp(-0.138) - 1$). The extensive margin becomes increasingly negative over time: sanctioned products are about 1–2 percentage points less likely to be imported by the end of the sample, with an average decline of 1.4 percentage points (column (4) of Table B.1). These results indicate that rerouting and substitution did not fully offset the import shock; sanctions reduced both the value of continuing product flows and, increasingly, the set of sanctioned products imported into Russia.

Figure B.2 reports the staggered-DiD analogue. The estimates are noisier than in the pre-post specification, reflecting more limited variation in product-level sanction timing, but they point to the same conclusion. Total imports of sanctioned products decline after the first sanction is imposed on the product. The intensive-margin estimates fall by roughly 0.2 log points, while the extensive-margin estimates become increasingly negative over the post-treatment horizon. The larger monthly extensive-margin response is consistent with more intermittent imports after sanctions, as products may disappear from Russian imports in some months while still appearing at the quarterly frequency used in the pre-post specification.

The product-level estimates are robust to using import weight instead of value (Figure B.5) and to replicating the analysis with UN Comtrade mirror-export data (Online Appendix B.5), which addresses concerns about omissions or manipulation in Russian customs records, and relabeling across HS10 codes within the same HS6 product.

In summary, the trade results show that rerouting substantially mitigated the decline in sanctioned country-product import flows, but did not fully offset the reduction in total imports of sanc-

Figure 4: The Impact of Export Sanctions on Russian Imports of Sanctioned Products, in Value



(a) Intensive Margin

(b) Extensive Margin

Notes: This figure assesses the impact of sanctions on total imports of sanctioned products into Russia, independent of the country of shipment or country of production, estimated via the pre-post DiD in Equation (2). Panel A reports intensive-margin estimates from a log specification restricted to product-quarters with positive imports; Panel B reports extensive-margin estimates from a linear probability model for whether the corresponding import flow is positive. The data are quarterly with 2021Q4 as the omitted period; regressions include HS3-product-time fixed effects. The red vertical line marks the start of the war. Bars represent 95% confidence intervals. Standard errors are clustered at the product level. Sample: 205,400 product-quarter observations across 10,270 products. For the weight-based analogue, see Figure B.5; for the corresponding staggered-DiD evidence, see Figure B.2 in Online Appendix B.2.

tioned products. The remaining shortfall is sizable and persistent. In Section 8, we provide a back-of-the-envelope aggregate quantification of this gap and decompose the share of the direct sanctions-induced decline offset by rerouting and substitution. We next ask whether this import disruption translated into measurable downstream effects on Russian firms and supply chains.[20]

6 Results: Impact on Firms

A reduction in imports need not mechanically imply a disruption to production. Firms may substitute toward domestic suppliers, draw down inventories, change production technologies, receive state support, or obtain restricted inputs through illicit channels that evade both Russian customs records and mirror-export statistics. In this section, we test whether firms that relied on inputs later subject to export restrictions experienced worse postwar outcomes. This analysis is central to evaluating whether export sanctions operated as instruments of *economic warfare* that

[20] In Online Appendix B.6, we also estimate a firm-product-level import specification with firm-quarter fixed effects. The results show that the decline in sanctioned imports is present within importing firms over time, helping bridge the trade and firm-level analyses and mitigating the concern that firm-specific shocks drive the observed import declines.

constrained production in the targeted economy, including in strategically important sectors.

Empirical Strategy. We construct an annual panel of Russian firms and merge it with the customs data to measure each firm's prewar exposure to export sanctions. Specifically, for each firm f, we use its imports between January 2019 and February 2022 and define $Exposed_f$ as an indicator equal to one if the firm imported at least one country-product variety that later became subject to export sanctions. We then estimate the following event-study specification:

$$y_{ft} = \sum_{s \neq 2021} \beta_s \, Exposed_f \times \mathbb{1}\{t = s\} + \mu_f + \gamma_t + \sum_{s \neq 2021} \delta_s \mathbf{X}_f \times \mathbb{1}\{t = s\} + \epsilon_{ft}, \qquad (3)$$

where y_{ft} denotes firm-year outcomes such as sales, costs, profits, and value added; μ_f and γ_t are firm and year fixed effects; and 2021 is the omitted year. Standard errors are clustered at the firm level. The coefficients β_s trace the differential evolution of firms exposed to export sanctions relative to firms that did not import soon-to-be-sanctioned varieties before the war.

The vector $\mathbf{X}_f$ contains time-invariant prewar firm characteristics and prewar exposure measures. We interact these variables with year fixed effects, allowing firms with different prewar characteristics and exposure to other sanctions-related shocks to follow flexible differential trends. In our preferred specification, $\mathbf{X}_f$ includes indicators for: (i) whether the firm was an importer or exporter before the war; (ii) the firm's two-digit OKVED industry; (iii) exposure to targeted sanctions against specific firms from the War & Sanctions Database (Defence Intelligence of Ukraine, 2026); (iv) exposure to sanctions on Western imports from Russia (*import sanctions*); and (v) exposure to financial sanctions or the exit of foreign-owned banks from Russia.[21]

These controls help isolate the impact of export sanctions from other components of the sanctions regime or confounding wartime shocks. That is, firms importing soon-to-be-sanctioned inputs may also have been more internationally oriented, concentrated in sectors differentially affected by the war, directly hit by targeted sanctions, exposed to foreign restrictions on Russian exports, or reliant on foreign banks or banks later subject to financial sanctions. By allowing each of these prewar characteristics and exposure measures to have its own flexible time path, the preferred

[21] In the spirit of Jiao and Wei (2025), we use banking information in the 2019–2021 customs data to identify, for each firm, whether any of its prewar import value was intermediated through banks that were later sanctioned, or through foreign banks that later exited Russia.

specification compares firms with and without prewar reliance on export-sanctioned inputs, net of broad industry trends, importer and exporter dynamics, and exposure to other major sanctions-related shocks. Under the corresponding conditional parallel-trends assumption, β_s identifies the causal effect of prewar exposure to export-sanctioned inputs on firm outcomes.[22]

6.1 Baseline Impact on Firm Output and Performance

Figure 5 presents the estimates of Equation (3) for firm sales, total cost of goods sold, gross profits, and value added. Firms exposed to export sanctions through their prewar imports experienced a sharp and persistent decline in performance after the war's onset, with no comparable decline among firms that did not import soon-to-be-sanctioned varieties before the war. The sales effects in Panel A are large: exposed firms' sales fall by roughly 13–18% from 2022 through 2024. Total cost of goods sold in Panel B declines by similar magnitudes, indicating a *broad contraction in firm activity* rather than only a change in output prices. Furthermore, the lack of pretrend for the cost of goods sold demonstrates that firms were unlikely to stack up inventories before the start of the conflict and likely did not anticipate it. Panels C and D show that gross profits and value added also fall, suggesting that the shock translated into lower overall firm output.

The persistence of these declines suggests that firms' adjustment strategies—including rerouting, substitution, inventories, or domestic support—were insufficient to offset the shock. Beyond their standalone importance, these findings indirectly validate the import disruptions documented in Section 5: if sanctioned inputs continued to reach exposed firms at scale through unobserved or black-market channels, we would be less likely to observe such sharp, persistent declines.

Table 1 quantifies these patterns in the corresponding nondynamic specification. Column (1) confirms a significant average sales decline of 11.9% among exposed firms $(= \exp(-0.127) - 1)$. The effects are similar across other measures of firm performance: total cost of goods sold falls by 12.5% (column 2), gross profits by 10.6% (column 3), and value added by 9.2% (column 4). The table also reveals sizable declines in specific input categories: capital expenditures by 9.0% (col-

[22] Following best practice for event-study visualization, the figures use a more minimalistic specification with importer-year fixed effects, allowing us to assess pretrends without relying on a large set of additional covariates (Roth, Sant'Anna, Bilinski, and Poe, 2023). The tables report our preferred specification with the full set of controls. The full-specification event-study estimates are similar.

Table 1: The Impact of Export Sanctions on Exposed Russian Firms

	(1) Log Sales	(2) Log Costs	(3) Log Gross Profit	(4) Log Value Added	(5) Log Capital Costs	(6) Log Labor Costs	(7) Log Materials Costs	(8) 𝟙[Sales Missing]
Post-2022 × Exposed to Export Sanctions	-0.127***	-0.133***	-0.112***	-0.096***	-0.094***	-0.099***	-0.143***	0.001
	(0.010)	(0.010)	(0.011)	(0.011)	(0.014)	(0.013)	(0.017)	(0.002)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Mean Dep. Var.	16.00	15.93	14.08	14.11	14.46	15.50	17.25	0.23
SD Dep. Var.	2.30	2.25	2.41	2.43	2.60	2.37	2.73	0.42
Observations	11,290,066	10,548,581	9,038,126	8,916,939	5,268,122	1,515,728	1,569,338	16,136,232
Number of Firms	2,017,029	1,916,564	1,811,364	1,801,035	1,021,715	324,714	337,779	2,017,029

Notes: This table examines the impact of export sanctions on the performance of exposed Russian firms. It reports the nondynamic version of Equation (3), comparing firms exposed and not exposed to export sanctions before and after the war's onset. A firm is considered exposed if, prior to the war, it imported any country-product variety that was later sanctioned. With the exception of the missing sales indicator, all dependent variables are in logarithms of Russian rubles. All specifications include firm fixed effects and year fixed effects interacted with prewar importer status, exporter status, two-digit OKVED industry, targeted-sanction exposure, financial-sanction exposure, foreign-bank-exit exposure, and import-sanctions exposure. The sample is restricted to firms with capital observed at least once. Firm outcomes are measured annually from 2017 through 2024. Standard errors in parentheses are clustered at the firm level. * p<0.1, ** p<0.05, *** p<0.01.

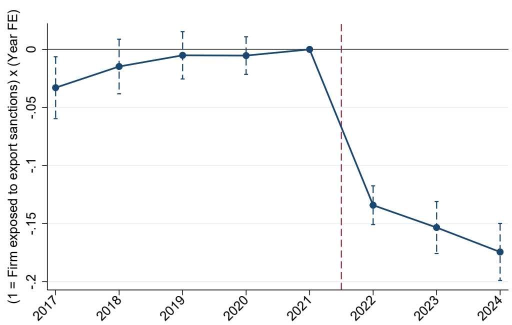
umn 5), labor expenditures by 9.4% (column 6), and material expenditures by 13.3% (column 7).[23]

Taken together, these findings indicate that export sanctions had substantial and persistent disruptive effects on exposed firms across multiple margins.

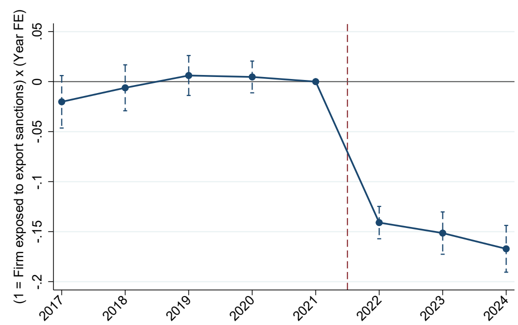
Robustness. The results are not driven by sample-composition changes. Column (8) of Table 1 shows no evidence that exposed firms are more likely to disappear from the financial-statements data. More directly, effects are similar when we (i) restrict the analysis to a strictly balanced panel, (ii) exclude firms that entered during the war, or (iii) exclude firms that exited in the first postwar year (Online Appendix Table C.1). Across these checks, the coefficients remain large, negative, and precisely estimated, implying a 10%–13% decline in sales and total cost of goods sold.

[23] The lower number of observations in columns (5)–(7) reflects the fact that the more detailed cost items are available only for firms filing full financial statements. In contrast, smaller firms submitting simplified financial statements report revenues and profits but generally do not provide disaggregated labor or materials expenditures.

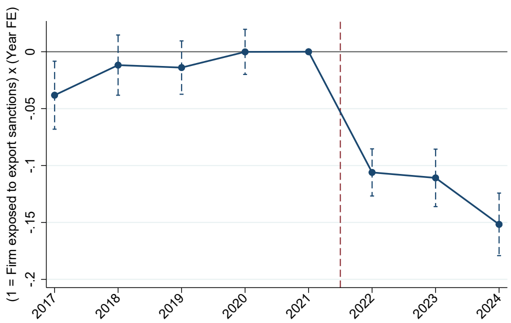
Figure 5: The Impact of Export Sanctions on Exposed Firms' Outcomes



(a) Sales



(b) Total Cost of Goods Sold



(c) Profits

(d) Value Added

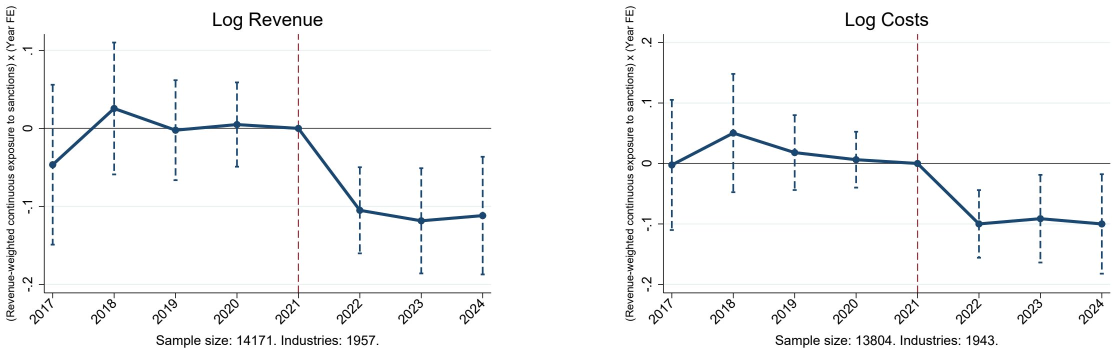
Notes: This figure examines the impact of export sanctions on the revenues, total cost of goods sold, gross profits and value added of firms that, prior to the war, imported any country-product variety that was later sanctioned. Specifically, it presents the dynamic DiD estimates of Equation (3), comparing firms with and without prewar exposure to future export sanctions, before and after the war's onset. The parallel decline in both sales and production costs is consistent with a contraction in real output rather than merely a decrease in output prices. The regressions absorb firm and year-by-importer fixed effects. The sample is restricted to firms with capital observed at least once. The value added is calculated as revenues minus materials, or revenue minus costs of goods sold for firms that did not report materials. The outcome data are at the yearly level (2017–2024), with 2021 serving as the baseline period. The red vertical line indicates the start of the war. The bars represent 95% confidence intervals. Standard errors are clustered at the firm level. Panel A: Number of records is 11,356,817 observations, 2,049,099 firms; Panel B: 10,612,446 observations; 1,947,304 firms. Panel C: 9,085,573 observations, 1,834,325 firms; Panel D: 8,962,629 observations; 1,823,118 firms.

6.2 Are the Losses Offset by Other Firms? Industry-Level Effects

A remaining concern is that firm-level losses may overstate aggregate disruption if non-exposed firms or new entrants quickly replaced exposed firms' output. Such reallocation would weaken the interpretation of export sanctions as an effective tool of economic warfare: even if exposed firms contracted, total production in the affected industries may have remained intact.

To address this possibility, we aggregate the analysis to the 5-digit industry level. We construct

Figure 6: The Impact of Export Sanctions on Total Sales and Costs of 5-Digit Industries



Notes: This figure examines the impact of export sanctions on industry-level sales and costs. The dataset is collapsed at the 5-digit industry level. The exposure to export sanctions at the industry level is calculated as the share of prewar soon-to-be-sanctioned import flows weighted by the revenues in an industry earned by importers. The exposure is then normalized by its standard deviation. The plots display the dynamic DiD estimates analogous to Equation (3) but implemented at the industry rather than firm level, comparing industry revenues between 5-digit industries more versus less exposed to the export sanctions, before and after the war's onset. Both regressions control for 2-digit industry-by-year FE and 5-digit-industry FE. The revenue and costs data come at the yearly level (2017–2024), with 2021 serving as the baseline period. The red vertical line indicates the start of the war. The bars represent 95% confidence intervals. Standard errors are clustered at the 5-digit industry level.

industry exposure as the revenue-weighted average across the industry's firms of the prewar share of their imports accounted for by later-sanctioned varieties. We then estimate specifications analogous to Equation (3), with industry-level outcomes such as total sales and total cost of goods sold as dependent variables, 5-digit industry fixed effects, and 2-digit-industry-by-year fixed effects. Online Appendix C.2 provides details on the panel construction and empirical specification.

Figure 6 presents the dynamic estimates. There is no evidence of differential pretrends before 2022. After the invasion, however, more exposed industries experience sizable declines in both total sales and total cost of goods sold. Quantitatively, a one-standard-deviation increase in exposure is associated with declines of roughly 10 percent in both outcomes. Table C.2 reports the corresponding nondynamic estimates. It also shows, if anything, fewer new entrants in more exposed industries (column 3), as well as a decline in the number of reporting firms (columns 5–6). These results suggest that the firm-level losses were not offset by expansion among non-exposed firms or by entry within the same industries. Rather, export sanctions reduced activity at the industry level.

6.3 Strategic Relevance and Heterogeneity

We next examine heterogeneity in the firm-level effects. This is central to interpreting export sanctions as a tool of economic warfare: their bite depends not only on average firm losses, but on whether they disrupt sectors and firms important for Russia's productive and military capacity. We therefore study heterogeneity by industry, military relevance, and firm characteristics. The results show especially large losses in science and technology and little evidence that state-owned, strategic, or military-linked firms were shielded from the shock.

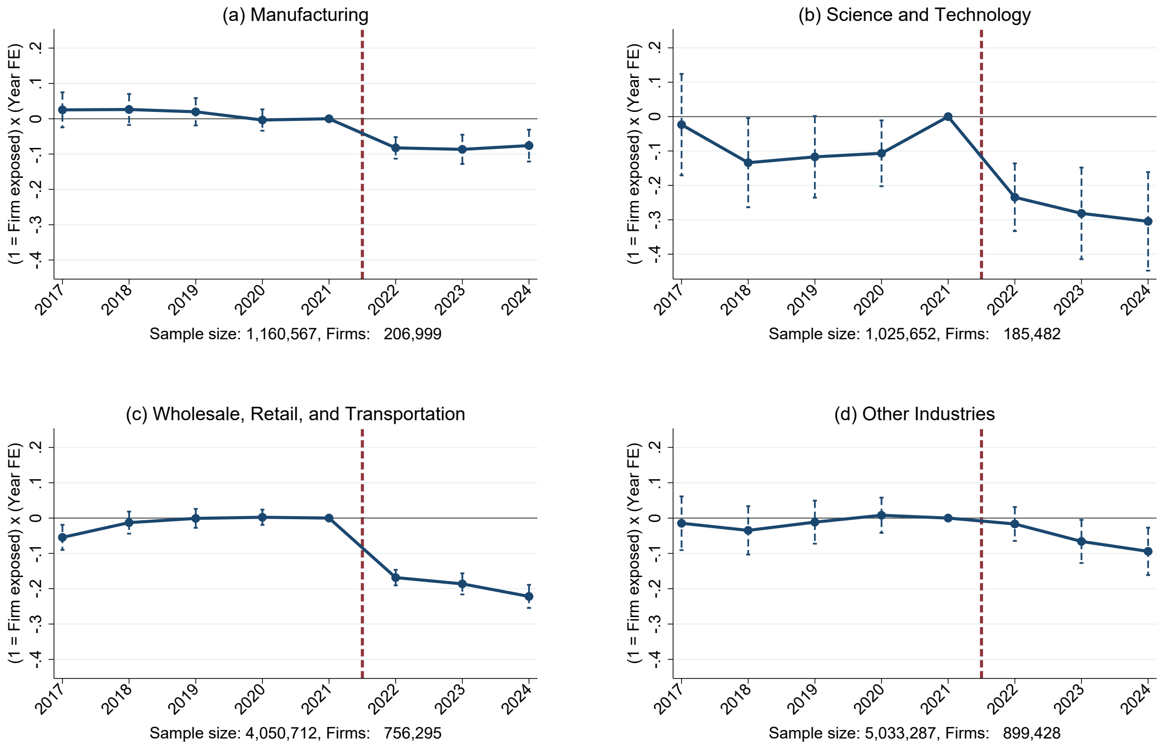
Effects by Industry. Figure 7 displays the estimates for firm sales across industry subsamples. The downstream impact of export sanctions is present within manufacturing firms (Panel A), but is *particularly pronounced in the science and technology sector* (Panel B), where sales fall by roughly 20–25% in the postwar years. We also find sizable declines in wholesale, retail, and transportation (Panel C), while the effects are smaller but still negative in the residual category of other industries, which includes agriculture (Panel D).

These patterns are consistent with one of the central strategic aims of the sanctions regime—*economic warfare*: disrupting the target country's industrial and technological capabilities by restricting access to critical manufacturing and high-tech inputs. They also align with the stylized facts in Section 4, which show that high-tech and manufacturing inputs are among the most heavily sanctioned product categories. At the same time, the effects are not confined to narrowly strategic sectors. The broad-based declines suggest that export sanctions propagated beyond directly targeted high-tech firms and affected a wider set of downstream economic activity.

Heterogeneity by Military Status. We next ask whether firms connected to the military sector were differentially affected by export sanctions. For each definition of military status, we estimate a triple-difference version of Equation (3), estimating whether prewar exposure to export-sanctioned inputs had a different postwar effect for these military-related firms. Thus, the coefficient of interest captures whether exposed military-related firms experienced larger or smaller postwar changes than other exposed firms.

Table C.3 reports this exercise using four definitions of military-related firms: inclusion in the

Figure 7: The Impact of Export Sanctions on Exposed Firms' Sales, by Industry



Notes: This figure examines the impact of export sanctions on the revenues of exposed firms by industry. Specifically, the plots display the dynamic DiD estimates of Equation (3), comparing firm revenues between firms with and without prewar exposure to future export sanctions, before and after the war's onset. A firm is considered exposed if, prior to the war, it imported any country-product variety that was later sanctioned. Each panel absorbs firm and year-importer fixed effects. The sample is restricted to firms with capital observed at least once. The revenue data come at the yearly level (2017–2024), with 2021 serving as the baseline period. The red vertical line indicates the start of the war. The bars represent 95% confidence intervals. Standard errors are clustered at the firm level.

defense-industry roster of the *Novyi Oboronnyi Zakaz* magazine (column 1),[24] location in a closed administrative-territorial formation (ZATO; column 2), serving as a defense-procurement buyer or supplier (column 3), and an indicator for satisfying any of these criteria (column 4). Across all four definitions, the interaction between export-sanctions exposure and military relevance is statistically insignificant. At the same time, the implied total effect for military-related exposed firms is negative in every column, with statistically significant declines under the defense-procurement and any-military definitions, where the larger number of military-related firms allows for greater precision. We therefore find little evidence that military-related firms were insulated from the ef-

[24] https://dfnc.ru/

fects of export sanctions. Rather, the firm-level disruptions documented in Section 6.1 extended to firms with direct or indirect links to Russia's military sector.

We also test directly whether export sanctions restricted military-related firms' access to sanctioned products. Figure C.1 presents firm-product-level import estimates for military-related firms, defined here as firms that ever participated in contracts under the military procurement law. The estimates are negative, statistically significant, and comparable in magnitude to those for the full firm sample. This evidence suggests that export sanctions constrained access to targeted products even among firms closely connected to the defense sector.

Heterogeneity by Firm Characteristics. Finally, we examine whether the effects vary with firm characteristics that proxy for political importance, adjustment capacity, exposure to related markets, or access to alternative supply channels. Table C.4 provides *little evidence that politically or strategically important firms were shielded from the shock.* The differential effects are small and statistically insignificant for state-owned firms (column 1), firms on the broad strategic-firms list (column 4), and system-forming enterprises (column 5). Larger firms experience losses that are somewhat smaller, but still substantial (column 2): the implied sales decline is about 8.0% for firms with above-median prewar capital ($p < 0.001$), compared with 17.7% for smaller firms.

Column (3) provides an additional robustness check on within-market reallocation. Firms that were top competitors of exposed firms in government procurement appear to experience smaller declines, consistent with some substitution toward firms operating in the same procurement markets. However, this effect is only marginally significant and, in line with the industry-level analysis above, such reallocation does not drive the baseline effect on exposed firms.

Finally, we test heterogeneity by firms' international orientation and use of alternative supply channels. Russian exporters experience larger losses, even after accounting for their exposure to sanctions on imports from Russia (column 6), suggesting that internationally oriented firms were especially vulnerable to the broader disruption of cross-border supply chains. The largest differential declines appear for firms that engaged in rerouting through friendly countries (columns 7–8). This pattern suggests that rerouting was concentrated among firms especially dependent on sanctioned inputs, rather than being sufficient to insulate them from the shock.

7 Downstream Effects: State Procurement and Domestic Supply Chains

The results above show that firms directly exposed to export-sanctioned inputs contracted after the war's onset. We next ask whether these disruptions remained confined to exposed firms or instead affected broader economic activity. We examine two margins. First, we test whether the Russian state offset the shock by increasing procurement from exposed firms, or whether exposed firms instead became less able to supply the public sector. Second, we use firm-to-firm railway shipment data to study whether exposed firms adjusted through domestic substitution and whether the shock propagated to their domestic buyers and suppliers.

7.1 Government Procurement

The firm-level disruptions documented above may also affect firms' procurement relationship with the Russian state. The sign of this effect is ex ante ambiguous. On the one hand, exposed firms could receive additional government contracts as compensation for sanctions-related losses (Nigmatulina, 2021). On the other hand, if export sanctions impaired firms' productive capacity, exposed firms may become less able to participate in procurement or fulfill government demand. We therefore examine whether exposure to export sanctions changed firms' procurement activity.

Table 2 reports estimates from a nondynamic version of Equation (3), with the same core firm fixed effects and time-varying exposure controls used in the firm-level analysis. Odd-numbered columns use an indicator for whether the firm won at least one government contract in a given year, while even-numbered columns restrict the sample to firm-years with positive procurement and use the log value of contracts won. Columns (1)–(2) report the baseline estimates, columns (3)–(4) restrict the sample to firms that secured contracts in at least two years of the sample, and columns (5)–(6) account for possible supply reallocation by allowing firms that competed with exposed firms before the war to experience a separate postwar shift.

The results show a clear decline on the extensive margin. In the full sample, exposed firms become 2.4 percentage points less likely to win any publicly observable government contract in a given year (column 1). The estimate remains similar, at 2.1 percentage points, when we restrict attention to firms with a more regular presence in procurement markets (column 3). Predictably, allowing firms that competed with exposed firms before the war to experience a separate postwar

Table 2: Export Sanctions and Government Procurement

	Baseline		Regular Procurement Firms		Competitor Adjustment	
	(1)	(2)	(3)	(4)	(5)	(6)
	$\mathbb{1}$[Won At Least One Contract]	Log Value of Contracts Won (If Nonzero)	$\mathbb{1}$[Won At Least One Contract]	Log Value of Contracts Won (If Nonzero)	$\mathbb{1}$[Won At Least One Contract]	Log Value of Contracts Won (If Nonzero)
Post-2022 × Exposed to Export Sanctions	-0.024***	-0.034	-0.021***	-0.034	-0.016***	-0.028
	(0.002)	(0.039)	(0.007)	(0.039)	(0.002)	(0.039)
Firm FE	✓	✓	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓
Regular Procurement Firms			✓	✓		
Post × Prewar Competitor of Exposed Firm					✓	✓
Mean Dep. Var.	0.11	14.96	0.63	14.96	0.11	14.96
SD Dep. Var.	0.31	2.39	0.48	2.39	0.31	2.39
Observations	10,505,517	971,528	1,547,049	971,528	10,505,517	971,528
Number of Firms	2,146,579	255,519	260,447	255,519	2,146,579	255,519

Notes: This table examines the impact of export sanctions on the government procurement activity of exposed Russian firms, estimated using a pre-post version of Equation (3). A firm is considered exposed if, prior to the war, it imported any country-product variety that was later sanctioned. Odd-numbered columns report extensive-margin estimates from a linear probability model with outcome equal to one if a firm won at least one government contract in a given year. Even-numbered columns report intensive-margin estimates from a log specification using the value of contracts won, restricted to firm-years with at least one contract won. Columns (3)–(4) restrict the sample to firms that secured contracts in at least two years of the sample. Because the intensive-margin specification includes firm fixed effects, one-time contract winners are omitted even without this restriction; column (4) therefore coincides with column (2) by construction. Columns (5)–(6) add post-period controls for firms that competed with exposed firms before the war. All specifications include firm fixed effects and year by importer-status, exporter-status, two-digit industry, targeted-sanctions exposure, financial-sanctions exposure, foreign-bank-exit exposure, and import-sanctions exposure fixed effects. The government procurement outcomes are aggregated at the firm-year level from 2017 through 2023. Standard errors in parentheses are clustered at the firm level. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

shift attenuates the estimate, but it remains negative and statistically significant at 1.6 percentage points (column 5). By contrast, the intensive-margin estimates are small and statistically insignificant: conditional on winning at least one publicly observable contract, exposed firms do not experience a meaningful decline in the value of contracts won (columns 2, 4, and 6). Thus, the decline in observed procurement operates primarily through fewer exposed firms winning public contracts, rather than through smaller contracts among winners.[25]

These findings provide little support for the view that the Russian state systematically compensated exposed firms through procurement. This contrasts with Nigmatulina (2021), who docu-

[25] A caveat is that a post-2022 shift toward classified or otherwise non-public procurement could reduce the visibility of some contracts in the public procurement data. This is unlikely to fully account for the results: the procurement decline is accompanied by contractions in exposed firms' total sales, value added, and domestic railway inshipments, which do not rely on procurement records and point to a broader disruption to firm activity.

ments compensatory government support for Russian firms targeted by post-2014 sanctions. One interpretation is that broad product-based export sanctions are harder for the target state to offset than targeted firm-level sanctions. When specific firms are sanctioned, the set of affected firms is directly observable and support can be targeted relatively easily. By contrast, export sanctions operate through firms' input networks: identifying affected firms, measuring their exposure, and compensating losses proportionally require substantially more information and administrative capacity. Overall, the procurement results provide further evidence of downstream disruption on a margin central to the logic of economic warfare: export sanctions reduced not only exposed firms' output, but also *impaired their ability to supply the Russian state*.

7.2 Supply-Chain Propagation and Domestic Shipments

The preceding results show that export sanctions reduced exposed firms' output and their ability to win contracts from the state. We next examine two margins that shape the aggregate consequences of these firm-level disruptions. First, the shock may propagate beyond directly exposed importers through domestic production networks, affecting their suppliers and customers. Second, exposed firms may substitute toward domestic suppliers, replacing sanctioned foreign inputs with local inputs. Firm-to-firm railway shipment data allow us to examine both margins. These data identify a subset of domestic buyers and suppliers and are especially informative in the Russian context: according to official Russian statistics, rail accounts for roughly 87 percent of non-pipeline freight turnover in ton-kilometers (Federal State Statistics Service, 2026).

We first ask whether the shock propagated through domestic production networks. Table D.1 in Online Appendix D augments Equation (3) with indicators for whether a firm's direct buyers or suppliers, or their buyers' or suppliers' partners, were exposed to export sanctions. All specifications except the baseline in column (1) control for the number of railway trading partners interacted with year indicators, accounting both for differential shocks to railway-trade participants and for the possibility that more connected firms were differentially exposed to concurrent aggregate shocks, in the spirit of Borusyak and Hull (2023). Columns (3)–(5) show that exposure through suppliers generates an additional negative effect nearly as large as the direct effect, while exposure through buyers yields a smaller but still marginally significant effect of about one-fourth in the full model. Importantly, the baseline coefficient remains stable at about a 12% decline.

We then examine whether exposed firms changed their domestic shipments, both in volume and in the number of trading partners. Table D.2 in Online Appendix D estimates a nondynamic version of Equation (3) for firms' in-shipments, out-shipments, and total railway trade. Columns (1)–(3) show a significant 9% decline in total shipment volume, driven entirely by a 15% drop in in-shipments, while out-shipments remain statistically unchanged. Columns (4)–(6) show no differential change in the number of suppliers, buyers, or trading partners. Thus, exposed firms do not appear to have offset sanctioned foreign inputs by expanding domestic sourcing of bulk inputs. Instead, they reduced domestic in-shipments, consistent with a broader contraction in production.

To sum up, these results rule out two important escape valves. The shock did not remain confined to directly exposed importers: it propagated to their suppliers and customers, amplifying the disruption through Russia's production network. Nor did exposed firms compensate for lost foreign inputs by expanding domestic sourcing of bulk goods. Instead, export sanctions reduced exposed firms' domestic input flows and generated spillovers to connected firms.

8 Aggregate Economic Implications

The preceding sections show that export sanctions reduced imports of targeted products and disrupted production among exposed firms. We now use these estimates to provide back-of-the-envelope aggregate magnitudes. We do so in two complementary ways. On the trade side, we aggregate the product-level import effects to quantify the size of the sanctions-induced trade disruption, the extent to which rerouting through friendly countries cushioned it, and the implied welfare cost under a standard sufficient-statistic approach. On the firm side, we aggregate the firm-level estimates to quantify the decline in domestic economic activity among exposed firms.

Both exercises use the same counterfactual logic. For each treated observation, we use the regression estimates to recover an implied no-sanctions counterfactual and then sum the difference between that counterfactual and the realized outcome. These calculations are best interpreted as reduced-form aggregation exercises, not as a full quantitative general-equilibrium evaluation of sanctions' impact, which we view as beyond the scope of this paper. Our goal is instead to assess whether our micro-level effects documented above are economically meaningful in the aggregate.

8.1 Dollar Magnitudes and Welfare Loss

We first aggregate the product-level trade estimates from Section 5.3.[26] This exercise asks how large the cumulative import disruption was and how much of the direct sanctions-induced decline was offset by rerouting through friendly countries. The procedure, detailed in Online Appendix E, recovers a no-sanctions counterfactual path for Russian imports of sanctioned products, compares it to realized imports, and decomposes this aggregate gap into the direct decline and the offsetting increase through friendly countries. Our preferred aggregation combines the intensive-margin estimates with a conservative adjustment for product-quarters in which imports disappear altogether.

Panel A of Figure E.1 plots the resulting counterfactual. Over 2022–2023, the direct sanctions-induced decline in Russian imports of sanctioned products amounted to about $207.6 billion. This decline was partly offset by a $135.2 billion increase in imports through friendly countries, leaving a net shortfall of roughly $72.4 billion. *Rerouting through friendly countries therefore offsets roughly two-thirds of the direct trade disruption*. The country-product-level rerouting documented in Section 5.2 was thus quantitatively large, but it did not fully close the import gap.

As a benchmark, we also translate the net trade shortfall into a welfare-equivalent magnitude using the sufficient-statistic formula in Arkolakis et al. (2012). At a trade elasticity of 4, *the implied real-income loss is about 0.5 percent per year*. In a counterfactual without rerouting through friendly countries, the implied loss would rise to about 1.4 percent. These magnitudes are economically meaningful relative to standard gains-from-trade benchmarks: as shown in Online Appendix E, the full import-autarky benchmark is about 3.6 percent using our customs-based import share, and about 4.5 percent using the broader national-accounts goods-and-services import share. Thus, rerouting substantially attenuated the aggregate welfare cost of export sanctions, but the remaining loss is non-trivial.

8.2 Aggregate Firm Value Added

We next aggregate the firm-level estimates from Section 6.1. Rather than measuring missing imports, we now quantify the decline in domestic economic activity among firms exposed to

[26] With the product-level specification, we do not have to assume the same level of rerouting across different products, as would be the case with the trade-flow-level specification. Moreover, the extensive margin is much less important at the product level, and thus our aggregation depends less on the related assumptions.

export-sanctioned inputs. As detailed in Online Appendix E, we use the year-specific treatment effects from Equation (3) to recover a no-sanctions counterfactual for exposed firms and then sum the implied losses across the Russian firms in our sample. Panel B of Figure E.1 plots the realized and counterfactual aggregate value-added paths.

This exercise implies that export sanctions reduced aggregate firm value added by approximately 6.8 trillion rubles over the post-invasion period. This corresponds to about 2.8 percent of counterfactual aggregate firm value added in our data, or roughly 1.3 percent of cumulative Russian GDP over the same period. The annual loss reaches 2.5 trillion rubles by 2024. This firm-side aggregation is not directly additive with the trade-side welfare calculation above: the latter translates the import shortfall into a real-income loss, while the former aggregates value-added losses among exposed firms. Still, both exercises point to economically meaningful aggregate costs, despite relying on different data and aggregation strategies.

9 Conclusion

Trade sanctions have become a central instrument of economic statecraft, especially in settings where direct military confrontation is constrained by nuclear deterrence and escalation risks. Export sanctions are designed to operate as a form of economic warfare: by restricting access to critical foreign inputs, they seek to weaken the target country's industrial, technological, and military capacity. Whether they achieve this economic objective is not obvious. Targeted countries may reroute trade through third countries, substitute toward domestic or alternative foreign suppliers, subsidize affected firms, or rely on informal and unobserved supply channels. This paper studies whether the post-2022 export sanctions on Russia overcame these adjustment margins and generated meaningful disruptions inside the target economy.

We address this question using a unique combination of administrative data, including Russian customs records, firm-level financial statements, domestic railway shipments, and government procurement contracts. This allows us to trace the effects of export sanctions from cross-border trade flows to firm performance, domestic supply chains, and interactions with the Russian state.

We find large and persistent declines in sanctioned country-product trade flows after the invasion, only partially offset by rising imports of sanctioned products from friendly countries such as China and Turkey. A key advantage of the Russian customs data is that they report both the country of production and the country of shipment in each transaction, allowing us to separate substitution toward goods produced in friendly countries from rerouting of goods produced in sanctioning economies. Our analysis shows that rerouting was substantial, especially for goods originating in sanctioning economies. Yet it was incomplete: aggregating across products, we estimate a cumulative shortfall of roughly $72 billion in sanctioned-product imports over 2022–2023, with rerouting offset about two-thirds of the direct trade disruption.

The effects extend well beyond the customs data. Firms with prewar exposure to sanctioned imports experienced large and persistent declines in sales, costs, profits, value added, and input expenditures. These losses were not offset by non-exposed firms or new entrants within the same industries. The effects are especially pronounced in science and technology, but they are also present in manufacturing and among firms connected to defense procurement. Exposed firms also became less likely to win government procurement, even controlling for procurement contract competitors, suggesting that the Russian state had lost suppliers. Using domestic railway shipment data, we further show that exposed firms reduced domestic in-shipments and that the shock propagated to their suppliers and customers.

In conclusion, the results challenge the view that export sanctions on Russia were merely symbolic or easily circumvented. Rerouting and substitution substantially mitigated the shock, highlighting an important limitation of this policy tool. But the offset was far from complete. Export sanctions reduced access to targeted inputs, generated persistent production losses among exposed firms, weakened exposed firms' ability to supply the Russian state, reached strategically and militarily relevant firms, and propagated through domestic supply chains. In this sense, they produced economically meaningful disruptions consistent with the logic of economic warfare, even if they did not yield any immediate political concessions.

Several limitations are important to highlight. First, we study short- to medium-run effects; longer-run adaptation through technological upgrading, innovation, or deeper reorganization of supply chains remains an open question.[27] Second, our analysis is positive rather than normative:

[27] See Liu, Liu, Makarin, and Wen (2025) for evidence that export controls can spur R&D and innovation among exposed firms in the targeted country.

we document the economic effects of sanctions but do not assess their desirability or optimal design. Third, the external validity of our findings is likely context-dependent. The effectiveness of export sanctions elsewhere will depend on the target economy's import dependence, domestic substitution possibilities, state capacity, and the degree of international coordination. Finally, while we focus on export sanctions, studying the pass-through effects of import sanctions on Russian hydrocarbons and other products remains an important avenue for future work.

As export sanctions become an increasingly important tool of international conflict, understanding when and how they bind is essential. Our evidence shows that, even in a large economy with substantial rerouting opportunities, coordinated export sanctions can generate meaningful disruptions to firms and supply chains inside the target country.

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Online Appendix for "Export Sanctions: Rerouting, Disruption, and the Reach of Economic Warfare" **(not for publication)**

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Part I

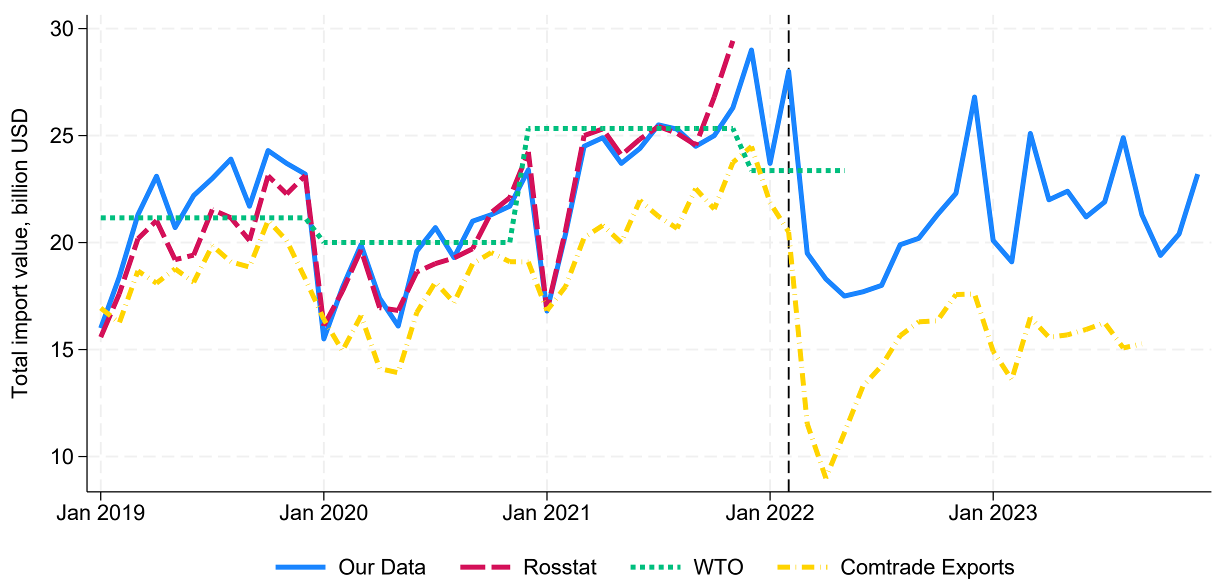
Table of Contents

A Data Coverage, Summary Statistics, and Additional Descriptive Evidence

This appendix provides additional data documentation and descriptive evidence supporting the stylized facts in Section 4. Section A.1 documents the coverage of the customs data and reports summary statistics for the import and firm-level samples. Section A.2 provides additional evidence on the breadth, concentration, and cross-country heterogeneity of export-sanction lists. Section A.3 reports aggregate import trends by sanctioning-country status, sanctioned-product status, and route type. Section A.4 presents two case studies—semiconductors and critical components—that illustrate the richness of the customs data and the limitations of relying on raw descriptive trends alone.

A.1 Data Coverage and Summary Statistics

Figure A.1: Aggregate Trends in Russia's Imports



Notes: This figure depicts the total value of goods imported by Russia from January 2019 to December 2023 (in USD), as specified by various data sources: (i) our transaction-level customs data, aggregated to the monthly level, with imports of physical cash excluded (blue, solid line); (ii) official data from the Russian Statistical Service (red, long-dashed); (iii) data from the WTO (green, short-dashed); and (iv) UN Comtrade mirror data, reported by other countries (yellow, dashed). The gray vertical line indicates the start of the war.

Table A.1: Summary Statistics: Russian Imports

	Observations	Mean	SD	Min	Max
Panel A: Country-Product-Quarter Imports					
Number of transactions	7,128,940	19	248	0	101,874
Total value, USD ’000	7,128,940	250	5,385	0	4,715,639
Total net weight, tons	7,128,940	70.8	4,588	0	5,477,937
Log total value	7,128,940	3.65	5.09	0	22
Log total weight	7,128,940	2.55	4	0	22
$\mathbb{1}$[Ever sanctioned]	7,128,940	0.28	0.45	0	1
$\mathbb{1}$[Sanctioned at t by c]	7,128,940	0.07	0.24	0	1
$\mathbb{1}$[Critical component]	7,128,940	0.09	0.29	0	1
Panel B: Product-Quarter Imports					
Number of transactions	287,644	470	3,232	0	282,139
Total value, USD ’000	287,644	6,200	50,233	0	4,873,493
Total net weight, tons	287,644	1,754	27,164	0	5,477,937
Unit value, USD ’000	227,052	146	22,177	0	7,218,129
Log total value	287,644	10.3	5.94	0	22
Log total weight	287,644	8.57	5.45	0	22
$\mathbb{1}$[Ever sanctioned]	287,644	0.60	0.49	0	1
$\mathbb{1}$[Critical component]	287,644	0.04	0.19	0	1

Notes: This table displays the summary statistics for Russian imports. Panel A depicts the summary statistics for country-product quarterly import flows from 2019Q1 through 2023Q4. Panel B depicts the summary statistics for product-level quarterly import flows from 2019Q1 through 2023Q4. Unit value is not defined for quarters with zero imports of a particular product. *Product* refers to ten-digit HS codes, unless they were aggregated due to changes in HS classification, following Pierce and Schott (2012).

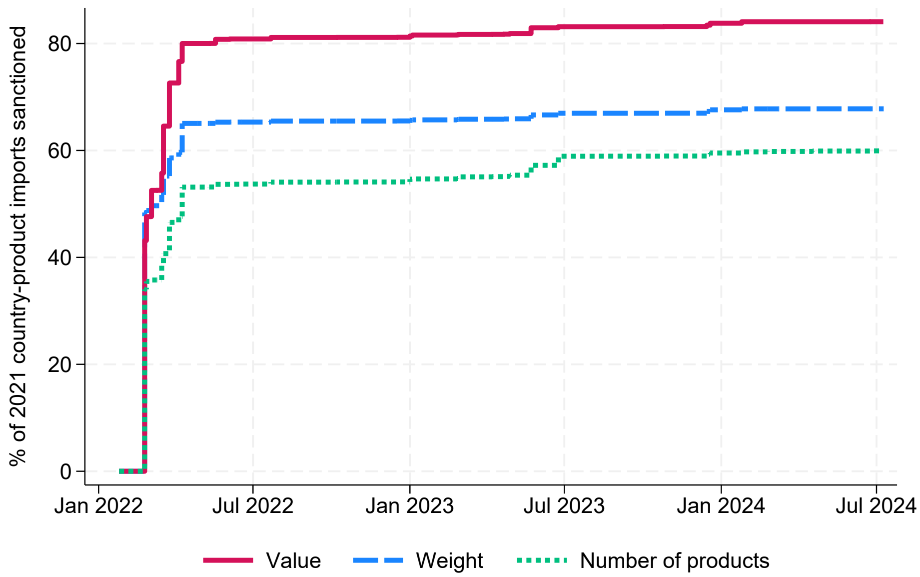
Table A.2: Summary Statistics: Russian Firms

	Observations	Mean	SD	Min	Max
Panel A: Accounting Outcomes					
Sales, Rub ’000 000	11,835,061	176	7,632	6.0e-06	7,979,027
Costs of Goods Sold, Rub ’000 000	11,401,304	147	5,858	0	4,815,225
Gross Profits , Rub ’000 000	11,401,304	34.3	3,288	-3,833,100	3,640,459
Capital, Rub ’000 000	7,786,921	90.6	13,438	-4,002	14,596,295
Material Costs, Rub ’000 000	2,776,397	449	10,909	0	4,820,694
Labor Costs, Rub ’000 000	2,736,950	40.6	1,058	-123,851	536,828
Log of Sales	11,835,061	16	2.31	1.8	30
Panel B: Measures of Exposure, Firm Characteristics					
𝟙[Firm Exposed to Export Sanctions]	2,186,013	0.024	0.154	0	1
Firm Exposure to Export Sanctions	2,186,013	0.013	0.104	0	1
𝟙[Firm Exposed to Financial Sanctions]	2,186,013	0.007	0.064	0	1
𝟙[Firm Exposed to Foreign Banks Exit]	2,186,013	0.0003	0.012	0	1
𝟙[Firm Exposed to Import Sanctions]	2,186,013	0.008	0.088	0	1
𝟙[Buyer Exposed to Export Sanctions]	2,186,013	0.003	0.057	0	1
𝟙[Supplier Exposed to Export Sanctions]	2,186,013	0.007	0.083	0	1
𝟙[Importer]	2,186,013	0.043	0.204	0	1
𝟙[Exporter]	2,186,013	0.022	0.148	0	1
𝟙[Firm Is Target-Sanctioned]	2,186,013	0.002	0.044	0	1
𝟙[Railway Trader]	2,186,013	0.010	0.100	0	1
𝟙[Industry=Manufacturing]	2,186,013	0.098	0.294	0	1
𝟙[Industry=Wholesale]	2,186,013	0.315	0.461	0	1
𝟙[Industry=Transportation]	2,186,013	0.060	0.235	0	1
𝟙[Industry=Science and Technology]	2,186,013	0.091	0.285	0	1
𝟙[Industry=Other]	2,186,013	0.436	0.492	0	1
Panel C: Railway Shipments					
In-Shipments Weight, Tons	146,292	57.4	745	0	56,932
Out-Shipments Weight, Tons	146,292	61.3	855	0	70,587
Total Shipments Weight, Tons	146,292	119	1,330	0	92,236
Num. of Suppliers	146,292	5.69	15.6	0	895
Num. of Buyers	146,292	5.83	33.8	0	1,890
Total Partners	146,292	8.09	43.3	0	2,363

Notes: This table presents summary statistics for Russian firms. Panel A provides summary statistics for firm-level yearly accounting outcomes spanning the years 2017 to 2023. Negative values for labor and capital costs reflect accounting reversals and are excluded from log specifications in the main analysis. Panel B reports various measures of firms’ exposure to export sanctions based on their prewar import flows and firm characteristics. Buyers and suppliers are identified using railway shipment data. Panel C summarizes firms’ yearly railway shipments from 2017 to 2023.

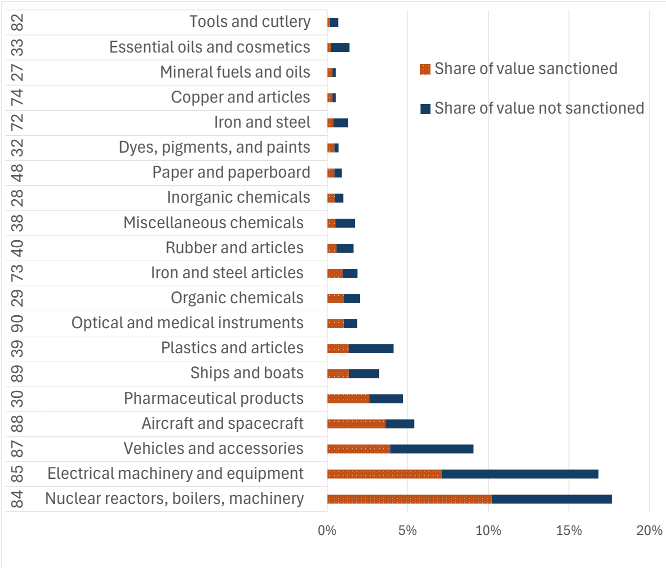
A.2 Stylized Facts on Sanctions Coverage

Figure A.2: Timing and Magnitude of Export Sanctions Imposed on Russia: Product-Level Imports

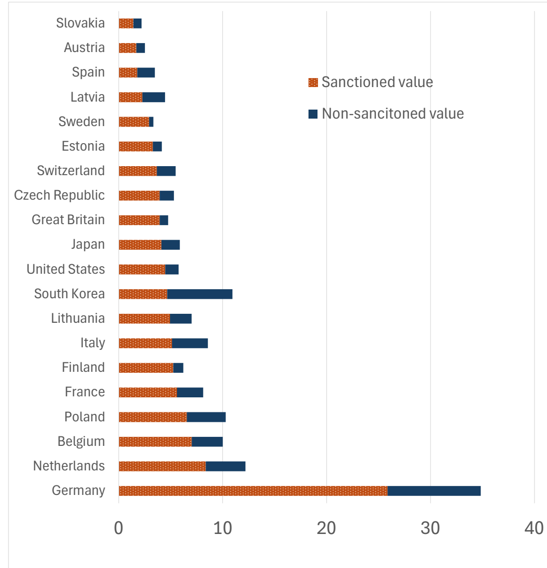


Notes: This figure displays the timing and volume of sanctions imposed on Russia's imports at the product level, measured based on their prewar levels. Specifically, for each date from February 2022 to July 2024, we compute the share of Russian product imports sanctioned by any country, assigning each product the earliest date at which it was sanctioned by any country. The shares are reported by value (in red), by weight (in blue, long-dashed), and by the number of sanctioned HS10 products (in green, short-dashed). For the country-product-level analogue, see Figure 1.

Figure A.3: Sanctioned Volume of Russian Imports: Top-20 Product Categories and Countries



(a) Most Sanctioned Products (% of 2021 Imports)



(b) Most Sanctioning Countries (in Bln USD)

Notes: Panel A displays the top-20 sanctioned 2-digit product categories. Each bar shows the share of a category in Russia's total 2021 imports by value, with the first segment (in orange) indicating the portion of the category that was sanctioned. Panel B displays the top-20 countries with the highest value of sanctioned exports to Russia. The total length of each bar represents the size of each country's 2021 exports to Russia (in billion USD), while the first segment (in orange) highlights the sanctioned portion of its export value.

Table A.3: Correlation of Sanctioned Product Lists Across Countries

	AU	CA	CH	EU	GB	JP	KR	TW	US
AU: Australia	1								
CA: Canada	0.4490	1							
CH: Switzerland	0.5453	0.3011	1						
EU: European Union	0.1214	0.1517	0.4934	1					
GB: Great Britain	0.1722	0.2072	0.5252	0.8855	1				
JP: Japan	0.3234	0.4139	0.2948	0.5025	0.4915	1			
KR: South Korea	0.2402	0.2607	0.2926	0.4584	0.4555	0.5318	1		
TW: Taiwan	0.1567	0.1791	0.1457	0.1613	0.1619	0.1973	0.3350	1	
US: United States	0.4189	0.4496	0.2787	0.5033	0.5248	0.7522	0.5633	0.1901	1

Notes: This table displays pairwise correlations between the sets of 10-digit HS product codes that contain products eventually sanctioned by different countries. Each correlation coefficient is calculated based on the correlation between two binary variables, where each variable indicates whether a specific 10-digit HS product code was sanctioned by a particular country or bloc. These variables are defined over the universe of 10-digit codes imported by Russia in 2021.

A.3 Descriptive Import Trends by Sanction Status and Route

This section presents additional descriptive evidence on the evolution of Russian imports after the invasion. These aggregate patterns complement the country-product-level variation documented in Section 4 and provide useful background on the main margins of adjustment.

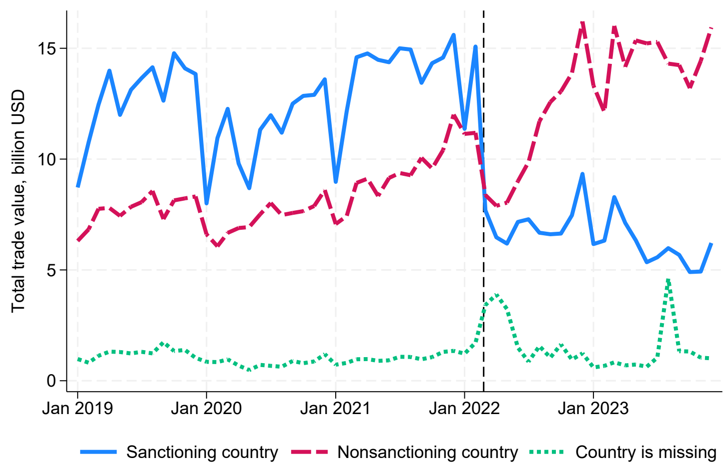
Figure A.4a shows the evolution of total Russian imports by whether the shipment came from a sanctioning or nonsanctioning country. Imports shipped from sanctioning countries fell sharply after the invasion, declining by roughly two-thirds in March 2022, from around $15 billion to just above $5 billion per month, and continued to decline gradually thereafter. Imports shipped from nonsanctioning countries also fell initially, from around $12 billion to $8 billion per month, consistent with heightened uncertainty and broader wartime disruption. Unlike imports from sanctioning countries, however, these flows rebounded quickly and eventually exceeded their prewar levels, reaching around $15 billion per month.

Figure A.4b instead groups imports by product status. Imports of products sanctioned by at least one country fell sharply after the invasion, from a prewar peak of around $24 billion to about $14 billion in March 2022. By 2023, these imports had partially recovered to around $18 billion, though they remained below their 2021 average. In contrast, imports of products that were never sanctioned remained comparatively stable over the period. These patterns suggest that an important part of Russia's adjustment occurred through changes in source countries, rather than solely through substitution away from sanctioned product categories.

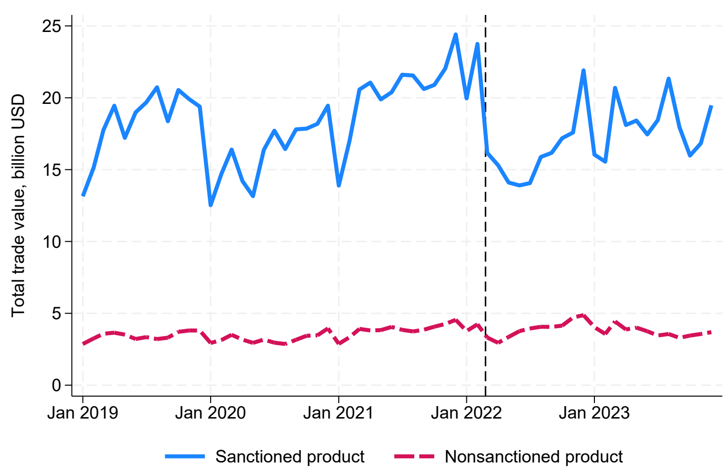
Figure A.5 further decomposes total Russian import value into five categories: sanctioned products shipped from sanctioning countries; nonsanctioned products shipped from sanctioning countries; sanctioned products shipped from nonsanctioning countries but produced elsewhere; sanctioned products shipped from and produced in nonsanctioning countries; and nonsanctioned products shipped from nonsanctioning countries. Following the invasion, shipments of sanctioned products from sanctioning countries fell sharply. By the end of 2022, this decline had been substantially offset by increased shipments of sanctioned products from nonsanctioning countries, both those originating elsewhere and those produced in the shipping country. These patterns point to both rerouting through third countries and substitution toward third-country production as important margins of aggregate adjustment.

These aggregate patterns are useful for characterizing the main margins along which Russian imports adjusted after the invasion: a sharp decline in flows from sanctioning countries and a partial recovery through nonsanctioning countries. Because these trends also reflect contemporaneous changes in demand, logistics, payments, exchange rates, and other wartime shocks, we interpret them only as descriptive evidence. The main analysis in Section 5 uses country-product-time variation in sanctions to estimate the causal effects of export sanctions on trade flows.

Figure A.4: Dynamics of the Total Value of Russian Imports (2019–2023), by Country and Product Sanction Status



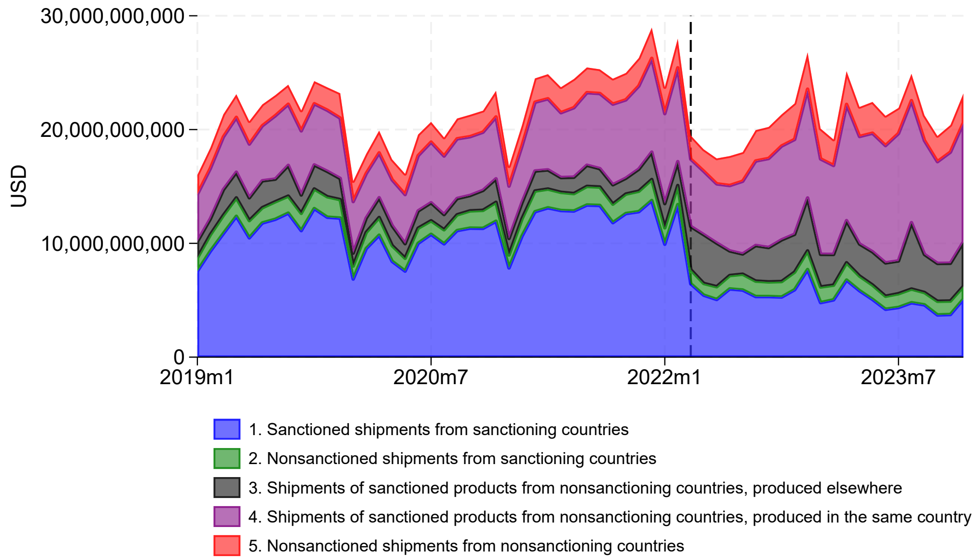
(a) Total Value of Imports: Sanctioning vs. Nonsanctioning Countries



(b) Total Value of Imports: Ever-Sanctioned vs. Never-Sanctioned Products

Notes: This figure displays the evolution of Russia's total import value from January 2019 to December 2023. The gray vertical line indicates the start of the war. In Panel A, the data are broken down by whether the exporting country imposed any sanctions or was missing from the data. In Panel B, the data are broken down by whether the product was sanctioned by any country for export to Russia.

Figure A.5: Total Import Flows by Type



Notes: This figure displays import value flows by their sanctioned status and categories of country of production and country of shipment from January 2019 to December 2023. The gray vertical line indicates the start of the war.

A.4 Case Studies: Semiconductors and Critical Components.

This appendix illustrates how our granular data allow us to track import flows of specific product categories along the various routes through which goods enter Russia, while highlighting the limitations of such descriptive trade patterns. We focus on two categories of particular relevance to wartime production: semiconductors and critical components.

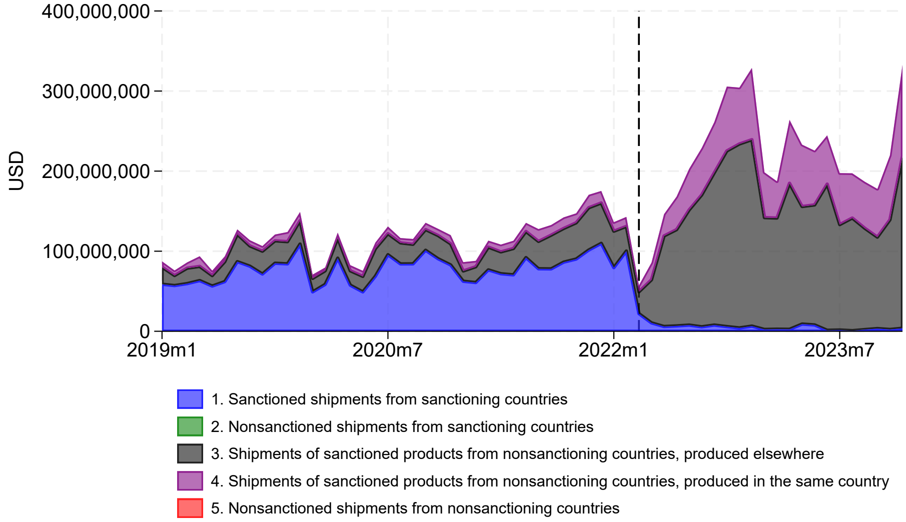
Figure A.6a examines import flows of semiconductors and related products (HS codes starting with 8541 and 8542), disaggregated by route type. Following the invasion, imports of sanctioned semiconductors from sanctioning countries (blue area) collapsed to nearly zero. In contrast, imports shipped from nonsanctioning countries surged, eventually pushing total semiconductor imports to roughly twice their 2021 level. For most of these flows, the country of production differed from the country of shipment (gray area), consistent with rerouting through third countries. A meaningful share, however, originated and was shipped from the same nonsanctioning country (purple area), indicating direct substitution in production.

Figure A.6b extends the analysis to a broader list of "critical components" directly used in weapons production.[1] Here too, imports from sanctioning countries fell sharply. But compared to semiconductors, rerouting and substitution patterns appear more modest. Imports of critical components produced and shipped from the same friendly country remained stable across the war period, while rerouted flows increased only gradually. However, despite the growth in these alternative supply routes, the total value of critical component imports remained somewhat lower than in 2021, in stark contrast to the trends observed for semiconductors.

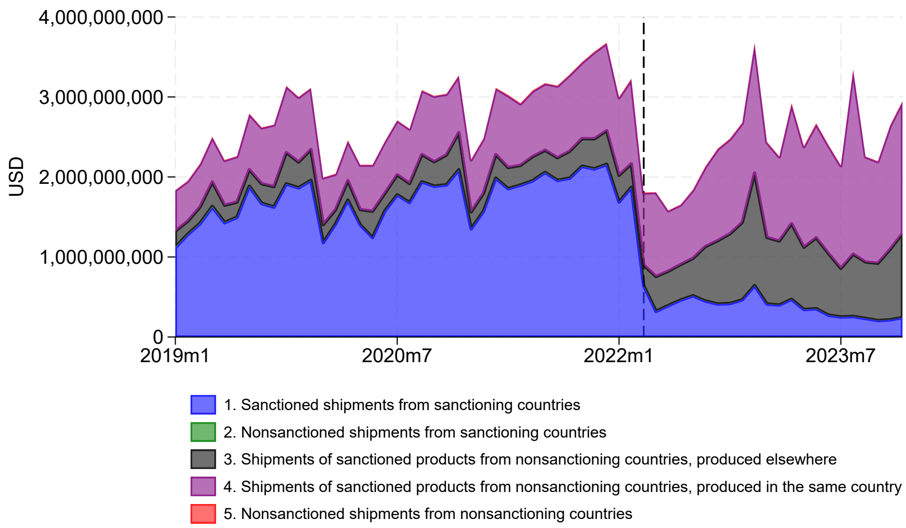
Together, these patterns highlight the granularity of our data and underscore two key points. First, Russia's access to high-tech and war-related imports in the post-sanctions period varied significantly across product categories, reflecting differences in demand, supply availability, and rerouting feasibility. Second, descriptive trends alone can be misleading, as they may confound the impact of export sanctions with changes in underlying demand—especially for goods with heightened wartime importance, such as semiconductors. Our econometric approach, presented in the main text, is thus key to separating these confounding factors and isolating the causal effects of export sanctions.

[1] The list is drawn from two lists, "Components in Weapons" and "Instruments of War," categorized in the Defence Intelligence of Ukraine (2026). These items were either recovered from the battlefield or identified by investigators as machinery used in weapons production. The associated product descriptions and models were then matched to the closest 6-digit HS codes manually and with the help of GPT-4o.

Figure A.6: Case Studies: Imports of Semiconductors and Critical Components, by Route Type



(a) Imports of Semiconductors



(b) Imports of Critical Components

Notes: This figure displays imported value flows of products by their sanctioned status and categories of country of production and country of shipment from January 2019 to December 2023. The gray vertical line indicates the start of the war. In Panel A, the sample is restricted to semiconductors or related products, identified by HS codes starting with 8541 and 8542. In Panel B, imports of critical-component categories are identified using the "Components in Weapons" and "Instruments of War" lists compiled by Defence Intelligence of Ukraine (2026). Component descriptions from these lists were matched to the closest HS6 headings, manually and with assistance from GPT-4o. The sample then comprises all HS10 products within the matched HS6 headings.

B Trade Effects: Additional Estimates and Robustness

This appendix provides additional trade estimates and robustness checks supporting Section 5. Section B.1 reports the nondynamic coefficients corresponding to the fully dynamic estimates in the main text. Section B.2 describes the staggered-DiD implementation and reports the corresponding event-study estimates. Section B.3 replicates the main trade results using import weight instead of import value. Section B.4 examines robustness to alternative definitions of friendly countries, treatment of countries with missing sanctions information, exclusion of early sanction cohorts, and alternative reference periods in the staggered design. Section B.5 replicates the product-level estimates using UN Comtrade mirror-export data. Section B.6 estimates within-firm import responses.

B.1 Main Table

Table B.1: The Impact on Russian Imports of Sanctioned Country-Product Varieties or Sanctioned Products, Extensive and Intensive Margins

	(1)	(2)	(3)	(4)	(5)	(6)
	Country-Product Level			Product Level		
	$\mathbb{1}$[Import>0]	Log Total Value (If Nonzero)	Log Total Weight (If Nonzero)	$\mathbb{1}$[Import>0]	Log Total Value (If Nonzero)	Log Total Weight (If Nonzero)
Post-War × Sanctioned Flow	-0.063***	-0.502***	-0.493***			
	(0.011)	(0.096)	(0.107)			
Post-War × Sanctioned Product × Friendly Country	0.061***	0.517***	0.473***			
	(0.016)	(0.108)	(0.108)			
Post-War × Sanctioned Product				-0.014**	-0.138***	-0.143***
				(0.006)	(0.031)	(0.037)
Product-Country FE	✓	✓	✓			
Product-Quarter FE	✓	✓	✓			
Country-Quarter FE	✓	✓	✓			
Product FE				✓	✓	✓
3-Digit Product-Quarter FE				✓	✓	✓
Mean Dep. Var.	0.36	9.89	6.73	0.78	13.11	10.85
SD Dep. Var.	0.48	3.01	3.95	0.41	2.93	3.66
Observations	5,076,220	1,767,378	1,765,701	205,400	160,168	160,120
Number of Countries	214	173	173	—	—	—
Number of Products	9,486	7,992	7,989	10,270	9,418	9,416

Notes: This table reports baseline nondynamic trade estimates. Columns (1)–(3) present country-product-level estimates from a nondynamic version of Equation (1). The coefficient on *Post-War* × *Sanctioned Flow* measures the change in directly sanctioned country-product imports, while the coefficient on *Post-War* × *Sanctioned Product* × *Friendly Country* measures the corresponding change in imports of sanctioned products from friendly countries. Columns (4)–(6) present product-level estimates from a nondynamic version of Equation (2). The coefficient on *Post-War* × *Sanctioned Product* measures the net effect of sanctions on total imports of sanctioned products, aggregating across shipment countries. Columns (1) and (4) report extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. Columns (2)–(3) and (5)–(6) report intensive-margin estimates from log specifications restricted to positive import flows. *Product* refers to ten-digit HS codes, unless they were aggregated due to changes in HS classification, following Pierce and Schott (2012). Standard errors, reported in parentheses, are two-way clustered at the country and product levels in columns (1)–(3) and at the product level in columns (4)–(6). * p<0.1, ** p<0.05, *** p<0.01.

B.2 Additional Staggered DiD Details and Estimates

The pre-post design in Equation (1) treats the invasion as the relevant break for sanctioned trade flows. This approach is transparent and well suited to our setting, since many export sanctions were imposed shortly after the war began. A remaining concern, however, is that some country-product or product-specific shocks may have also occurred around the invasion. We therefore complement the pre-post analysis with a staggered DiD design that exploits variation in the timing of sanction imposition. Rather than comparing all sanctioned flows before and after the invasion, the staggered design compares import flows around the month in which a given country-product pair, or product, becomes sanctioned to flows that are not yet sanctioned or never sanctioned at that point in time.

For example, holding shipment routes fixed, the invasion may have increased Russian demand for advanced chips shipped from Taiwan because of wartime military production. Such a shock would vary at the country-product level: product-time fixed effects would absorb aggregate changes in demand for the same ten-digit chip category, and country-time fixed effects would absorb aggregate shocks to imports shipped from Taiwan, but neither would absorb a differential wartime demand increase for chips shipped specifically from Taiwan. At the product level, the analogous concern is even simpler: wartime demand for advanced chips could increase imports of sanctioned chip categories after the invasion, biasing pre-post estimates toward zero. By using the actual month of sanction imposition, the staggered design helps separate these invasion-related shocks from the effect of export sanctions themselves.

Specifically, for the country-product analysis, we estimate the staggered design separately[1] for each treatment arm $a \in \{D, F\}$, where D denotes directly sanctioned flows and F denotes imports of sanctioned products from friendly countries:

$$y_{gct} = \sum_{e} \sum_{s \geq e} \beta^a_{es} \mathbb{1}\{E^a_{gc} = e\} \times \mathbb{1}\{t = s\} + \tau_{gc} + \eta_{gt} + \omega_{ct} + \zeta_{gct}. \tag{B1}$$

For the direct-sanctions arm, E^D_{gc} is the month when sanctions take effect on product g shipped from country c; for nonsanctioned country-product pairs, $E^D_{gc} = \infty$. For the friendly-country arm, E^F_{gc} is the month when product g is first sanctioned by any country for flows shipped from friendly countries; for products never sanctioned by any country, $E^F_{gc} = \infty$. When estimating a given arm, we exclude observations belonging to the other treated arm: sanctioned-product flows from friendly countries are excluded from the direct-sanctions regression, and directly sanctioned flows are excluded from the friendly-country regression. The comparison group in each regression therefore consists of not-yet-treated and never-treated flows for the corresponding treatment arm.

[1] We estimate the two arms separately for computational feasibility. Joint estimation yields nearly identical results.

For product-level specifications, we estimate:

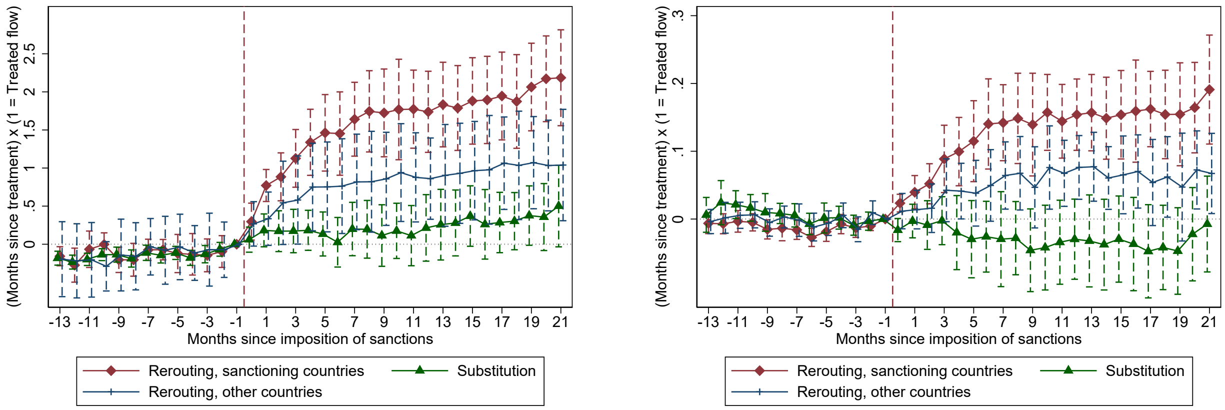
$$y_{gt} = \sum_{e} \sum_{s \geq e} \beta_{es} \mathbb{1}(E_g = e) \times \mathbb{1}\{t = s\} + \omega_{h(g)t} + \tau_g + \eta_t + \zeta_{gt} \tag{B2}$$

where E_g is the month in which product g is first sanctioned by any country; for never-sanctioned products, $E_g = \infty$. The remaining notation follows Equation (2), again with time indexed by month rather than quarter.

Recent work has shown that staggered DiD designs can be biased when treatment effects vary across units and over time (Arkhangelsky and Imbens, 2024). We therefore estimate Equations (B1) and (B2) using the ETWFE estimator of Wooldridge (2021), which accommodates heterogeneous treatment effects and is well suited for computationally intensive gravity-style applications (Rios-Avila et al., 2024). The event-study figures aggregate the estimated cohort-by-month effects by event time. To display pre-treatment coefficients, we estimate the analogous pretrend specifications separately, omitting all post-treatment observations of treated units from the estimation (*cf*. Borusyak, Jaravel, and Spiess, 2024).

We replicate all our baseline trade estimates from Section 5 using a staggered DiD design. Panels C and D of Figure 2 report the staggered-DiD counterparts to the pre-post estimates in Panels A and B. Figures B.1 and B.2 present the corresponding staggered-DiD analogues of the rerouting decomposition and product-level estimates in Figures 3 and 4, respectively. The estimates remain qualitatively and quantitatively similar, suggesting that the baseline trade results are not driven by treating the invasion as a common treatment date or by country-product- and product-specific shocks coinciding with the onset of the war.

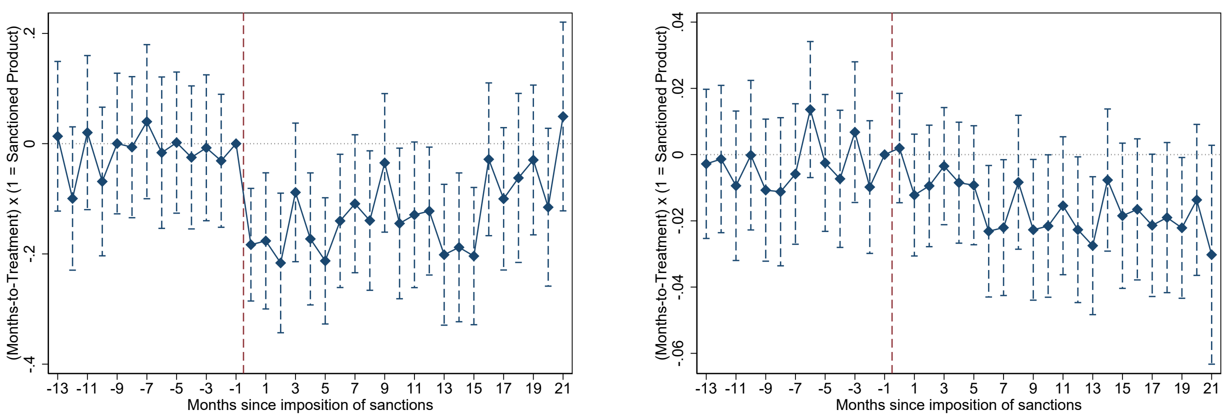
Figure B.1: Decomposing Rerouting and Substitution via Friendly Countries: Staggered DiD



(a) Intensive Margin (b) Extensive Margin

Notes: This figure presents the staggered DiD analogue of Figure 3. We separate each import flow of the sanctioned products shipped from friendly countries into three flows: those produced within the same friendly country (*in green*), those produced in sanctioning countries (*in red*), and those produced elsewhere (*in blue*). The data use monthly frequency, and the estimates are aggregated across cohorts by event time. The red vertical line marks the first sanction imposition on a given product. The bars represent 95% confidence intervals. Standard errors are clustered two-way by country and product.

Figure B.2: The Impact of Export Sanctions on Russian Imports of Sanctioned Products: Staggered DiD



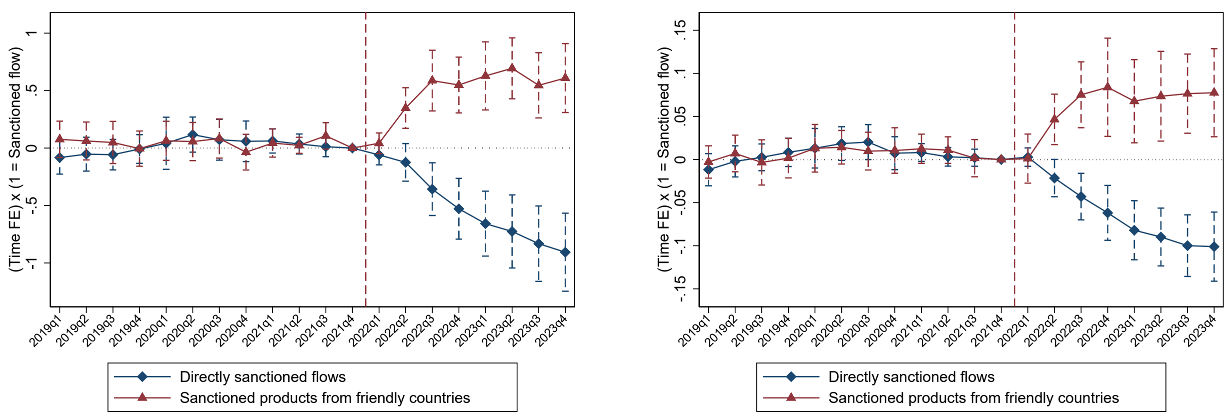
(a) Intensive Margin (b) Extensive Margin

Notes: This figure reports dynamic staggered DiD estimates from Equation (B2), comparing the import value for sanctioned products to that of nonsanctioned products before and after the imposition of first sanctions on the former. Panel A presents the intensive-margin estimates; Panel B presents the extensive-margin estimates. The data use monthly frequency, and the estimates are aggregated across cohorts by event time. Regressions include HS3-product-time fixed effects. The red vertical line marks the first sanction imposition on a given product. The bars represent 95% confidence intervals. Standard errors are clustered at the product level.

B.3 Weight Analogues of Main Results

We replicate all estimates in Section 5 using import weight as the outcome instead of import value. Figures B.3–B.5 present the corresponding weight-based analogs for the value-based results in Figures 2–4. The estimates remain qualitatively and quantitatively similar, indicating that the main trade results are not driven solely by changes in prices or unit values.

Figure B.3: Direct Effects of Export Sanctions and Adjustment Through Friendly Countries, in Weight

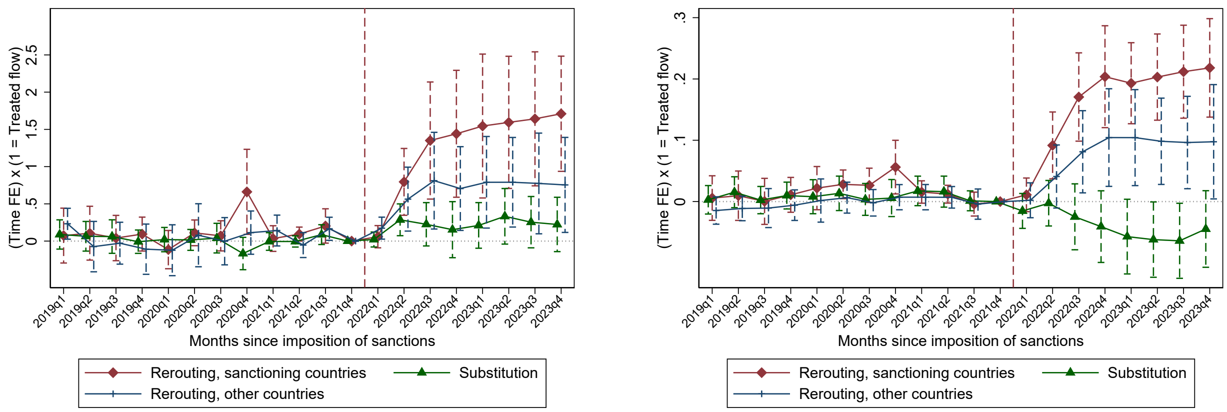


(a) Intensive Margin: Pre-Post DiD

(b) Extensive Margin: Pre-Post DiD

Notes: This figure reports the weight-based analogues of Panels A and B of Figure 2. *Friendly* countries are Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE; *Enemy* countries include all nations that ever imposed trade sanctions on Russia. Panel A reports intensive-margin estimates from a log specification restricted to country-product-quarters with positive imports; Panel B reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The data are quarterly with 2021Q4 as the omitted period. The red vertical line marks the start of the war. The short-dashed lines plotted on a secondary axis represent the total volume of prewar trade with friendly and sanctioning countries. Bars represent 95% confidence intervals. Standard errors are two-way clustered by country and product. Sample: 5,076,220 observations across 9,486 products and 214 countries.

Figure B.4: Decomposing Substitution and Rerouting via Friendly Countries, in Weight

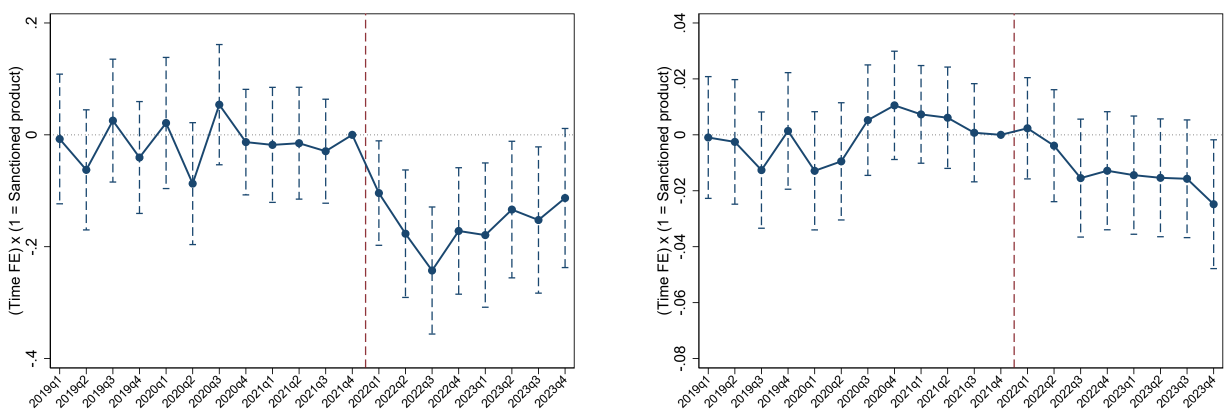


(a) Intensive Margin

(b) Extensive Margin

Notes: This figure reports the weight-based analog of Figure 3. We separate each import flow of the sanctioned products shipped from friendly countries into three flows: those produced within the same friendly country (*in green*), those produced in sanctioning countries (*in red*), and those produced elsewhere (*in blue*). The impact of export sanctions is then estimated on each of these flow's weight, with the nonsanctioned imports from third countries serving as a control group. Directly sanctioned flows from sanctioning countries are excluded from the estimation sample. *Friendly countries* are defined as Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE. Panel A reports intensive-margin estimates from a log specification restricted to country-product-quarters with positive imports; Panel B reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The data use quarterly frequency, with 2021Q4 as the omitted period. The red vertical line marks the start of the war. The bars represent 95% confidence intervals. Standard errors are clustered two-way by country and product. Total observations: 3,669,220 across 8,770 products and 205 countries.

Figure B.5: The Impact of Export Sanctions on Russian Imports of Sanctioned Products, in Weight



(a) Intensive Margin: Pre-Post DiD

(b) Extensive Margin: Pre-Post DiD

Notes: This figure reports the weight-based analogue of Figure 4, estimated via the pre-post DiD in Equation (2). Panel A reports intensive-margin estimates from a log specification restricted to product-quarters with positive imports; Panel B reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The data are quarterly with 2021Q4 as the omitted period; regressions include HS3-product-time fixed effects. The red vertical line marks the start of the war. Bars represent 95% confidence intervals. Standard errors are clustered at the product level. Sample: 205,400 product-quarter observations across 10,270 products.

B.4 Specification Robustness

This appendix reports additional robustness checks for the trade estimates in Section 5. We consider three main concerns: possible issues with the definition of friendly countries used to measure adjustment through potential rerouting hubs; unavailable sanctions information for a small set of countries; and implementation choices in the staggered-DiD design, including the role of the first sanction cohort and possible anticipation of later sanctions. Across these exercises, the estimates remain close to the baseline results.

We first examine whether our definition of countries friendly to the Russian regime is too narrow, potentially excluding countries that became important sources of sanctioned products after the war began. To address this concern, we repeat the country-product analysis in Section 5.1 after expanding the set of friendly countries to include all BRICS members. Specifically, we add Brazil, Egypt, Ethiopia, India, Indonesia, Iran, and South Africa to the baseline list. Figure B.6 reports the results using this expanded classification. The estimates remain similar in magnitude to the baseline, indicating that our results are not driven by the particular definition of friendly countries.

Second, we examine whether unavailable sanctions data for a small set of countries affects our estimates. Table B.2 reports four exercises. Columns (1)–(2) exclude all imports from Ukraine. Columns (3)–(4) classify Norway as a sanctioning country applying EU-equivalent measures. Columns (5)–(6) exclude imports of sanctioned products from countries that Russia officially designates as "unfriendly" but for which we do not have official sanctions data. Columns (7)–(8) exclude all imports from these countries entirely.[2] Consistent with the small prewar import shares of these countries, the estimates are largely unchanged across all specifications compared to baseline estimates in columns (1)–(2) of Table B.1.

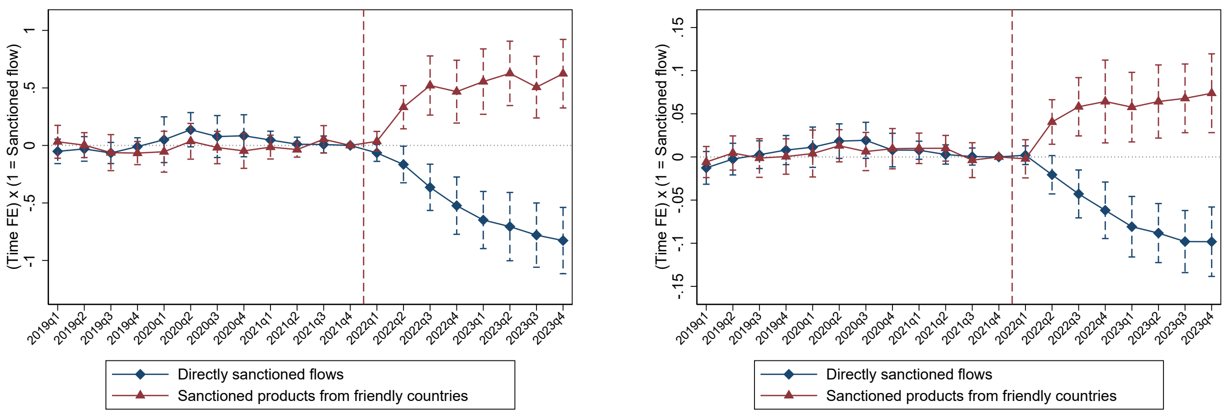
Third, we examine whether our country-product staggered DiD results are driven primarily by the first cohort of sanctioned varieties, which coincided with the outbreak of the war. If so, this would limit the ability of the staggered design to address concerns about war-related confounding shocks. However, as shown in columns (3)–(4) of Table B.3, excluding the first cohort leaves our estimates largely unchanged—and if anything, the magnitude of the direct effect increases.

Fourth, we address possible violations of the no-anticipation assumption in the country-product staggered design. While Figure 2 documents flat pretrends prior to the war—supporting this as-

[2] Sanctions data are unavailable for the following countries that Russia officially considers *unfriendly* (Government of the Russian Federation, 2022): Albania, Andorra, Anguilla, Bahamas, Bermuda, British Indian Ocean Territory, British Virgin Islands, Cayman Islands, Falkland Islands, Gibraltar, Guernsey, Iceland, Isle of Man, Jersey, Liechtenstein, Monaco, Montenegro, New Zealand, North Macedonia, Norway, Pitcairn Islands, San Marino, Singapore, Turks and Caicos Islands, and the U.S. Virgin Islands. Before the war, these countries accounted for only 0.78% of Russian total imports and 0.75% of imports of ever-sanctioned products, both measured by value. We treat Ukraine separately, since Russia-Ukraine trade was nearly eliminated after the 2022 invasion irrespective of product type.

sumption for early sanctions—subsequent cohorts and sanction waves may have been at least partially anticipated. To correct for this, we augment Equation (B1), where for each treated flow we add additional cohort-specific coefficients for each period after February 2022 and before the month when sanctions take effect.[3] This ensures that the omitted category consists only of prewar months (and specifically excludes months where sanctions could have been anticipated) for all treated flows. Columns (5)–(6) of Table B.3 show that the results are robust to this alternative normalization. Thus, allowing for post-invasion anticipation before the formal sanction date does not materially affect either the estimated direct decline in sanctioned flows or the offsetting increase through friendly countries.

Figure B.6: Robustness: Including BRICS in the List of Friendly Countries



(a) Intensive Margin

(b) Extensive Margin

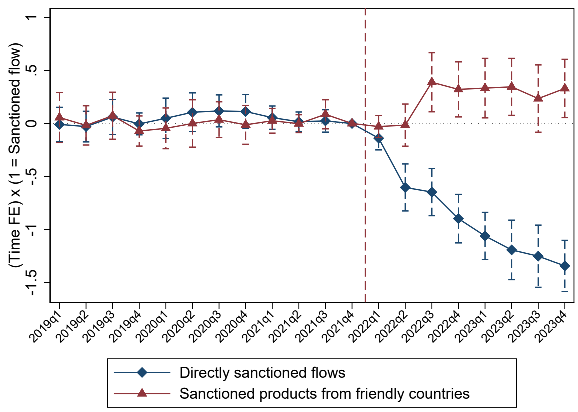
Notes: This figure assesses the robustness of our direct-effect and friendly-country adjustment estimates to expanding the list of friendly countries to include all BRICS members: Brazil, Egypt, Ethiopia, India, Indonesia, Iran, and South Africa. The baseline friendly-country list already includes Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE. Both panels use pre-post DiD estimates of Equation (1), quarterly data with 2021Q4 as the omitted period. Panel A reports intensive-margin estimates from a log specification restricted to country-product-quarters with positive imports; Panel B reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The red vertical line marks the start of the war. The short-dashed lines plotted on a secondary axis represent the total prewar trade volumes for each treated group. Bars represent 95% confidence intervals. Standard errors are two-way clustered by country and product. Total observations: 5,076,220 across 9,486 products and 214 countries.

[3] Specifically, we estimate

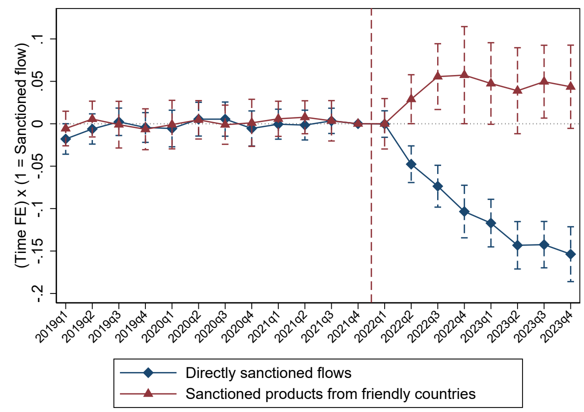
$$y_{gct} = \sum_{e} \sum_{t^* < s < e} \alpha_{es} \mathbb{1}(E_{gc} = e) \times \mathbb{1}\{t = s\} + \sum_{e} \sum_{s \geq e} \beta_{es} \mathbb{1}(E_{gc} = e) \times \mathbb{1}\{t = s\} + \tau_{gc} + \eta_{gt} + \omega_{ct} + \zeta_{gct} \quad \text{(B3)}$$

where t^* denotes February 2022 and $\{\alpha_{es}\}$ is the set of additional coefficients.

Figure B.7: Robustness: Accounting for Imports from Sanctioning Countries that Did Not Explicitly Sanction Them



(a) Intensive Margin



(b) Extensive Margin

Notes: This figure presents a robustness check that excludes imports of sanctioned products from sanctioning countries that did not sanction the corresponding product, using a corresponding version of Equation (1). *Friendly* countries are Armenia, Belarus, China, Georgia, Hong Kong, Kazakhstan, Kyrgyzstan, Serbia, Turkey, and the UAE. Panel A reports intensive-margin estimates from a log specification restricted to country-product-quarters with positive imports; Panel B reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The data are quarterly with 2021Q4 as the omitted period. The red vertical line marks the start of the war. The short-dashed lines plotted on a secondary axis represent the total prewar trade volumes for each treated group. Bars represent 95% confidence intervals. Standard errors are two-way clustered by country and product. Total observations: 5,076,220 across 9,486 products and 214 countries.

Table B.2: Alternative Specifications for the Impact of Export Sanctions on Russian Imports of Sanctioned Country-Product Varieties

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log Total Value (If Nonzero)	𝟙[Import>0]	Log Total Value (If Nonzero)	𝟙[Import>0]	Log Total Value (If Nonzero)	𝟙[Import>0]	Log Total Value (If Nonzero)	𝟙[Import>0]
Post-War × Sanctioned Flow	-0.503***	-0.064***	-0.501***	-0.062***	-0.509***	-0.064***	-0.510***	-0.064***
	(0.098)	(0.012)	(0.097)	(0.011)	(0.099)	(0.012)	(0.099)	(0.012)
Post-War × Sanctioned Product × × Friendly Country	0.516***	0.060***	0.517***	0.061***	0.512***	0.061***	0.512***	0.060***
	(0.109)	(0.016)	(0.108)	(0.016)	(0.109)	(0.016)	(0.109)	(0.017)
Product-Country FE	✓	✓	✓	✓	✓	✓	✓	✓
Product-Quarter FE	✓	✓	✓	✓	✓	✓	✓	✓
Country-Quarter FE	✓	✓	✓	✓	✓	✓	✓	✓
Mean Dep. Var.	9.88	0.36	9.89	0.36	9.90	0.37	9.91	0.37
SD Dep. Var.	3.02	0.48	3.02	0.48	3.01	0.48	3.01	0.48
Observations	1,743,485	4,991,360	1,767,553	5,076,220	1,744,591	4,948,020	1,739,344	4,916,360
Number of Countries	172	213	173	214	168	211	157	190
Number of Products	7,966	9,473	7,992	9,486	7,988	9,486	7,972	9,469
Robustness Check	Exclude Ukraine		Impute Norway		Exclude 'unfriendly', sanctioned products		Exclude 'unfriendly', all imports	

Notes: This table examines the robustness of the estimates for export sanctions' impact on sanctioned country-product imports to addressing the issues with completeness of our sanctions database. Columns (1)–(2) reproduce the baseline excluding all imports from Ukraine across all years. Columns (3)–(4) instead code Norway as a sanctioning country applying EU-equivalent measures. Columns (5)–(6) exclude flows of sanctioned products (sanctioned by any of the countries for which sanctions data are available) from countries that Russia officially designated *unfriendly* but for which data on export sanctions are missing. Columns (7)–(8) exclude all imports from *unfriendly* countries lacking sanctions data. Separate data on export sanctions are unavailable for the following *unfriendly* countries: Albania, Andorra, Anguilla, Bahamas, Bermuda, British Indian Ocean Territory, British Virgin Islands, Cayman Islands, Falkland Islands, Gibraltar, Guernsey, Iceland, Isle of Man, Jersey, Liechtenstein, Monaco, Montenegro, New Zealand, North Macedonia, Norway, Pitcairn Islands, San Marino, Singapore, Turks and Caicos Islands, and the U.S. Virgin Islands. Note that before the war, these countries accounted for only 0.78% of Russian total imports and 0.75% of imports of ever-sanctioned products (both in value). The odd-numbered columns report intensive-margin estimates from a log specification restricted to country-product-quarters with positive imports; the even-numbered columns report extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. The time span is from 2019Q1 through 2023Q4. *Product* refers to ten-digit HS codes, unless they were aggregated due to changes in HS classification, following Pierce and Schott (2012). Standard errors in parentheses are two-way clustered at the country and product levels. * p<0.1, ** p<0.05, *** p<0.01.

Table B.3: The Impact on Russian Imports of Sanctioned Country-Product Varieties or Sanctioned Products, Staggered Design

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log Total Value (If Nonzero)	𝟙[Import>0]	Log Total Value (If Nonzero)	𝟙[Import>0]	Log Total Value (If Nonzero)	𝟙[Import>0]	Log Total Value (If Nonzero)	𝟙[Import>0]
Post-Treatment × Treated Flow	-0.488***	-0.073***	-0.735***	-0.086***	-0.520***	-0.079***	-0.128***	-0.016**
	(0.118)	(0.012)	(0.078)	(0.009)	(0.113)	(0.013)	(0.037)	(0.007)
Post-Treatment × Sanctioned Product ×	0.533***	0.055***	0.286***	0.039***	0.552***	0.063***		
× Friendly Country	(0.119)	(0.016)	(0.096)	(0.012)	(0.124)	(0.017)		
Product-Country FE	✓	✓	✓	✓	✓	✓		
Product-Month FE	✓	✓	✓	✓	✓	✓		
Country-Month FE	✓	✓	✓	✓	✓	✓		
No First Cohort			✓	✓				
Anticipation Allowed					✓	✓		
Product FE							✓	✓
3-Digit Product-Month FE							✓	✓
Observations	2,901,762	10,145,904	2,039,993	7,570,032	2,055,480	7,609,428	345,533	465,744
Number of Products	7,574	8,934	6,645	8,421	7,255	8,934	9,274	9,703
Number of Countries	165	197	164	197	151	197	—	—

Notes: This table examines the effect of sanctions on imports of sanctioned country-product varieties (columns 1–6), as well as the effect of sanctions on the imports of sanctioned products from any country (columns 7 and 8). Specifically, the first two columns present the estimates of Equation (B1), and the last two columns present the estimates of the corresponding product-level equation. Columns (3) and (4) estimate Equation (B1) without the first cohort, and columns (5) and (6) estimate the more conservative Equation (B3), where sanctions are allowed to be anticipated after February 2022. All estimates are aggregated across cohorts and months into a single nondynamic average coefficient. For the last two columns, the first date of imposed sanctions is used as the treatment date for a product. The odd-numbered columns report intensive-margin estimates from a log specification restricted to cells with positive imports; the even-numbered columns report extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. *Product* refers to ten-digit HS codes, unless they were aggregated due to changes in HS classification, following Pierce and Schott (2012). Standard errors in parentheses are two-way clustered at the country and product levels. * p<0.1, ** p<0.05, *** p<0.01.

B.5 Replicating Main Results Using UN Comtrade Data

Our baseline trade estimates in Section 5 rely on Russian customs data. These data have several advantages: they are available at the ten-digit product level, report both country of shipment and country of production, identify importing firms, and include shipment weight as well as shipment value. A potential limitation is that the customs data do not fully cover trade flows with some members of the Eurasian Economic Union (EAEU), including Belarus and Kazakhstan. Since these countries are important potential rerouting hubs, this omission could bias our estimates if the missing flows account for a substantial share of Russia's adjustment to export sanctions.

To address this concern, we replicate the main trade estimates using UN Comtrade mirror-export data. Russia stopped reporting to UN Comtrade after the invasion, so we use exports to Russia reported by partner countries, including the EAEU members. The cost is lower granularity: the data are available only at the HS6 level, and reporting of shipment weights is too sparse and inconsistent for a reliable weight-based analysis. Similar to the main analysis, we construct synthetic HS6 product codes following Pierce and Schott (2012) to account for the 2022 HS classification changes, and classify a synthetic HS6 product as sanctioned if any of its constituent HS10 codes is sanctioned by any country. We then reestimate the baseline country-product and product-level specifications using mirror-export values.[4]

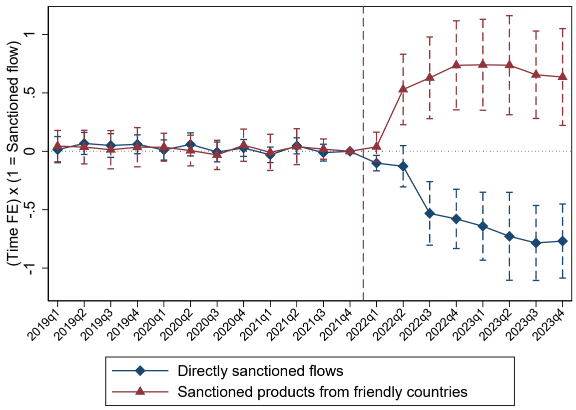
Figure B.8 presents the results. Panels A and B replicate the country-product estimates from Panels A and B of Figure 2: directly sanctioned flows fall sharply after the invasion, while imports of sanctioned products from friendly countries rise. By the end of 2023, the intensive-margin estimate for directly sanctioned flows is close to -0.9 log points, implying a decline of roughly 55–60%, and the extensive-margin estimate falls by about 8–10 percentage points. The compensating increase through friendly countries also has magnitudes comparable to the baseline results.

Panels C and D show that the product-level estimates remain negative in the UN Comtrade data, indicating that total imports of sanctioned products declined even in partner-reported mirror-export data that include EAEU flows. The intensive-margin product-level estimates are around -0.15 to -0.25 log points during much of 2023, corresponding to declines of roughly 14–22%, while the extensive-margin effects are smaller but also negative.

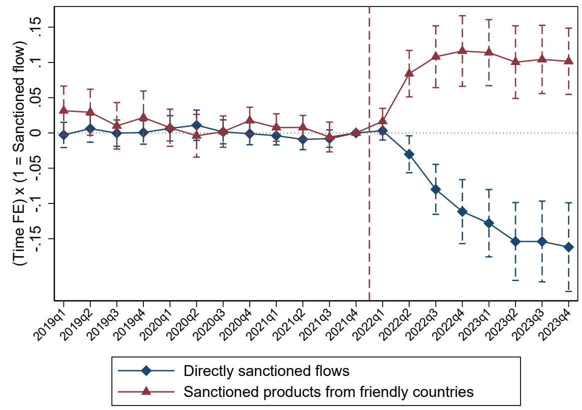
Overall, these results show that the main trade findings are not driven by the incomplete coverage of EAEU flows in the Russian customs data. Further, because UN Comtrade is available only at the HS6 level, they also alleviate concerns that the baseline estimates are driven by relabeling or substitution across nearby ten-digit product codes within the same HS6 category.

[4] Given the higher level of aggregation in the UN Comtrade data, the product-level specification includes HS1-by-quarter, rather than HS3-by-quarter, fixed effects.

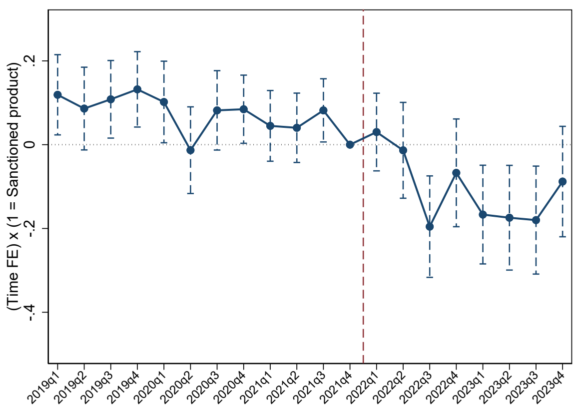
Figure B.8: The Impact of Export Sanctions on Russian Imports, UN Comtrade



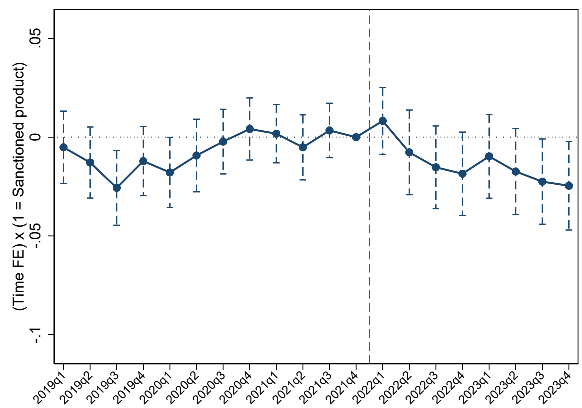
(a) Country-Product: Intensive Margin



(b) Country-Product: Extensive Margin



(c) Product-Level: Intensive Margin



(d) Product-Level: Extensive Margin

Notes: This figure replicates the main trade estimates using mirror-export data from UN Comtrade instead of Russian customs data. Panels A–B report country-product-level dynamic DiD estimates from Equation (1): the blue series reports directly sanctioned flows, while the red series reports imports of sanctioned products from friendly countries. Panels C–D report product-level dynamic DiD estimates from Equation (2), with HS1-quarter fixed effects. *Product* refers to six-digit HS codes, except when codes are aggregated because of changes in HS classification, following Pierce and Schott (2012). The data are quarterly, with 2021Q4 as the omitted period. The red vertical line marks the start of the war. The outcome is import value. Within each row, the left panel reports intensive-margin estimates from log specifications restricted to positive import flows; the right panel reports extensive-margin estimates from linear probability models for whether the corresponding import flow is positive. Bars represent 95% confidence intervals. Standard errors are two-way clustered by country and product in Panels A–B (2,973,780 observations; 5,286 products; 139 countries) and clustered by product in Panels C–D (108,920 observations; 5,446 products).

B.6 Impact on Firm-Level Imports of Sanctioned Products

Before estimating the pass-through of export sanctions onto Russian firms, one may want to assess whether these sanctions negatively affected *firm-level* imports. This exercise serves two key purposes. First, it establishes a firm-level first stage, crucial for interpreting the firm-level regressions. Second, it provides an additional robustness check by incorporating firm-time fixed effects, thereby addressing concerns that export sanctions may have coincided with other industry-specific shocks affecting firms that import certain types of products.

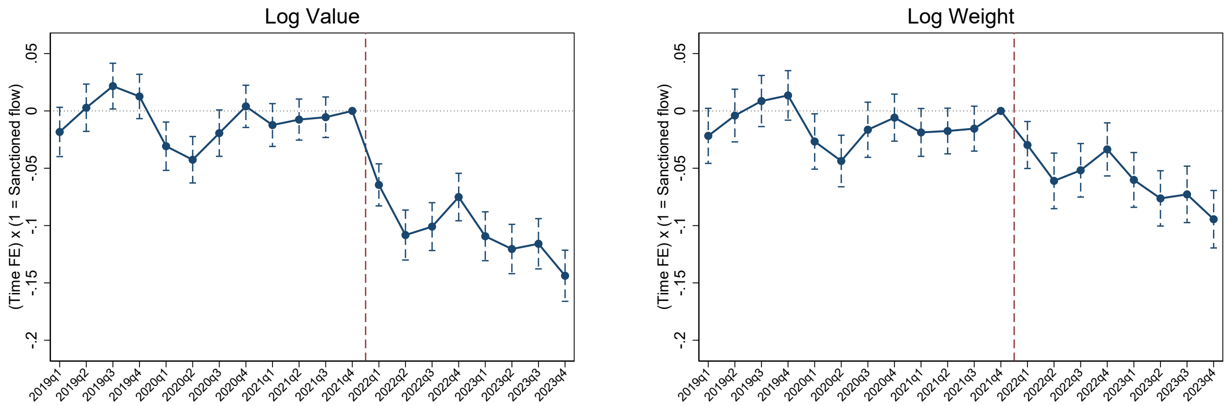
We estimate the impact of export sanctions on firms' imports via the following DiD equation:

$$y_{fgt} = \sum_{s \neq \text{2021Q4}} \theta_s \, ImportedSanctioned_{fg(c)} \times \mathbb{1}\{t = s\} + \tau_{fg} + \eta_{gt} + \omega_{ft} + \zeta_{fgt} \tag{B4}$$

where y_{fgt} represents the log of total imports of product g by a Russian firm f in quarter t, measured either by total value or by total weight shipped, defined on the intensive margin only for computational reasons; $ImportedSanctioned_{fg(c)}$ is an indicator that equals 1 if, before the war, a firm f imported product g from a country c that later imposed sanctions on its exports of that product to Russia. The specification includes firm-product fixed effects (τ_{fg}), product-quarter fixed effects (η_{gt}), and firm-quarter fixed effects (ω_{ft}), with the latter accounting for any firm-level shocks that may influence its imports independent of the product type. The standard errors are clustered at the product-firm level.

Figure B.9 presents the results. After the invasion, firms reduced imports of products that they had previously sourced, at least in part, from country-product varieties that later became sanctioned. These exposed firm-product imports declined by roughly 10%–15% in value and 5%–10% in weight relative to other firm-product import flows. The results provide a firm-product-level counterpart to the aggregate trade estimates: exposed firms did not fully offset the increased difficulty of importing sanctioned products by switching to alternative suppliers or routes.

Figure B.9: The Impact on Russian Firm-Level Imports of Sanctioned Products



(a) Value

(b) Weight

Notes: This figure assesses the impact of sanctions on the imports of exposed products for each specific firm. Specifically, it displays the estimates comparing the import volume for exposed firm-products to that of nonexposed firm-products before and after the first quarter of 2022. Exposed firm-products are those later-sanctioned ten-digit HS codes that a firm imported from a sanctioning country at least once prior to 2022. An HS code that was always imported from a nonsanctioning country is not exposed. This specification controls for any firm-level shocks that take place at the same time as the sanctions; it also controls for product-by-time fixed effects. The data are at the quarterly level. The red vertical line indicates the start of the war. Panel A (B) uses the log of total import value (net weight) of a given product in a given quarter as the outcome. The firm-product panel excludes structural zeros by construction, so the outcome is log imports, defined on the intensive margin only. The bars represent 95% confidence intervals. Standard errors are clustered at the product-by-firm level. Total observations: 10,489,566; firms: 69,185; products: 7,917.

C Firm-Level Effects: Additional Results and Robustness

This appendix provides additional evidence supporting the firm-level analysis in Section 6. Section C.1 shows that the estimated decline in output among firms exposed to export sanctions is robust to alternative sample definitions that address concerns about entry, exit, and changes in reporting behavior. Section C.2 aggregates the analysis to the five-digit industry level, providing evidence that the losses of exposed firms were not offset by gains among other firms within the same industries. Section C.3 shows that the negative effects extend also to firms with direct or indirect links to the defense sector. Section C.4 reports additional heterogeneity by firm and strategic characteristics.

C.1 Robustness to Sample Composition Changes

We probe the robustness of our baseline firm-level estimates to alternative sample definitions. This exercise addresses the concern that the estimated effects may partly reflect changes in sample composition, including firms' entry into and exit from the data. Columns (1)–(2) of Table C.1 present the baseline specification. Columns (3)–(4) restrict the sample to a balanced panel of firms with nonmissing revenue data in every year from 2017 to 2024. Columns (5)–(6) exclude firms that entered the dataset only after the war began, while columns (7)–(8) exclude firms that do not survive into the war period, i.e., have no observations after 2021. Across all sample definitions, we continue to find a large and statistically significant negative effect of export-sanctions exposure on firm revenue and total cost of goods sold. The coefficient estimates range from -0.103 to -0.134, corresponding to a 9.8–12.5% decline in firm output, depending on the outcome and subsample considered.

C.2 Industry-Level Aggregation

We next aggregate the analysis to the five-digit industry level to assess whether losses among exposed firms were offset by gains among other firms in the same narrowly defined industries. If such reallocation were substantial, we would expect the firm-level effects to be attenuated in aggregate industry outcomes, or to be accompanied by increases in entry in more exposed industries.

We collapse the firm panel to the five-digit OKVED industry-by-year level, yielding an annual panel of 2,551 industries from 2017 through 2024. We measure an industry's exposure to export sanctions as the revenue-weighted average of its member firms' prewar exposure. Firm exposure is defined as the prewar share of imports accounted for by country-product varieties that were later sanctioned. We average this measure across firms within each five-digit industry, weighting firms by prewar revenue, and standardize the resulting industry-level exposure by its cross-industry standard deviation. The treatment coefficient can therefore be interpreted as the effect of a one-

Table C.1: The Impact of Export Sanctions on Exposed Firms' Output, Robustness to Various Sample Definitions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Baseline Sample		Balanced Panel		No Entrants		No Exiters	
	Log Sales	Log Total Cost of Goods Sold	Log Sales	Log Total Cost of Goods Sold	Log Sales	Log Total Cost of Goods Sold	Log Sales	Log Total Cost of Goods Sold
Post-2022 × Exposed to Export Sanctions	-0.127***	-0.133***	-0.103***	-0.111***	-0.127***	-0.133***	-0.128***	-0.134***
	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Mean Dep. Var.	16.00	15.93	16.43	16.29	16.00	15.93	16.14	16.05
SD Dep. Var.	2.30	2.25	2.12	2.12	2.30	2.25	2.25	2.21
Observations	11,290,066	10,548,581	5,733,920	5,422,660	11,106,078	10,377,167	9,483,305	8,905,235
Number of Firms	2,017,029	1,916,564	716,740	696,567	1,946,800	1,851,182	1,417,852	1,366,920

Notes: This table examines the robustness of the impact of export sanctions on the performance of the exposed Russian firms to focusing on alternative sample definitions. Specifically, it presents the nondynamic version of the estimates of Equation (3), comparing revenues and cost of goods sold of firms exposed (and not exposed) to the export sanctions, before and after the war's onset. A firm is considered exposed if, prior to the war, it imported any country-product variety that was later sanctioned. All dependent variables are denominated in the logarithm of Russian rubles. All specifications absorb firm, year-importer, year-exporter, year-industry, year-target-sanctioned, year-financial-exposure, year-international-bank-exposure, and year-import-sanctions fixed effects. The sample is restricted to firms with capital observed at least once. Columns (1) and (2) show the results for the baseline sample. Columns (3) and (4) focus on the fully balanced panel of firms that reported revenue each year in 2017–2024. Columns (5) and (6) drop all firms that have observations only after the war starts. Finally, columns (7) and (8) drop the firms that exited after the war, i.e., do not have observations after the war's onset. Standard errors in parentheses are clustered at the firm level. * p<0.1, ** p<0.05, *** p<0.01.

standard-deviation increase in industry exposure.

We estimate the following nondynamic industry-level analogue of Equation (3):

$$y_{st} = \beta\left(Exposure_s \times Post_t\right) + \mu_s + \delta_t + \gamma_{k(s)t} + \varepsilon_{st}, \tag{C1}$$

where s indexes five-digit industries, t indexes years, and $Post_t = \mathbb{1}\{t \geq 2022\}$. The specification includes five-digit-industry fixed effects (μ_s), year fixed effects (δ_t), and two-digit-industry-by-year fixed effects ($\gamma_{k(s)t}$). The latter helps us account for larger-industry-specific shocks that may be concurrent with the war. Since exposure is time-invariant, its main effect is absorbed by the industry fixed effects, while the postwar indicator is absorbed by year fixed effects. Standard errors are clustered at the five-digit-industry level.

We report six outcomes. Columns (1)–(2) use the logarithms of total industry sales and total operating costs; these specifications exclude the small number of industry-years with nonpositive values. Columns (3)–(6) use level counts on the balanced industry-by-year panel: the number of entrants, defined as first-time reporters; exits, defined as last-time reporters; firms with positive revenue; and reporting firms.

The dynamic estimates in Figure 6 in the main text show that more exposed industries experienced sizable postwar declines in total sales and costs. Table C.2 reports the corresponding nondynamic estimates and extends the analysis to entry, exit, and reporting outcomes. A one-standard-deviation increase in exposure is associated with a 10.3% decline in industry sales and a 10.5% decline in operating costs. More exposed industries also exhibit fewer entrants and fewer reporting firms. These results provide no evidence that losses among exposed firms were offset by expansion or entry of other firms within the same five-digit industries.

Table C.2: The Impact of Export Sanctions on Exposed Industries

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Sales	Log Costs	N of Entrants	N of Exits	N of Firms with Nonmissing Revenue	N of Reporting Firms
Post-2022 × Normalized Exposure	-0.110***	-0.113***	-0.078***	-0.017	-0.343**	-0.507**
	(0.038)	(0.037)	(0.025)	(0.034)	(0.161)	(0.228)
5-Digit-Industry FE	✓	✓	✓	✓	✓	✓
Year-2-Digit-Industry FE	✓	✓	✓	✓	✓	✓
Mean Dep. Var.	19	18.8	.36	2.09	19.1	26.3
SD Dep. Var.	3.04	3.05	3.27	10.2	87.3	121
Observations	14,171	13,802	20,176	20,176	20,176	20,176
Number of Industries	1,957	1,943	2,522	2,522	2,522	2,522

Notes: This table examines the impact of export sanctions on industry-level outcomes. The dataset is collapsed at the 5-digit industry level. The exposure to sanctions at the industry level is calculated as the share of prewar soon-to-be-sanctioned import flows weighted by the revenues in an industry earned by importers. The exposure is then normalized by its standard deviation. The estimates are then from a nondynamic equivalent of Equation (3) but at the industry rather than firm level, comparing outcomes of 5-digit industries more versus less exposed to the export sanctions, before and after the war's onset. The outcome variables are: total revenue, total operation costs, the number of entrants (first-time reporters), the number of exits (last-time reporters), the number of reporting firms with nonmissing sales, and the number of reporting firms. Data come at the yearly level from 2017 through 2024. Standard errors are clustered at the 5-digit industry level. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

C.3 Military-Related Firms

We next test whether the firm-level effects differ for firms linked to the defense sector. We consider four indicators of military relevance: inclusion in a defense-industry roster by a leading Russian defense-industry publication, location in a closed administrative-territorial formation, status as a defense-procurement participant, and a composite indicator equal to one if the firm satisfies any of these definitions. For each indicator R_f, we estimate a triple-difference version of Equation (3), interacting export-sanctions exposure with R_f and the postwar indicator, while controlling for R_f-by-year fixed effects.

Table C.3 reports the results. The triple-interaction coefficients are statistically insignificant and change sign across specifications, providing little evidence of systematic heterogeneity by military relevance. At the same time, the implied effect of export-sanctions exposure for firms with $R_f = 1$ is negative in all four specifications and statistically different from zero for defense-procurement participants and for the composite military-relevance measure. The two specifications in which the effect for $R_f = 1$ firms is not statistically significant correspond to smaller military-related groups—firms on the defense-industry roster and firms located in closed administrative-territorial formations—where the estimates are much less precise. Thus, while we do not find robust evidence that military-related firms were differentially affected relative to other exposed firms, the estimates indicate that the *adverse firm-level effects of export-sanctions exposure extend to firms linked to the defense sector as well*.

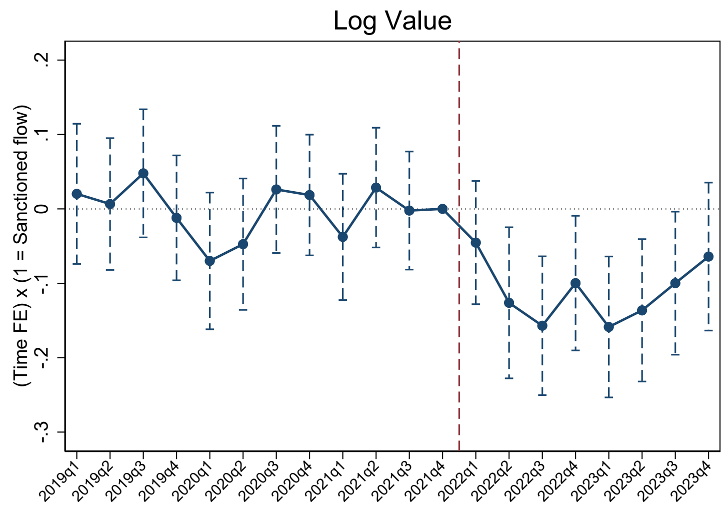
Table C.3: The Impact of Export Sanctions on Firms, Heterogeneity by Military Relevance

	(1)	(2)	(3)	(4)
	Dependent Variable: Log Sales			
	Column-Specific Military-Relevance Indicator R_f			
	Defense Industry Roster	ZATO	Defense Procurement Participant	Any Military
Post-2022 × Exposed to Export Sanctions	-0.127***	-0.127***	-0.127***	-0.127***
	(0.010)	(0.010)	(0.010)	(0.010)
Post-2022 × Exposed × R_f	-0.013	-0.014	0.021	0.027
	(0.160)	(0.140)	(0.027)	(0.027)
Firm FE	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓
Year × R_f FE (R_f = column variable)	✓	✓	✓	✓
Mean Dep. Var.	16.00	16.00	16.00	16.00
SD Dep. Var.	2.30	2.30	2.30	2.30
Observations	11,290,066	11,290,066	11,290,066	11,290,066
Number of Firms	2,017,029	2,017,029	2,017,029	2,017,029
Number of $R_f = 1$ firms	725	15,859	46,299	62,261
Total effect for $R_f = 1$ firms	-0.140	-0.141	-0.106***	-0.101***
p-value: Effect for $R_f = 1$ firms = 0	0.384	0.314	<0.001	<0.001

Notes: This table probes the heterogeneity of the impact of export sanctions on the revenue of exposed Russian firms across military-related characteristics. *Post-2022 × Exposed to Export Sanctions* estimates the effect for firms with $R_f = 0$ (where R_f is the column header); *Post-2022 × Exposed × R_f* estimates the differential effect for firms with the column-specific characteristic. Each column additionally absorbs a *Year × R_f* fixed effect, on top of the baseline FEs (firm, year-importer, year-exporter, year-industry, year-target sanctioned, year-financial-exposure, year-international-bank-exposure, and year-import-sanctions). The columns report heterogeneity by appearing in the roster of key defense-industrial-complex enterprises published by *Novyi Oboronnyi Zakaz* (a leading Russian defense-industry trade publication; https://dfnc.ru/), being located in a closed administrative-territorial formation (ZATO), being a defense-procurement participant as a buyer or supplier. The last column defines $R_f = 1$ if a firm satisfies at least one of the three military-relevance measures. A firm is considered exposed if, before the war, it imported any country-product variety that was later sanctioned. The dependent variable is the logarithm of yearly sales in Russian rubles, 2017–2024. The sample is restricted to firms with capital observed at least once. Standard errors in parentheses are clustered at the firm level. * p<0.1, ** p<0.05, *** p<0.01.

Table C.3 shows little evidence that military-related firms were systematically insulated from the negative effects of export sanctions. Across all four definitions, the interaction terms are statistically insignificant and mixed in sign. Figure C.1 complements this evidence by restricting the firm-product import analysis in Section B.6 to firms linked to military procurement either as buyers or suppliers. The estimates are noisier in this smaller sample, but they show the same pattern: even among military-related firms, imports of exposed products decline postinvasion.

Figure C.1: The Impact on Russian Firm-Level Imports of Sanctioned Products, Firms That Are Part of Military Supply Chains



Notes: This figure assesses the impact of sanctions on the imports of exposed products for each specific firm. The sample is restricted to a list of firms that were part of military supply chains. This list is created by taking all buyers and sellers of procurement contracts that feature *Military Procurement* or related keywords in the contract wording. Specifically, they display the estimates comparing the import volume for exposed firm-products to that of nonexposed firm-products before and after the first quarter of 2022. Exposed firm-products are those later-sanctioned ten-digit HS codes that a firm imported from a sanctioning country at least once prior to 2022. An HS code that was always imported from a nonsanctioning country is not exposed. This specification controls for any firm-level shocks that take place at the same time as sanctions; it also controls for product-by-time fixed effects. The data are at the quarterly level. The red vertical line indicates the start of the war. The outcome is the log of total import value of a given product in a given quarter. The firm-product panel excludes structural zeros by construction, so the outcome is log imports, defined on the intensive margin only. The bars represent 95% confidence intervals. Standard errors are clustered at the product-by-firm level. Total observations: 558,824; firms: 2,500; products: 3,835.

C.4 Additional Heterogeneity by Firm Characteristics

Table C.4: The Impact of Export Sanctions on Exposed Firms' Output, Heterogeneity by Firm and Strategic Characteristics (Non-Military)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Log Sales							
	Column-Specific Firm Characteristic R_f							
	State Owned	Size > Median	Competitor Top-10	Strategic (Wide)	System Forming	Exporter	Rerout Before	Rerout After
Post-2022 × Exposed to Export Sanctions	-0.127***	-0.194***	-0.130***	-0.127***	-0.127***	-0.122***	-0.122***	-0.179***
	(0.010)	(0.014)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)	(0.011)
Post-2022 × Exposed × R_f	0.035	0.111***	0.032	0.036	0.019	-0.015	-0.237***	-0.469***
	(0.074)	(0.014)	(0.020)	(0.066)	(0.073)	(0.016)	(0.047)	(0.026)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓	✓	✓
Year × R_f FE (R_f = column variable)	✓	✓	✓	✓	✓	✓	✓	✓
Mean Dep. Var.	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
SD Dep. Var.	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Observations	11,290,066	11,290,066	11,290,066	11,290,066	11,290,066	11,290,066	11,290,066	11,290,066
Number of Firms	2,017,029	2,017,029	2,017,029	2,017,029	2,017,029	2,017,029	2,017,029	2,017,029

Notes: This table probes the heterogeneity of the impact of export sanctions on the revenue of exposed Russian firms across non-military firm characteristics. *Post-2022* × *Exposed to Export Sanctions* is the main sanctions effect; *Post-2022* × *Exposed* × R_f (where R_f is the column header) is the triple interaction that measures the differential effect for firms with the corresponding characteristic. Each column additionally absorbs a *Year* × R_f fixed effect, on top of the baseline FEs (firm, year-importer, year-exporter, year-industry, year-target sanctioned, year-financial-exposure, year-international-bank-exposure, and year-import-sanctions). The columns report heterogeneity by state ownership, firm size (above-median pre-war 2019–2021 capital), being a top-10 competitor of an exposed firm in government procurement, being on the (broad) strategic-firms list, being a system-forming enterprise, being an exporter, having rerouted sanctioned products through friendly countries before the war (January 2021–February 2022), and having rerouted during the war (February 2022 onward). A firm is considered exposed if, before the war, it imported any country-product variety that was later sanctioned. The dependent variable is the logarithm of yearly sales in Russian rubles, 2017–2024. The sample is restricted to firms with capital observed at least once. Standard errors in parentheses are clustered at the firm level. * p<0.1, ** p<0.05, *** p<0.01.

D Supply-Chain Propagation and Domestic Shipments

Table D.1: Propagation of Export Sanctions Through Supply Chain Linkages

	(1)	(2)	(3)	(4)	(5)
			Log Sales		
Post-2022 ×	-0.127***	-0.127***	-0.129***	-0.128***	-0.129***
× Firm Exposed to Export Sanctions	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Post-2022 ×			-0.117***		-0.110***
× Supplier Exposed to Export Sanctions			(0.011)		(0.012)
Post-2022 ×				-0.089***	-0.034*
× Buyer Exposed to Export Sanctions				(0.017)	(0.018)
Firm FE	✓	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓	✓
Year FE × Number of Suppliers and Buyers		✓	✓	✓	✓
Mean Dep. Var.	16.00	16.00	16.00	16.00	16.00
SD Dep. Var.	2.30	2.30	2.30	2.30	2.30
Observations	11,290,066	11,290,066	11,290,066	11,290,066	11,290,066
Number of Firms	2,017,029	2,017,029	2,017,029	2,017,029	2,017,029

Notes: This table examines the impact of export sanctions on the performance of directly and indirectly exposed Russian firms. Specifically, it extends the baseline estimates in Table 1 by examining whether firm revenues were affected by whether a given firm's buyers or suppliers were exposed to export sanctions. Data on firm-to-firm connections come from data on railway shipments within Russia. A firm is considered exposed if, prior to the war, it imported any country-product variety that was later sanctioned. All specifications absorb firm, year-importer, year-exporter, year-industry, year-targeted-sanctions-exposure, year-financial-sanctions-exposure, year-foreign-bank-exit-exposure, and year-import-sanctions fixed effects. Columns (2)–(5) additionally absorb year-by-traded fixed effects. The dependent variable in all columns is the logarithm of yearly sales in Russian rubles from 2017 through 2024. Standard errors in parentheses are clustered at the firm level. * p<0.1, ** p<0.05, *** p<0.01.

Table D.2: The Impact of Export Sanctions on Exposed Firms' Railway Shipments

	(1) Log In-Shipments	(2) Log Out-Shipments	(3) Log Total Shipments	(4) Log # Suppliers	(5) Log # Buyers	(6) Log # Partners
Post-2022 × Firm Exposed to Export Sanctions	-0.168***	0.041	-0.097***	-0.010	0.010	-0.012
	(0.040)	(0.058)	(0.037)	(0.019)	(0.034)	(0.019)
Firm FE	✓	✓	✓	✓	✓	✓
Year × Importer FE	✓	✓	✓	✓	✓	✓
Year × Exporter FE	✓	✓	✓	✓	✓	✓
Year × Industry FE	✓	✓	✓	✓	✓	✓
Year × Targeted-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓
Year × Financial-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓
Year × Foreign-Bank-Exit Exposure FE	✓	✓	✓	✓	✓	✓
Year × Import-Sanctions Exposure FE	✓	✓	✓	✓	✓	✓
Mean Dep. Var.	7.73	8.18	8.10	1.21	1.48	1.44
SD Dep. Var.	2.53	2.66	2.60	1.10	1.35	1.26
Observations	106,165	53,288	127,925	106,219	53,323	127,962
Number of Firms	23,224	12,009	27,710	23,240	12,021	27,719

Notes: This table examines the impact of export sanctions on railway shipments of exposed Russian firms, estimated using a pre-post version of Equation (3). Columns (1)–(3) report effects on the log of total weight of incoming, outgoing, and combined shipments, respectively. Columns (4)–(6) present results for the log number of suppliers, buyers, and total trading partners. A firm is considered exposed if, before the war, it imported any country-product variety that was later sanctioned. All specifications absorb firm, year-importer, year-exporter, year-industry, year-targeted-sanctions-exposure, year-financial-sanctions-exposure, year-foreign-bank-exit-exposure, and year-import-sanctions fixed effects. The railway outcome variables are aggregated at the firm-year level from 2017 through 2023. Standard errors in parentheses are clustered at the firm level. * p<0.1, ** p<0.05, *** p<0.01.

E Aggregate Accounting

This appendix details the back-of-the-envelope aggregation procedures underlying the estimates in Section 8. We first describe the trade-side aggregation, including the welfare calculations based on the resulting import shortfall. We then describe the firm-level aggregation.

E.1 Trade-Side Aggregation

E.1.1 Import Counterfactuals

To convert the product-level estimates in Section 5.3 into cumulative dollar magnitudes, we construct counterfactual import paths that combine intensive- and extensive-margin responses. We first estimate two product-level pre-post DiD regressions based on Equation (2), using log product-level imports as the outcome and restricting attention to positive product-quarter import flows. Similar to our baseline estimates, the first specification uses imports from all countries as a dependent variable. Thus, these estimates capture the net effect of sanctions after allowing for adjustment through friendly countries. Next, we subtract shipments from friendly countries from the dependent variable, and repeat the same analysis. These new estimates now reflect the direct decline in trade outside the friendly-country adjustment channel. Comparing the resulting direct and net gaps allows us to quantify how much of the direct trade disruption was offset by increased shipments through friendly countries, whether through rerouting of sanctioning-origin goods or substitution toward goods produced in friendly countries.

Let m^r_{gt} denote realized imports of product g in quarter t under aggregation $r \in \{\mathrm{All}, \mathrm{NF}\}$, where All uses imports from all shipment countries and NF excludes shipments from friendly countries. Let $\hat{\beta}^r_t$ denote the corresponding product-level DiD estimate for sanctioned products in quarter t. For product-quarters with positive realized imports, we construct a residual-preserving no-sanctions counterfactual by removing the estimated sanctions effect from realized log imports:

$$\log m^{r,\mathrm{cf}}_{gt} = \log m^r_{gt} - \hat{\beta}^r_t \, Sanctioned_g,$$

or, equivalently,

$$m^{r,\mathrm{cf}}_{gt} = m^r_{gt} \cdot \exp\left(-\hat{\beta}^r_t \, Sanctioned_g\right). \tag{E1}$$

For pre-invasion quarters, we set $m^{r,\mathrm{cf}}_{gt} = m^r_{gt}$. Thus, for sanctioned products in post-invasion quarters, realized positive imports are scaled by the inverse of the estimated sanctions effect; for nonsanctioned products, the counterfactual equals realized imports. This procedure preserves each product-quarter's realized residual relative to the fitted log specification and asks what imports would have been if the estimated sanctions effect were set to zero.

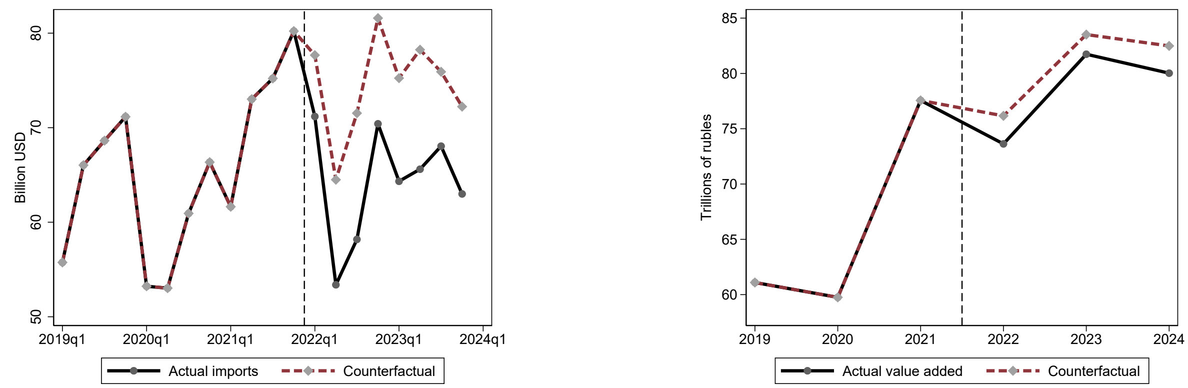
We aggregate Equation (E1) across products separately for All and NF. To keep the two intensive-margin calculations comparable, both are evaluated on the common sample of product-quarters with positive non-friendly imports. Product-quarters in which non-friendly imports fall to zero are therefore left out of the intensive-margin aggregation and handled by the extensive-margin correction below. The gap between counterfactual and realized imports under All gives the intensive-margin component of the net import shortfall. The corresponding gap under NF gives the intensive-margin component of the direct decline outside the friendly-country channel. The difference between the two gaps is the intensive-margin offset through friendly countries.

Because the log specifications are estimated only on positive flows, Equation (E1) does not assign a counterfactual import value to product-quarters in which non-friendly imports fall to zero. We therefore add a simple extensive-margin correction for sanctioned products whose non-friendly imports disappear after the invasion. For each post-invasion quarter t, let $\mathcal{E}_t$ denote the set of sanctioned products that had positive average quarterly imports from non-friendly countries before the war but have zero realized imports from non-friendly countries in quarter t. For each product in this set $\mathcal{E}_t$, we impute its average quarterly prewar imports from non-friendly countries, denoted $\bar{m}_g^{\text{NF}}$, as the no-sanctions level of non-friendly imports. Since realized non-friendly imports are zero for these product-quarters by construction, any realized imports of the same product must come through friendly countries. We therefore treat total realized imports of the product, m_{gt}^{All}, as the offset through the friendly-country channel. Equivalently, each disappearing non-friendly product-quarter contributes $\bar{m}_g^{\text{NF}} - m_{gt}^{\text{All}}$ to the net import shortfall. Summing these terms over all products in $\mathcal{E}_t$ gives the extensive-margin correction.

The extensive-margin correction is conservative in how it attributes adjustment through friendly countries. For product-quarters in $\mathcal{E}_t$, we count the disappearance of non-friendly imports relative to the product's own prewar non-friendly import level, but credit all realized friendly-country imports of the same product as an offset. This likely understates the net shortfall, since some of these friendly-country imports may have occurred even absent sanctions, or may not represent one-for-one replacement of the missing non-friendly flows. The procedure therefore counts disappearing non-friendly flows only when they fall to zero, while giving maximum credit to friendly-country shipments as compensating adjustment. In addition, to the extent that these products would have followed secular import growth absent sanctions, using the prewar non-friendly mean as the no-sanctions benchmark also understates the missing non-friendly flow.

Panel A of Figure E.1 plots the resulting realized and counterfactual paths for total imports in our customs data. Cumulated over 2022Q1–2023Q4, the combined intensive- and extensive-margin procedure implies a \$72.4 billion net shortfall in imports, reflecting a \$207.6 billion direct

Figure E.1: Actual and Counterfactual Aggregate Trajectories: Imports and Firm Value Added



(a) Total Imports in Customs Data ($bn)

(b) Russian Firm Value Added (trillion rubles)

Notes: Panel A shows realized and counterfactual total imports in our customs data. As described in Section E.1, the counterfactual differs from the realized series only through the estimated effects on sanctioned products. Panel B shows aggregate Russian firm value added from the firm-level aggregation described in Section E.2. Solid lines plot realized series; dashed lines plot counterfactuals absent sanctions. The sample is 2019Q1–2023Q4 in Panel A and 2017–2024 in Panel B. The vertical line marks the start of the full-scale Russian invasion of Ukraine.

decline outside the friendly-country channel partly offset by $135.2 billion of increased shipments through friendly countries. The extensive-margin adjustment is quantitatively smaller than the intensive-margin component, accounting for roughly one-quarter of the combined net shortfall. Alternative extensive-margin imputations could therefore change the precise cumulative magnitude, but not the main conclusion: increased shipments through friendly countries offset a large share of the direct sanctions-induced decline, but not all of it.

E.1.2 Welfare Translation

We next translate the import shortfall into a welfare-equivalent benchmark using the sufficient-statistic result of Arkolakis et al. (2012). Let M' denote realized post-sanctions imports, M^{cf} the no-sanctions counterfactual, and Y GDP. Scaling both import flows by the same GDP denominator, the implied change in the domestic expenditure share is

$$\hat{\lambda} = \frac{1 - M'/Y}{1 - M^{\text{cf}}/Y}.$$

The corresponding welfare change is

$$W'/W \;=\; \hat{\lambda}^{-1/\varepsilon}, \tag{E2}$$

where ε is the trade elasticity. Intuitively, the sanctions-induced import shortfall raises the domestic expenditure share; the welfare cost is larger when foreign goods are harder to substitute.

Using our preferred import aggregation, average annual post-invasion imports in our customs data are approximately $M' = \$257.1$ billion, compared with no-sanctions counterfactual imports of $M^{\text{cf}} = \$293.3$ billion.[1] Combining these import totals with the average 2022–2023 Russian GDP of approximately $Y = \$2.13$ trillion and a trade elasticity of $\varepsilon = 4$,[2] Equation (E2) implies $W'/W = 0.995$, or a real-income loss of about 0.5 percent.[3] In the counterfactual without rerouting through friendly countries, the implied real-income loss rises to about 1.4 percent. Thus, rerouting substantially reduced the welfare cost of export sanctions, but did not eliminate it.

The magnitude is sizable in the context of standard trade-welfare calculations. In the ACR framework, the natural benchmark is complete import autarky. Using our customs-based counterfactual import share, $M^{\text{cf}}/Y = 293.3/2130 = 13.8\%$, moving from the no-sanctions allocation to goods-import autarky would imply a real-income loss of $1 - (1 - 0.138)^{1/4} \simeq 3.6\%$. The corresponding benchmark based on national-accounts imports of goods and services is somewhat larger: Russia's total import share averaged about 16.7 percent of GDP in 2022–2023, implying full-import-autarky gains from trade of about 4.5 percent at $\varepsilon = 4$. Thus, the sanctions-induced loss of roughly 0.5 percent is a non-negligible share of the entire import-autarky benchmark, while the no-rerouting counterfactual loss of about 1.4 percent would be very large in comparison. These calculations also highlight the economic importance of rerouting: friendly-country supply chains absorbed roughly two-thirds of the direct import disruption, substantially attenuating the real-income costs of export sanctions. For perspective, Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020) estimate that the 2018 U.S. trade war reduced aggregate U.S. real income by only 0.04% of GDP.

[1] For comparison, the corresponding Central Bank of Russia import series is annualized at roughly $\$288$ billion over the same March 2022–December 2023 window, about 12 percent above our customs-based total (Central Bank of Russia, 2026). Differences of this magnitude are not surprising given differences in valuation, exchange-rate conversion, aggregation, and statistical reconciliation conventions between transaction-level customs records and official aggregate import statistics. We use the lower customs-based import totals for internal consistency. This makes our welfare calculations conservative relative to applying the same estimated proportional shortfall to official aggregates.

[2] The number relatively commonly discussed and used in the literature, see, e.g., Costinot and Rodríguez-Clare (2014) or Simonovska and Waugh (2014).

[3] Using a common GDP denominator keeps the ACR calculation focused on the import-share change implied by the trade-side counterfactual. This normalization is quantitatively innocuous. For example, allowing realized GDP to be 1.3 percent lower, as suggested by our firm-level aggregation, gives

$$\left(\frac{1 - 0.2571/(2.13 \times 0.987)}{1 - 0.2933/2.13}\right)^{-1/4} = 0.9956,$$

compared with 0.9951 in the baseline calculation with a fixed denominator.

E.2 Firm-Level Value-Added Aggregation

We construct the firm-level counterfactual using the same residual-preserving procedure as in the trade-side aggregation. For each firm f and post-invasion year t, we remove the estimated treatment effect from realized log value added:

$$\log y_{ft}^{\text{cf}} = \log y_{ft} - \hat{\beta}_t Exposed_f \iff y_{ft}^{\text{cf}} = y_{ft} \cdot \exp\left(-\hat{\beta}_t Exposed_f\right), \tag{E3}$$

where y_{ft} is realized value added, $\hat{\beta}_t$ is the year-specific treatment effect estimated in Equation (3), and $Exposed_f$ is the prewar exposure indicator. For unexposed firms, $y_{ft}^{\text{cf}} = y_{ft}$. For exposed firms, Equation (E3) gives the level of value added the firm would have produced absent the estimated sanctions effect, holding fixed the firm's realized residual in the log specification.

We then aggregate the implied losses, $y_{ft}^{\text{cf}} - y_{ft}$, across firms and post-invasion years. As shown in Panel B of Figure E.1, the resulting counterfactual series lies above realized value added throughout the post-invasion period. The cumulative gap implies aggregate value-added losses of 6.8 trillion rubles, equal to 2.8 percent of counterfactual value added and approximately 1.3 percent of cumulative Russian GDP over the 2022–2024 period.[4] The value-added estimates therefore point to a sizable decline in domestic production among firms exposed to sanctioned inputs, with the annual loss reaching 2.5 trillion rubles by 2024.

These firm-level aggregate losses should be interpreted as a partial-equilibrium measure of the decline among firms directly exposed to sanctioned inputs. The calculation applies the estimated firm-level treatment effects to exposed firms and therefore does not incorporate possible general-equilibrium adjustment, spillovers to unexposed firms, or losses among firms outside our sample.

The firm-side calculation should also be viewed as complementary to, rather than additive with, the trade-side welfare calculation above. The ACR exercise translates the observed import shortfall into a real-income loss using a standard trade-welfare sufficient statistic. The present exercise instead aggregates the estimated decline in value added among firms exposed to sanctioned inputs. The two calculations therefore approach the sanctions-induced disruption from different sides of the adjustment process: reduced access to imported inputs and the associated decline in domestic production. We do not sum the two estimates. Instead, their convergence on economically meaningful aggregate losses provides a useful cross-check on the magnitude of the disruption.

[4] Allowing treatment effects to vary by prewar firm size leaves this total essentially unchanged. Re-estimating the aggregation with separate coefficients for above- and below-median prewar-capital firms, using the split in column (2) of Table C.4, yields a cumulative loss of 6.3 trillion rubles, or 2.6 percent of counterfactual value added. More detailed splits by firm size yield, if anything, larger aggregate loss estimates.