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(Trade) War and Peace: How to Impose International Trade Sanctions

Abstract

Trade sanctions are a common instrument of diplomatic retaliation. To guide current and future policy, we ask: What is the most cost-efficient way to impose trade sanctions against Russia? We build a quantitative model of international trade with input-output connections. Sanctioning countries choose import tariffs to simultaneously maximize their income and minimize Russia's income, with different weights placed on these objectives. We find, first, that for countries with low willingness to pay for sanctions against Russia, the most cost-efficient sanction is a uniform tariff on all Russian products of about 20%. Second, if countries that are willing to pay at least US$0.70 for each US$1 drop in Russian welfare, an embargo on Russia's mining and energy products – with tariffs above 50% on other products – is the most cost-efficient policy. Finally, if countries target politically relevant sectors, an embargo on Russia's mining and energy sector is the cost-efficient policy, even when there is low willingness to pay for sanctions.

JEL-Codes: F130, O240.

Keywords: trade sanctions, tariff, tariff competition.

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1 Introduction

Trade sanctions are a common instrument of diplomacy, with over 100 of them active in 2016. In the wake of Russia's invasion of Ukraine, trade sanctions have once again come into the public spotlight. Countries such as Canada, Japan, and the United Kingdom (UK) responded by imposing import tariffs on Russia, ranging from 8% to 35%. The Western countries jointly removed Russia's "Most Favored Nation (MFN)" status, enabling them to impose arbitrary tariffs against Russia without breaking World Trade Organization (WTO) regulations. Meanwhile, policymakers and politicians have advocated for an embargo on Russian oil and gas imports.

Ultimately, trade sanctions are meant to hurt the sanctioned country's economy. However, if they severely restrict trade, they also hurt the sanctioning countries. This trade-off raises the question: What is the most cost-efficient way to apply trade sanctions? How can a government reduce economic activity in the sanctioned country while minimizing local economic costs? When is an embargo cost-efficient?

We answer these questions using a quantitative model and empirical evidence. We build a model of tariff competition with international trade and input-output connections.[1] In the model, firms produce using labor, locally produced inputs, and inputs from other countries. To import inputs, firms have to pay an import tariff.

Tariffs are chosen by governments trading off two objectives. On the one hand, they want to maximize domestic real income, which is also a measure of household welfare. On the other hand, they want to minimize Russian welfare. If the government has a high willingness to pay for sanctions, it places greater weight on hurting the Russian economy. As the government is trading off the cost of sanctioning Russia and its own welfare, we refer to these sanctions as cost-efficient sanctions.[2]

[1]The model builds on Ossa (2014) and Caliendo and Parro (2015).

[2]In practice, sanctions can take various forms, such as limiting the movement of capital, goods, or people between countries. To narrow down the scope of the problem, we focus on a specific type of trade sanctions: import tariffs, which also include embargoes as a special case. Due to the Lerner Symmetry (Lerner (1936),Costinot and Werning (2019)), sanctions in the form of import tariffs are equivalent to export sanctions. Additionally, in the case of Russia, several countries, including the UK, Canada, Japan, United States (US), and the European Union (EU), have implemented sanctions in the form of import tariffs, making it the most relevant type of sanction for policy evaluation.

To construct reliable counterfactuals, we estimate the model to reproduce the effect of tariffs on Russia's international trade. Using the difference-in-differences estimation strategy introduced in de Souza and Li (2021), we find that a 10% ad-valorem tariff on Russia decreases imports of Russian products by 43% and total imports of the taxed goods by 15%, showing that both Russia and the sanctioning countries are negatively affected by tariffs. Using the method of de Souza and Li (2021) and tariff variation from all countries, we estimate sectoral trade elasticities to be 6 on average. These elasticities correlate with estimates by Caliendo and Parro (2015) and those that we recover using the Feenstra (1994) method.

We highlight five main findings. First, we show that for countries with low willingness to pay for sanctions, the best policy is to impose a small tariff on all products. For instance, if the sanctioning countries are willing to pay US$0.10 for every US$1 of economic damage in Russia, import tariffs should average 20%.[3]

Second, if the EU is willing to pay over US$0.70 for each US$1 of real income loss in Russia, an EU embargo on the mining and energy sectors with a 50% tariff on other sectors is cost-efficient.[4] For countries with high willingness to pay for sanctions, the main driver of cost-efficient tariffs is the import share; to cause more harm to Russia, sanctioning countries should target what Russia exports the most, i.e., mining and energy products.

Third, we show that the EU is the group of countries that can hurt the Russian economy the most – not the US or other sanctioning allies (OSA). Russia exports more to the EU than to the US or OSA.[5] Accordingly, tariffs imposed by the US or OSA can, at most, reduce Russian real income by only 0.07% or 0.22%, respectively. By contrast, the EU alone can reduce real income in Russia by as much as 0.8%. Therefore, the burden of trade sanctions against Russia has to be carried by the EU.

[3]For nations with low willingness to pay for sanctions, there are two forces affecting the choice of tariffs. On the one hand, the government wants to impose high tariffs on sectors with low trade elasticity, i.e., on products for which trade flows are less affected by tariffs. Yet, on the other hand, the government also wants to impose high tariffs on products with lower import shares from Russia so it does not affect the local economy very much.

[4]The mining and energy sectors include the extraction of crude oil, natural gas, and other energy products (D05 and D06 in International Standard Industrial Classification (ISIC) Rev. 4) and the coke and refined petroleum sector (D19 in ISIC Rev. 4).

[5]More specifically, Russia's exports to the EU represent 4.85% of the country's total production; its exports to the US represent 0.55%; and its exports to the OSA represent 1.63%.

Fourth, if Russia retaliates, i.e., if it also chooses to impose tariffs to punish the sanctioning countries, the economic consequences of tariff sanctions against Russia would be more than double. Because the EU is an important importing origin for Russia but Russia is not an important exporting destination for the EU, Russia cannot decrease EU welfare by much through the imposition of high tariffs on the EU, but it can cause a large decline in its own welfare.

Finally, we show that if sanctions target sectors with larger political relevance in Russia, an embargo on Russian mining and energy sectors is cost-efficient even for countries with a low willingness to pay for sanctions. To calculate political relevance, we link each Russian individual sanctioned by the US, UK, or EU U, whom we call an oligarch, to the companies associated with that individual in Russia. Using the company's revenue, we calculate the revenue share of oligarch-owned companies by sector. If the sanctioning countries are willing to pay US$0.10 for each US$1 of consumption drop in Russian oligarch income, tariffs on the Russian mining and energy sectors should be above 80%, which would cause imports of mining and energy products to drop by almost 100%. Therefore, if the goal of sanctions is to target politically influential sectors, an embargo the optimal policy, even for nations with low willingness to pay for sanctions.

To confirm the robustness of our main findings, we test various calibration strategies and model assumptions. First, we examine if our results hold under alternative trade elasticity calibrations. We find that using the trade elasticity estimated by Caliendo and Parro (2015) or our estimates of the long-run trade elasticity does not qualitatively change the results. Second, we show that our results remain unchanged when we use alternative functional forms of the production function. Even when we use a constant elasticity of substitution (CES) production function across inputs or the elasticity of substitution estimated by de Souza and Li (2021), the results are qualitatively the same. In addition, assuming a very low elasticity of substitution across inputs, which is closer to a Leontief than empirically plausible, still delivers the same cost-efficient sanction patterns. Third, our results are not affected by the retaliation strategies implemented by Russia. Therefore, after this battery of tests, we conclude that our findings are robust and remain consistent under alternative calibration and modeling choices.

This paper contributes to the literature on tariff competition by studying the problem of a government trading-off welfare maximization and diplomatic objectives. The tariff competition literature has investigated optimal trade policy in different settings when countries maximize their own welfare. These settings include tariff cooperation (Ossa 2014), competition on non-tariff trade barriers (Mei 2021), MFN rules (Bagwell et al. 2021), export subsidies (Beshkar and Lashkaripour 2020), market access concessions (Beshkar et al. 2022), deep trade agreements (Lashkaripour and Lugovskyy 2021), and industrial policies (Bartelme et al. 2021). These studies have found that tariffs should be larger on sectors with lower trade elasticities and that there are welfare gains from cooperation.[6]

We contribute to this literature by studying countries' trade-off between sanctions and welfare-maximizing trade policy. This departure allows us to calculate cost-efficient trade sanctions and contribute to important policy debates on sanctions. We show that, differently from the previous literature on tariff competition, the trade elasticity is not an important determinant of cost-efficient sanctions. As countries place more weight on hurting the Russian economy, optimal tariffs should rise in the sectors that have larger trade flows. If the willingness to pay is above US$0.70 for each US$1 drop in Russian welfare, tariffs should target the main sectors of Russian exports regardless of their trade elasticities.

Our work contributes to the literature on the economic impacts of sanctions. Sanctions and sanction threats are more effective if they impose more harm on the target and if the sender is more patient (Eaton and Engers 1992, Lacy and Niou 2004, Whang et al. 2013). Furthermore, sanctions should optimally trade off between the punishment of the target's leader and the negative impact on the general public (Baliga and Sjöström 2022). Empirical works have shown that the number of sanctions has risen over time(Elliott and Hufbauer 1999, Felbermayr et al. 2020a, 2021, van Bergeijk 2022). In the target country, sanctions exacerbate regional inequality (Lee 2018), induce firm exit (Ahn and Ludema 2020, Crozet et al. 2021), and lower stock market valuation (Draca et al. forthcoming). In the sender country, sanctions also negatively impact firm business (Felbermayr et al. 2020b, Gullstrand

[6] Another strand of this literature has developed theories on punitive tariffs. Punitive tariffs can sustain a cooperative equilibrium (Dixit and Bewley 1987) and thus lead to welfare gains (Mei 2020), should be higher when trade volume surges (Bagwell and Staiger 1990) and in small countries (Park 2000), can be more effective when implemented in a multilateral framework (Maggi 1999, Klimenko et al. 2008), and are easier to enforce than monetary fines (Limao and Saggi 2008).

2020, Besedeš et al. 2021). Furthermore, sanctions disrupt international trade (Crozet and Hinz 2020, Miromanova 2021a,b, Kwon et al. 2022).

A few works have studied the impact of sanctions against Russia in response to its recent aggressions in Ukraine, including how such sanctions have affected the ruble exchange rate (Lorenzoni and Werning 2022, Itskhoki and Mukhin 2022), the welfare implications of Western countries increasing the imposition of tariffs and non-tariff trade barriers on Russia (Evenett and Muendler 2022a,b), the consequences of banning Russian oil imports (Bachmann et al. 2022), and the effects on Russia's consumer prices of Russian retaliation in the form of import restrictions (Hinz and Monastyrenko 2022). Sturm (2022) shows that the sanctioning countries can hurt the Russian economy while increasing their own welfare. Sturm (2023) and Sonali Chowdhry and Wanner (2022) study the effect of coalitions on the effectiveness of sanctions.

We contribute to the literature on the economic impacts of sanctions by estimating cost-efficient trade sanctions and their economic impact. To the best of our knowledge, this is the first paper to study optimal economic sanctions in a quantitative trade framework. As such, we differ from Eaton and Engers (1992), Lacy and Niou (2004), Whang et al. (2013), and Baliga and Sjöström (2022), taking the motivation for sanctions as a given and computing the set of tariffs that hurt the targeted country the most and cost the sanctioning countries the least. Inspired by Baliga and Sjöström (2022), we also calculate cost-efficient sanctions when the sanctioning countries target politically relevant sectors.

The rest of the paper proceeds as follows. In Section 2, we present empirical evidence on how a large increase in tariffs can disrupt international trade with Russia. In Section 3, we present the model and the governments' problems. In Section 4, we calibrate the model. In particular, we introduce the sectoral trade elasticities to our empirical estimates. In Section 5, we show our findings based on model simulations. In Section 6, we conclude.

2 Empirics

We take advantage of the difference-in-differences strategy introduced by de Souza and Li (2021) to investigate how an increase in tariffs disrupts trade with Russia. We compare

Russian products that had an anti-dumping investigation that did not led to a tariff increase, the control group, to products that had an anti-dumping investigation and a tariff increase, the treatment group. According to WTO regulation, the decision to impose an anti-dumping tariff should be based on pre-determined characteristics of each product. Because of these characteristics are constant overtime, they can be teased out with a product level fixed effect.

This section is organized as follows. First, we discuss institutional details of anti-dumping tariff, which we will exploit to identify the causal effect of tariffs against Russia. Then we discuss the data and a series of validation exercises. Finally, we show our main specification and results. Section 2.4 discuss the main take-aways from the empirical section and Section 2.5 estimates sector level trade elasticities which will be used to calibrate the model.

2.1 Institutions

Dumping refers to an act of price discrimination in which an exporter charges a lower price in the destination market than in its home market.[7] The WTO allows the destination government to impose AD tariffs to correct for such price differences, but requires that they must follow certain procedures.[8] First, a sufficient number of firms in a domestic industry should submit a written request to the government. The request should provide evidence that import competition is doing harm to the domestic industry. It should also show that the foreign exporters are engagiing in dumping. Second, upon receipt of the request, the government should establish a committe to investigate the case. Third, using the evidence collected during the investigation and following WTO rules, the committee calculates the normal value of the foreign product and the export price. If the committee finds that the foreign exporter is indeed charging a lower price in the export destination that in its home market, the government will conclude that the foreign exporter is dumping, and it will impose an AD tariff equal to the price difference.[9] If the committee finds otherwise, no AD tariff

[7] Adjusted for allowances, trade costs, and currencies in different markets. See Section "Fair comparison of normal value and export price" of WTO's technical note on AD (https://www.wto.org/english/tratop_e/adp_e/adp_info_e.htm).

[8] See WTO's AD rule (https://www.wto.org/english/docs_e/legal_e/19-adp_01_e.htm).

[9] Some investigations ended with the foreign exporter raising their price to avoid an AD tariff. See WTO Agreements on AD, subsidies, safeguards: contingencies, etc. (https://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm8_e.htm) These observations are dropped from both the treatment and control groups.

will be introduced. AD duties should terminate no later than five years after first being imposed.

2.1.1 Data

Our data source for AD investigations is the Global Antidumping Database (Bown 2005). The database contains all AD investigations conducted by 31 major economies on all trade partners. For each investigation, the database covers the investigated product and its Harmonized System (HS) code, the exporter and importer, the beginning and end dates of each investigation, and the measures taken. Our data source for international trade is the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). We merge the two datasets on the country–bilateral and HS 6-digit level.

In the Appendix, Table A.1 shows the summary statistics for AD investigations targeting Russia.[10] During the sample period (1995–2020), Russia faced 393 AD investigations, of which 298 (75%) concluded with an affirmative ruling. Figure A.1a shows the number of AD investigations and affirmative investigations by year. Figure A.1b shows the average tariff rate by sector conditional on an affirmative ruling. Table A.3 shows the summary statistics, by country, of the AD investigations targeting Russia. The US conducted the most AD investigations targeting Russia.

Table A.2 shows the summary statistics for AD investigations imposed by all countries on their trade partners. During the sample period, there was a total of 15,131 AD investigations, of which 10,370 (68%) concluded with an affirmative ruling. Figure A.2a shows the number of global AD investigations and affirmative investigations by year. Figure A.2b shows, at the world level, the average tariff rate by sector conditional on an affirmative ruling. Tables A.4 and A.5 show the summary statistics for global AD investigations by the investigating country and exporting country.

2.1.2 Discussion

Based on the WTO AD rules, two important lessons can be learned about how one should identify the impact of AD tariffs. First, one should not compare the products that are

[10] We discuss these summary statistics in further detail in Appendix Section A.1.

subject to an AD tariff to those that are not. To initiate the imposition of an AD tariff, an investigation committee has to be formed first. As Staiger and Wolak (1994), Prusa (2001), Lu et al. (2013), and Besedeš and Prusa (2017), among others, have shown, these investigations can create trade policy uncertainty and disrupt trade even if the investigations do not conclude with tariff changes. Furthermore, as de Souza and Li (2021) show, the investigated products have a lower price, higher trade volume, decreasing price price trend, and increasing trade volume trend, compared to the products that are not investigated. Both the trade policy uncertainty and different trends can be confounding factors when comparing the tariffed products to the non-tariffed products without controlling for AD investigations. Therefore, we limit our sample to only the investigated products.

Second, conditional on an AD investigation, the WTO rules stipulate that whether a tariff should be imposed and, if so, the size of the tariff should depend on the difference in the prices set by the foreign exporter in the origin and destination countries in the pre-investigation period. We can use the product–country fixed effects to control for such a difference. Once we do so, the AD tariff should be exogenous to the potential trends of the treatment and control groups. To test that countries indeed follow the WTO rules, we employ an event study design showing parallel trends between the two groups before the treatment. In de Souza and Li (2021), we supplement it with additional evidence: (1) The AD tariff can be predicted by the exporting country's price that it charges and the AD tariff that it faces on the same product in a third country with a high R-squared. (2) The AD policy applied for a sector does not correlate with the sector's other benefits from the government, including political connections, public procurement, subsidies, and tax breaks. (3) Placebo tests show that if we replace the real treatment group with one that has similar trends or if we move the treatment time five years earlier, we do not identify any effect of AD tariffs.

2.2 Empirical Strategy

2.2.1 Impact of Import Restrictions on Russian Trade

Following de Souza and Li (2021), we study the impact of AD tariffs on Russian trade using:

$$y_{p,c,t} = \theta\tau_{p,c,t} + \beta\mathbb{I}_{p,c,t}\left\{\text{After AD}\right\} + X'_{p,c,t}\beta + \epsilon_{p,c,t}, \tag{1}$$

where $y_{p,c,t}$ is imports of product p by country c from Russia in year t;[11] $\tau_{p,c,t}$ denotes the AD tariff that country c imposes on product p from Russia in year t; $\mathbb{I}_{p,c,t}\left\{\text{After AD}\right\}$ is a dummy after the beginning of the first AD investigation (it captures common trends between treatment and control leading to the investigation); and $X'_{p,c,t}$ is a set of controls.[12]

Our variable of interest is θ, which captures the average effect of AD tariffs on trade. As it is common in difference-in-differences, the identifying assumption is of parallel trends between treatment and control groups. To show supportive evidence for this assumption, we test for the existence of parallel trends (prior to the beginning of the investigation) using:

$$y_{p,c,t} = \sum_{j}\theta_j\tau_{p,c,\text{first}}\mathbb{I}_{p,c,t}\left\{j \text{ Yrs. to AD}\right\} + \sum_{j}\beta_j\mathbb{I}_{p,c,t}\left\{j \text{ Yrs. to AD}\right\} + \eta_{p,c} + \eta_{c,t} + \epsilon_{p,c,t}, \tag{2}$$

where $y_{p,c,t}$ refers to imports of product p by country c from Russia in year t, and where $\tau_{p,c,\text{first}}$ denotes the first AD tariff that country c imposed on product p from Russia (this variable equals zero for the control group).[13] Moreover, in this equation, the dummy variable $\mathbb{I}_{p,c,t}\left\{j \text{ Yrs. to AD}\right\}$ takes 1 if year t is j years to the beginning of the first AD investigation; and $\eta_{p,c}$ and $\eta_{c,y}$ are the country–product fixed effects and country–year fixed effects, respectively. We are interested in the coefficient θ_j, which captures the dynamic effect of AD tariffs in the jth year. Having no pre-trend is equivalent to $\theta_j = 0, \forall j < 0$. We limit the

[11] A product is an HS 6-digit code.

[12] The controls are a product–country fixed effects, product–year fixed effects, and dummies for the number of AD investigations.

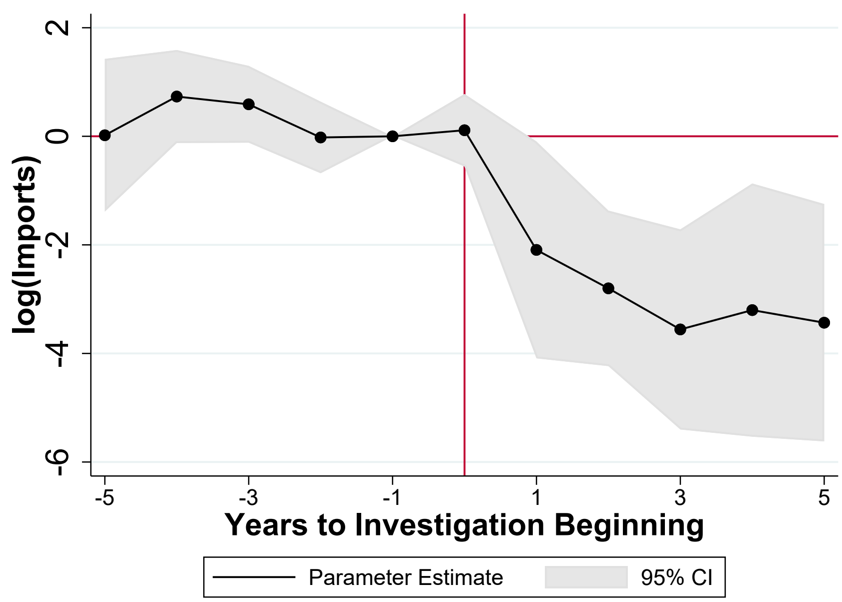
[13] In the difference-in-differences analysis, we limit our sample to the first AD investigation for a product that a country conducts on Russia. In this way, we ensure that there is no other investigation in the pre-period.

sample to product–country pairs that have at least one AD investigation.

2.3 Results

Figure 1 shows how AD tariffs against Russia affect a country's imports from Russia. AD tariffs cause a significant large drop in imports: A 10% increase in AD tariffs is associated with a nearly 40% decline in imports of the targeted products. The figure also confirms the nonexistence of a pre-trend; that is, before the increase in tariffs, the treatment and control groups display similar import trends.

Figure 1: **Impact of AD Tariffs on Imports**



Description: This figure shows the dynamic impact of AD tariffs on imports using Model 2. The impact on yearly imports is plotted on the y-axis. The number of years to the beginning of the investigation is plotted on the x-axis. We study HS 6-digit level imports. Imports are measured in free on board (FOB), current dollar value terms. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Antidumping Database (Bown 2005). The sample runs from 1995 to 2020. The sample includes the product–origins that faced at least one AD investigation. The shaded area contains the 95% confidence interval. Standard errors are clustered at the product–country level.

In the Appendix, Figure A.3 shows the impact of AD tariffs on the quantity and price of the targeted product imported from Russia. Similar to the value of imports, AD tariffs significantly reduce the quantity of imports from Russia. Figure A.3a shows that, five years from the beginning of an AD investigation, a 10% increase in AD tariffs leads to about a 30% drop in the quantity of imports from Russia. Figure A.3b shows that it takes longer for the import price to respond to AD tariffs. A 10% increase in AD tariffs leads to about a 5% drop in import prices. This suggests that Russian exporters have to lower prices to remain competitive, and there is an incomplete pass-through of AD tariffs to consumers in the destination country.

AD tariffs significantly reduce total exports (to all destinations) of the targeted Russian product, as shown in Figure 2. A 10% increase in tariffs leads to about a 15% decline in total exports five years after the AD investigation. This indicates that the decline in Russian exports of a product to the destination that imposes import restrictions dominates the potential increase in Russian exports of the same product to other destinations. Indeed, Column 1 of Table A.10 shows that Russia can only weakly divert exports to other destinations.[14] These findings suggest that import sanctions by other countries on Russia will likely reduce Russian output and income, a hypothesis we build on in Section 3.

Similarly, Figure 2b shows that AD tariffs significantly reduce total imports (from all origins) of the targeted product to the country that imposes the import restriction: A 10% increase in tariffs leads to about a 20% decline in that country's total imports in the fifth year from the beginning of the AD investigation. This demonstrates that the decline in imports of the targeted product from Russia dominates the potential increase in imports of the same product from other origins. This is further confirmed by Column 2 of Table A.10, the results of which show that AD tariffs also only weakly divert the sanctioning country's imports to other origins. These findings suggest that import sanctions by other countries on Russia will likely also reduce the sanctioning country's consumption and income, a hypothesis we evaluate in Section 3.

Using variation from all AD tariffs imposed on Russia, we show in Table 1 that tariffs on Russia decrease imports, prices, and total exports of Russian products. A 10% increase in tariffs causes a 43% drop in imports of the targeted product from Russia (Column 1), with a 37% drop in quantity imported (Column 2) and a 6% drop in the price of imports (Column 3). Columns 4 and 5 show that a 10% increase in tariffs reduces total Russian exports of the targeted product by 16% and total imports of the targeted product by the tariffing country

[14] This result is consistent with de Souza and Li (2021), who also find an insignificant trade diversion effect of the AD tariffs that the Brazilian government imposes on other countries.

by 19%.

Tables A.7, A.8, and A.9 show that the impacts of tariffs on imports from Russia, total exports, and total imports are robust to different combinations of fixed effect controls. Column 1 of these tables shows the baseline estimates. Column 2 clusters standard errors at the 4-digit product and importer level. Column 3 uses a dummy that denotes whether an investigation committee is formed (instead of the number of committees) to control for the impact of AD investigations. Column 4 controls for product, importer, and year fixed effects separately.

2.4 Discussion of Main Empirical Results

Tariffs against Russia decrease total imports of the taxed good and exports by Russia. This result implies that sanctions against Russia have two implications: one for domestic welfare and the other for Russian welfare.

First, the empirical results suggest that trade sanctions decrease domestic welfare. Because Russian products cannot be easily replaced, the domestic economy has to pay higher prices to either produce the product locally or import it from another country. Therefore, due to higher prices, domestic real income goes down.

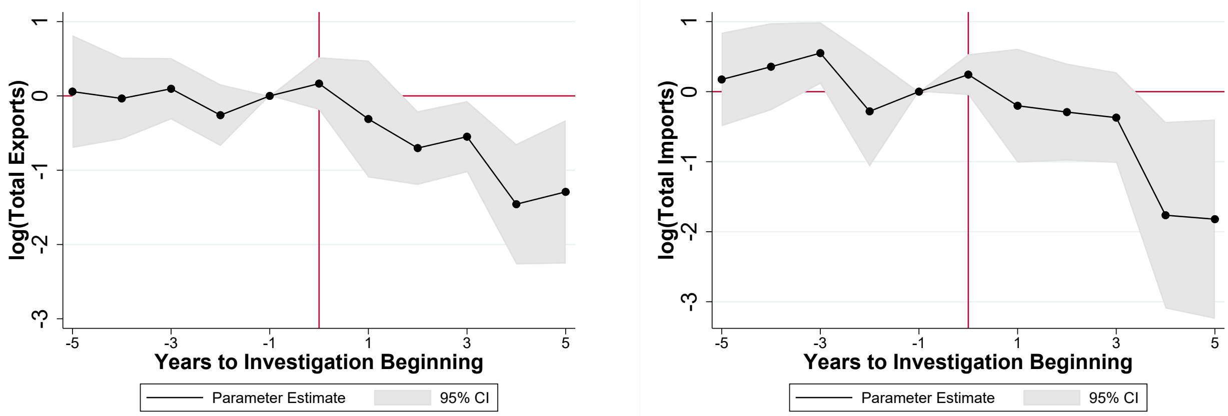
Second, the empirical results also suggest that trade sanctions can decrease Russian welfare. Because Russia decreases its total exports of the tariffed good, it must be the case that it cannot supply it easily to other countries. The decrease in total Russian demand leads to a drop in income, output, and prices in Russia.

Therefore, the empirical results indicate that if countries want to sanction Russia, they must incur economic loss. Given the degree of willingness to pay for sanctions, how should countries impose tariffs to maximize their own welfare and punish Russia? To answer this question, we build a model of international sanctions with input-output connection. The model is described in section 3.

Figure 2: **Impact of AD Tariffs on Product-level Total Exports and Total Imports**

(a) Exports to All Destinations

(b) Imports from All Origins



Description: This figure shows the dynamic impact of AD tariffs on total exports and total imports using Model 2. The impact on total imports and total exports is plotted on the y-axis. The number of years to the beginning of the investigation is plotted on the x-axis. Total exports refer to the total exports of the HS 6-digit level product by Russia to all destinations; these exports are of the same the same 6-digit product for which other countries initiated an AD investigation targeting Russia. Total imports refers to the imports of the HS 6-digit level product from all origins by the country that initiated an AD investigation targeting Russia; these imports are of the same 6-digit product on which the AD tariff has been imposed. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Antidumping Database (Bown 2005). The sample runs from 1995 to 2020. The sample includes the product–origins that faced at least one AD investigation. The shaded area contains the 95% confidence interval. Standard errors are clustered at the product–country level.

Table 1: **Effect of AD Tariffs on Russian Trade**

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Log Value	Log Quantity	Log Price	Log Total Exports	Log Total Imports
AD Tariff	-4.295**	-3.695*	-0.552**	-1.577**	-1.867**
	(1.890)	(1.951)	(0.217)	(0.726)	(0.743)
Observations	1,534	1,524	1,524	1,534	1,534
R-squared	0.807	0.811	0.872	0.804	0.839
Fixed Effects	Product X Importer, Importer X Year, Number of AD committees, After AD investigation				
Cluster	Product X Importer				
Robust standard errors in parentheses					
*** p<0.01, ** p<0.05, * p<0.1					

Description: This table presents the impact of AD tariffs that other countries imposed on Russia on Russian trade, estimated with Model 1. *Log Value* denotes the log of HS 6-digit level FOB current dollar value imports from Russia. *Log Quantity* denotes the log of the quantity (in metric tons) imported by another country from Russia on the HS 6-digit level. *Log Price* denotes the log of import price (measured with value per metric ton) by another country from Russia on HS 6-digit level. *Log Total Exports* denotes the log of HS 6-digit level total export value by Russia to all destinations for the same HS 6-digit product for which other countries initiated an AD investigation targeting Russia. *Log Total Imports* denotes the log of HS 6-digit level total imports from all origins by the country on which initiated an AD investigation targeting Russia for the same 6-digit product that the AD tariff is imposed. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Antidumping Database (Bown 2005). The sample runs from 1995 to 2020.

2.5 Estimation of Sector-level Trade Elasticity

We take advantage of the AD tariffs that all countries impose on all their trade partners to identify the trade elasticity at the sector level. We estimate trade elasticity for each goods sector listed in the 2018 OECD Inter-country Input-Output Database (OECD ICIO 2018).[15] To this end, we use a specification similar to Equation 1:

$$\begin{aligned} y_{p,d,o,t} = {} & \theta^{j(p)} \tau_{p,d,o,t} + \beta \mathbb{I}_{p,d,o,t} \{\text{After AD}\} + \gamma \mathbb{N}_{p,d,o,t} \{\text{Committee}\} \\ & + \eta_{p,t} + \eta_{p,d} + \eta_{p,o} + \eta_{d,t} + \eta_{o,t} + \epsilon_{p,d,o,t}, \end{aligned} \tag{3}$$

where p denotes the product, d denotes the destination, o denotes the origin of the trade flow, t denotes the year, and j denotes the sector that product p belongs to. Moreover, $y_{p,d,o,t}$ denotes the imports of product p from country o to country d in year t. $\tau_{p,d,o,t}$ denotes the AD tariff that country d imposes on country o in year t on the same product p. $\mathbb{I}_{p,d,o,t} \{\text{After AD}\}$ takes 1 if year t is after the first AD investigation that country d conducts on product p from country o. $\mathbb{N}_{p,d,o,t} \{\text{Committee}\}$ controls for the number of investigation committees formed at the same product-country-bilateral-year level. $\eta_{p,t}$, $\eta_{p,d}$, $\eta_{p,o}$, $\eta_{d,t}$, and $\eta_{o,t}$ denote product-year, product–destination, product–origin, destination–year, and origin–year fixed effects, respectively. Table A.6 shows the summary statistics for the variables included in this regression. Parameter $\theta^{j(p)}$ captures the effect of tariffs on imports of products in sector p. Because we are averaging the effect of tariffs over a long horizon, this parameter is an average of the long- and short-run trade elasticities. In Section 5.5, we calibrate the model using the long-run effect of tariffs on trade, i.e., the long-run trade elasticity. Table 2 shows our estimated trade elasticities by sector. These elasticities range from 1.36 (other non-metallic mineral products) to 8.98 (mining and energy products). After all sectors are pooled together, the estimated average trade elasticity is 6.09. Consistent with our intuition, sectors that are perceived as less substitutable across countries, for example, minerals and

[15]To ensure that there is sufficient cross-product variation to help us identify the trade elasticities by sector, we estimate the elasticities by pooling together the agriculture sector (D01-D02 of ISIC Rev. 4) and food sector (D10-D12 of ISIC Rev. 4), and pooling together all mining and energy sectors (D05-D09 and D19 of ISIC Rev. 4). We control for product–year, product–destination, product–origin, destination–year, and origin–year fixed effects separately to allow for sufficient variation in order to identify the elasticities by sector.

manufactured products, have lower trade elasticities than those that are perceived as more substitutable across countries, for example, energy and chemical products.

Figure A.5 shows that our estimated elasticities are correlated with the estimates of Caliendo and Parro (2015) and the values that we estimate using the Feenstra (1994) method.[16] On average, our estimates are lower than those found in Caliendo and Parro (2015) (in Figure A.5a more than half of the sectors are below the 45-degree line, and their average estimate across all sectors is 9.1).[17] Our estimates are higher than those that we estimate using the Feenstra (1994) method (in Figure A.5b, most sectors are above the 45-degree line).[18]

Table 2: **Estimated Sectoral Trade Elasticities, θ^j**

Sector	Estimate	Standard Err	p-value	Sector	Estimate	Standard Err	p-value
Agriculture	5.18	1.17	0.000	Plastic	5.56	1.06	0.000
Fishing	6.96	1.34	0.000	Mineral	1.36	1.69	0.423
Mining energy	8.98	1.47	0.000	Basic metals	6.59	1.20	0.000
Mining non-energy	8.98	1.47	0.000	Fabricated metals	5.19	1.11	0.000
Mining support	8.98	1.47	0.000	Computer	4.97	1.11	0.000
Food	5.18	1.17	0.000	Electrical	5.44	1.29	0.000
Textiles	6.96	1.34	0.000	Machinery n.e.c.	5.22	1.05	0.000
Wood	6.01	1.48	0.000	Auto	5.98	1.46	0.000
Paper	4.44	1.71	0.010	Other transport	5.33	1.17	0.000
Petroleum	8.98	1.47	0.000	Manufacturing n.e.c.	4.55	1.09	0.000
Chemical	7.45	1.26	0.000	Service	4.17	1.27	0.001
Pharmaceuticals	5.80	1.27	0.000				
All	6.09	0.86	0.000				

Description: This table presents the sector-level trade elasticities that we estimate using the difference-in-differences method. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Antidumping Database (Bown 2005). The sample runs from 1995 to 2020.

[16] The method relies on time series variation in prices and market shares of imported varieties of goods. The identifying assumption is that shocks to import demand and export supply are uncorrelated, which serves as the moment condition. The trade value and quantity data are from the BACI Database of CEPII (Gaulier and Zignago 2010), covering the time period 1995–2019.

[17] The reason why our estimates are lower than those recovered in Caliendo and Parro (2015) is likely the role of trade policy uncertainty. de Souza and Li (2021) show that our treatment and control groups faced similar trade policy uncertainty before a tariff was imposed. However, Caliendo and Parro (2015) do not control for trade policy uncertainty in their regressions. As trade policy uncertainty is likely positively correlated with tariffs (Handley and Limão 2017), this can exaggerate the estimates.

[18] Using the Feenstra (1994) method, the average elasticity across all sectors is 2.6. The reason why our estimates are higher than those estimated with the Feenstra (1994) method is likely that they did not take advantage of the time variations in tariffs.

3 Model

In this section, we present a multi-sector, multi-country quantitative trade model with input-output linkage. The exposition of the model has two sections. In the first section, tariffs are taken as given. In the second section, we present how governments choose tariffs.

3.1 Demographics

The global economy consists of N countries and J sectors. Each country has a mass L_n of households. The preference of country n's households is a Cobb-Douglas function of sector-level consumption goods, C_n^j. The labor supply of households is inelastic.

The household's problem is the following:

$$\max_{\{C_n^j\}_{j=1}^J} U_n = \prod_{j=1}^J \left(\frac{C_n^j}{\alpha_n^j}\right)^{\alpha_n^j}, \qquad \text{where} \sum_{j=1}^J \alpha_n^j = 1$$

$$\text{s.t.} \quad \sum_{j=1}^J P_n^j C_n^j = I_n,$$

where P_n^j denotes the sector j composite goods price in country n. I_n denotes the country's total income. The consumer's problem implies that country n's households face the following consumer price index:

$$P_n^C = \prod_{j=1}^J \left(P_n^j\right)^{\alpha_n^j}. \tag{4}$$

3.2 Intermediate Goods Producer

We assume that all markets are competitive, in the same way as Caliendo and Parro (2015). Labor is freely mobile across sectors within a country, but immobile across countries. A representative firm in country n and sector j produces with labor and intermediate inputs from all sectors with a Cobb-Douglas technology:[19]

$$Y_n^j = A_n^j \left[\frac{L_n^j}{\gamma_n^j}\right]^{\gamma_n^j} \prod_{k=1}^{J} \left[\frac{M_n^{j,k}}{\gamma_n^{j,k}}\right]^{\gamma_n^{j,k}},$$

where A_n^j denotes the total factor productivity (TFP), L_n^j denotes sectoral employment, and $M_n^{j,k}$ denotes the quantity of sector k composite goods used by sector j as an input. γ_n^j and $\gamma_n^{j,k}$ are input-output coefficients with $\gamma_n^j + \sum_{k=1}^{J} \gamma_n^{j,k} = 1$.

Profit maximization implies that the output price equals the marginal cost:

$$p_n^j = \frac{1}{A_n^j} [w_n]^{\gamma_n^j} \prod_{k=1}^{J} [P_n^k]^{\gamma_n^{j,k}}, \tag{5}$$

where w_n denotes the wage of country n.

3.3 Composite Goods

A country's consumers and firms source their composite goods from other countries. Let Q_n^j be the quantity of composite goods of sector j used in country n:

$$Q_n^j = \left[\sum_{i=1}^{N} (q_{ni}^j)^{(\sigma^j-1)/\sigma^j}\right]^{\sigma^j/(\sigma^j-1)},$$

where q_{ni}^j denotes the quantity of sector j output that country n buys from country i and where σ^j is the elasticity of substitution between countries. Because composite goods are used as consumption and inputs, it must be the case that:

$$Q_n^j = C_n^j + \sum_{k=1}^{J} M_n^{j,k} \tag{6}$$

[19]In the robustness test section, Section 5.5, we relax the assumption of a Cobb-Douglas production function. Instead, we use a CES production function and test the sensitivity of the results to different elasticities of substitution between inputs.

3.4 Expenditure Share

To get a unit of sector j output from country i, consumers and firms in country n need to pay:

$$p_{ni}^{j} = t_{ni}^{j} k_{ni}^{j} p_{n}^{j},$$

where $t_{ni}^{j} = 1 + \tau_{ni}^{j}$ is 1 plus the ad-valorem tariff that country n imposes on country i and where k_{ni}^{j} denotes the iceberg trade cost to ship one unit of sector j's output from country i to country n.

After country n chooses the quantity to source from each origin country i to minimize the cost of producing Q_{n}^{j}, country n's expenditure share on sector j's output from country i equals:

$$\pi_{ni}^{j} = \frac{(t_{ni}^{j} k_{ni}^{j} p_{i}^{j})^{1-\sigma^{j}}}{\sum_{h=1}^{N} (t_{nh}^{j} k_{nh}^{j} p_{h}^{j})^{1-\sigma^{j}}} \tag{7}$$

The composite goods price is thus given by:

$$P_{n}^{j} = \left[\sum_{i=1}^{N} (t_{ni}^{j} k_{ni}^{j} p_{i}^{j})^{1-\sigma^{j}} \right]^{1/(1-\sigma^{j})}. \tag{8}$$

From now on, we use $\theta^{j} = \sigma^{j} - 1$ to denote the trade elasticity.

3.5 Market Clearing

Let $X_{n}^{j} = P_{n}^{j} Q_{n}^{j}$ denote country n's total expenditure on sector j's composite goods. The market clearing condition for the composite goods implies that:

$$X_{n}^{j} = \sum_{k=1}^{J} \gamma_{n}^{k,j} \sum_{i=1}^{N} \frac{X_{i}^{k} \pi_{in}^{k}}{t_{in}^{k}} + \alpha_{n}^{j} I_{n}, \tag{9}$$

where the first term is country n's demand for inputs and the second term is the consumer's demand.

Household income, I_n, must be equal to labor income, tax revenue, and the trade deficit:

$$I_n = w_n L_n + R_n + D_n \tag{10}$$

where $w_n L_n$ is labor income, R_n is tariff revenue, and D_n is the trade deficit. Tariff revenue can be written as

$$R_n = \tau_{ni}^j \sum_{i=1}^{N} \frac{X_i^k \pi_{in}^k}{t_{in}^k}. \tag{11}$$

Using Equation 9 and the definition of the trade deficit, we can write the labor market clearing condition:

$$w_n L_n = \sum_{j=1}^{J} \gamma_n^j \sum_{i=1}^{N} \frac{X_i^j \pi_{in}^j}{t_{in}^j}. \tag{12}$$

With that, we are ready to define an equilibrium given tariffs.

Equilibrium given Tariffs *Given tariffs $\{\tau_{ni}^j\}_{j,n,i}$, an equilibrium is defined as a set of sectoral prices ,$\{P_n^j\}_{n,j}$, and wages, $\{w_n\}_n$, such that*

1. *firms maximize profit (Equation 5);*

2. *the price index satisfies Equations 7 and 8;*

3. *the goods markets clear, satisfying Equations 9 and 10;*

4. *the labor market clears, satisfying Equation 12;*

5. *the government budget constraint (Equation 11) holds.*

3.6 Tariff Competition

Import tariffs are chosen by governments. Countries are in three groups according to how they choose tariffs. There are sanctioning countries, the sanctioned country (Russia, in this case), and neutral countries (the rest of the world [ROW]). The sanctioning countries choose tariffs, trading off between two objectives. On the one hand, they want to maximize their domestic households' welfare. On the other hand, they want to minimize Russian welfare. Russia also chooses tariffs to maximize its own welfare and reduce the sanctioning countries' welfare. We assume that the neutral countries do not change tariffs.[20]

Before we formally define the problem of a sanctioning country, let $\boldsymbol{\tau_{nR}}$ be the vector of sectoral tariffs that country n imposes on Russia. Let $\boldsymbol{\tau_{-nR}}$ be all global tariffs except what n imposes on Russia. Use $G_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})$ to denote the equilibrium welfare in country n under tariff policy $(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})$:

$$G_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}) = \frac{I_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})}{P_n^C(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})}, \tag{13}$$

where $I_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})$ denotes household income (Equation 10) and $P_n^C(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})$ denotes the consumer price index (Equation 4).

Conditional on $\boldsymbol{\tau_{-nR}}$, the objective of sanctioning country n is:

$$g_n(\boldsymbol{\tau_{-nR}}) \in argmax_{\{\boldsymbol{\tau_{nR}}\}} \rho G_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}) - (1-\rho) G_R(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}), \tag{14}$$
$$\text{s.t. Equilibrium Conditions 5-12,}$$

where ρ is the willingness to pay for sanctions against Russia. In other words, the local government is willing to pay $\$\frac{1-\rho}{\rho}$ for every US\$1 of consumption forgone in Russia. This specification nests two special cases. When $\rho = 1$, country n maximizes its own real income, and when $\rho = 0$, country n minimizes Russia's real income without consideration for its own welfare.[21]

Russia, the sanctioned country, trades off maximizing its own welfare and retaliating against the countries imposing the sanctions. Use $\boldsymbol{S}$ to denote the set of sanctioning coun-

[20] In section 5.3.2, we study the case in which neutral countries join the sanctioning allies. In section 5.5.2, we also consider the case in which Russia keeps its tariffs constant.

[21] In Section C.5, we consider an alternative cost-efficient sanction problem whereby the sanctioning countries minimize Russia's welfare but require that their own welfare does not decrease.

tries. Russia's problem is as follows:

$$g_R(\boldsymbol{\tau_{-RS}}) \in argmax_{\{\boldsymbol{\tau_{RS}}\}} \rho G_R(\boldsymbol{\tau_{RS}}, \boldsymbol{\tau_{-RS}}) - (1-\rho) \sum_{n \in S} \frac{G_n(\boldsymbol{\tau_{RS}}, \boldsymbol{\tau_{-RS}})}{N_S} \tag{15}$$

s.t. Equilibrium Conditions 5-12,

where $G_R(\boldsymbol{\tau_{RS}}, \boldsymbol{\tau_{-RS}})$ is the equilibrium welfare in Russia and $\sum_{n \in S} \frac{G_n(\boldsymbol{\tau_{RS}}, \boldsymbol{\tau_{-RS}})}{N_S}$ is the average real income of the sanctioning countries. As with sanctioning countries, ρ captures the willingness to pay for tariff retaliation against sanctioning countries.[22] We call the equilibrium tariffs that are a solution to Problems 14 and 15 cost efficient sanctions.

Equilibrium with Sanctions *Given* $\{\{\tau^j_{ni}\}_{j,n \in S, i \neq R}, \{\tau^j_{Ri}\}_{j, i \notin S}, \{\tau^j_{ni}\}_{j, n \notin S, i \neq R}\}$, *an equilibrium with optimal sanctions is given by tariffs imposed on Russia by sanctioning countries,* $\{\boldsymbol{\tau_{nR}}\}_{n \in \boldsymbol{S}}$, *tariffs imposed on sanctioning countries by Russia,* $\{\boldsymbol{\tau_{Rn}}\}_{n \in \boldsymbol{S}}$, *a set of sectoral prices,* $\{P^j_n\}_{n,j}$, *and wages,* $\{w_n\}_n$, *such that*

1. *given tariffs* $\{\tau^j_{ni}\}_{j,n,i}$, $\{\{P^j_n\}_{n,j}, \{w_n\}_n\}$ *is an equilibrium;*

2. *sanctioning countries and Russia optimally choose their tariffs:*

$$\boldsymbol{\tau_{nR}} = g_n(\boldsymbol{\tau_{-nR}}), \forall n \in \boldsymbol{S}$$
$$\boldsymbol{\tau_{RS}} = g_R(\boldsymbol{\tau_{-RS}}).$$

To solve a counterfactual equilibrium, we rewrite the model in changes. In this way, we eliminate the fundamentals that are invariant to tariff changes and are difficult to calibrate (for example, non-tariff trade barriers $\{k^j_{ni}\}_{j,n,i}$). We present the sanction equilibrium in changes in Appendix Section B.1.

[22]In the baseline scenario in Section 5, we assume that Russia has the same ρ as the sanctioning countries. In Section 5.5.2, we also consider that Russia retaliates by always maximizing its own welfare $\rho_{RUS} \equiv 1$ and by always minimizing the sanctioning countries' welfare $\rho_{RUS} \equiv 0$. We show that sanctioning countries' strategies and their real income changes are not significantly affected by Russia's retaliation strategy.

4 Calibration

To calibrate our model, we rely on two main data sources: 1) the OECD Inter-Country Input-Output (OECD ICIO) Database and 2) our estimates of the trade elasticities. We calibrate the baseline global economy to their levels in 2018, the latest year for which a world input-output table is available. We let each sector $j \in \{1, 2, ..., 22\}$ denote the 22 goods sectors considered in OECD ICIO and $j = 23$ denotes a merged service sector.[23] Countries $i, n \in \{\text{EUN,OSA,ROW,RUS,USA}\}$ denote the European Union, other sanctioning countries, rest of the world, Russia, and the United States.[24] The EU and the US are the two largest economies that are sanctioning Russia. Other sanctioning countries include Australia, Canada, Israel, Japan, South Korea, New Zealand, Norway, Singapore, Switzerland, Taiwan, and the United Kingdom (UK), which are the economies that had joined sanctions on Russia by March 31, 2022.[25] We combine these other sanctioning economies because of the collaborative nature of the sanctions, and we reduce the number of countries for which we have to show the optimal sanctioning tariffs. ROW includes all other economies that are covered by OECD ICIO. These countries have not imposed sanctions on Russia and will thus not change their tariffs throughout our analysis. Therefore, we combine them into one economy.[26]

We calibrate country-bilateral and sector-level expenditure shares, π_{ni}^{j}, country-level input-output coefficients, $\gamma_n^{k,j}$, country-level value added, $w_n L_n$, and country-level trade deficit, D_n, directly to their data counterparts in OECD ICIO.

[23] See Appendix Table A.11 for the list of OECD ICIO sectors and their correspondence with the International Standard Industrial Classification (ISIC) Rev. 4 sectors. As there is no import tariff variation in the service sectors, we merge all service sectors into one single sector.

[24] The EU countries that are covered by OECD ICIO are as follows: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Morocco, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, and Sweden.

[25] See `https://graphics.reuters.com/UKRAINE-CRISIS/SANCTIONS/byvrjenzmve/` for the evolving list of countries that have sanctioned Russia.

[26] Section C.1 in the Appendix discusses the statistics of Russian trade.

5 Results

5.1 Cost-Efficient Sanctions

In this section, we discuss the cost-efficient sanctions imposed by the EU. Figure 3 shows the statistics relating to the optimal sanctions imposed by the EU according to the different levels of willingness to pay for sanctions, ρ. The first panel plots the cost-efficient sanctions for selected sectors. The second panel plots the change in imports in the EU implied by different sanctioning schemes.

The EU should increase tariffs and decrease trade with Russia, even if the willingness to pay for sanctions is zero ($\rho = 1$), as shown in Figure 3. This is because higher tariffs on Russia lead to a decrease in the price of imported goods relative to exported ones, resulting in an increase in the EU's real income.[27] This result suggests that, to a certain degree, sanctioning countries can improve their own welfare and harm the Russian economy simultaneously.

Even when there is low willingness to pay for sanctions, imports from Russia should drop by more than 80%. When the EU's willingness to pay for sanctions is positive, it decreases trade with Russia by more than 60%. When there is a willingness to pay only \$0.40 per \$1 decline in Russian income, i.e., $\rho = 0.7$, the EU imposes tariffs that decrease imports from Russia by 95%.

Cost-efficient sanctions are small and uniform across sectors when there is low willingness to pay for sanctions, as shown in to Figure 3. If the EU is willing to pay \$0.10 for each \$1 decline in Russian income, i.e., $\rho = 0.9$, tariffs should average about 20% for all sectors. Tariffs increase with a higher willingness to pay, but the dispersion across sectors is small.[28]

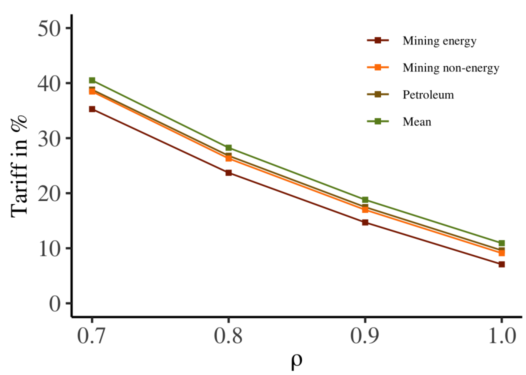
If the EU is willing to pay over \$0.70 dollars for each \$1 decline in Russian income, i.e., ρ is below 0.6, high taxes on mining and energy products are optimal. Figure 4 extends the horizontal axis of Figure 3 to $\rho = 0.4$, according to which the EU is willing to pay \$1.50 for each \$1 decline in Russian income, and shows the optimal tariffs and trade flow changes accordingly. If the EU pays \$0.70 dollars to reduce Russian real income by \$1, tariffs on

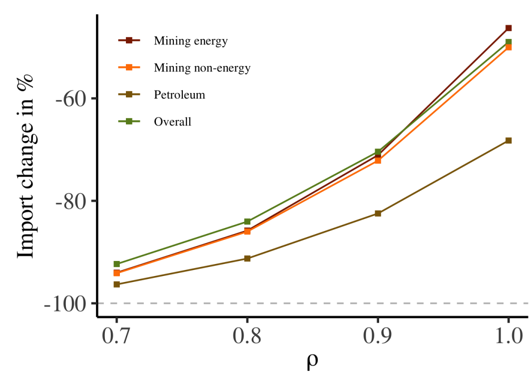
[27] This is the traditional terms-of-trade effect discussed in, for example, Bagwell and Staiger (1990).

[28] In Section C.5, we solve the alternative cost-efficient sanction problem where the sanctioning countries minimize Russia's welfare while not decreasing their own welfare. We find that those cost-efficient sanction tariffs resemble the optimal tariffs under low willingness to pay for sanctions.

mining and energy products are especially high, as shown in Figure 5. The tariff on energy extraction sector products, including crude oil and natural gas, is above 300%, and the tariff on petroleum is above 200%. In this case, an embargo on Russian oil and gas combined with high tariffs on other sectors is the most cost-efficient policy. When the willingness to pay rises to $1.50, tariffs on all sectors are above 80% and an embargo on all sectors is optimal.

Figure 3: **Cost-Efficient Sanctions in the EU for Different ρs,** $\rho \in [0.7, 1.0]$





Description: This figure shows the statistics for the EU under cost-efficient sanctions against Russia that vary by the level of willingness to pay for them. ρ ranges from 0.7 to 1.0. Figure 3a plots the cost-efficient sanctions on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors by different levels of willingness to pay for sanctions, ρ. Figure 3b plots the percentage change in imports in the EU for different sectors by different levels of willingness to pay for sanctions, ρ.

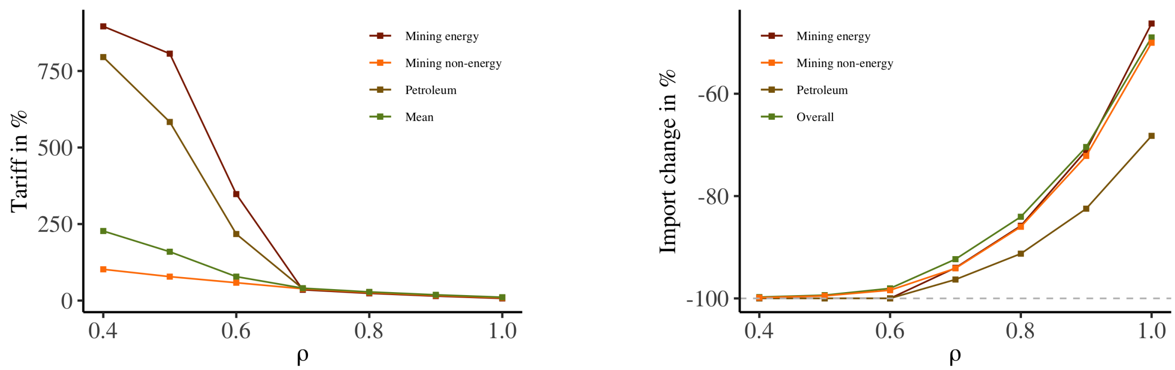
Conditional on the willingness to pay for sanctions, trade elasticities and initial import share are important determinants of tariffs. For a low willingness to pay, tariffs target products with a low trade elasticity and a low import share from Russia. In this case, countries use tariffs to manipulate the terms of trade, i.e., to raise the export price relative to the import price (see, for example, Bagwell and Staiger 1990). The products in which the terms of trade are more affected by tariffs are the ones with lower demand elasticity and lower import share.[29]

When there is a high enough willingness to pay for sanctions, tariffs are targeted at sectors with a large import share from Russia and with a high trade elasticity. Sanctioning these sectors can divert more Russian exports to other countries, reduce Russian output

[29]For a formal proof, see Gros (1987), Broda et al. (2008), Opp (2010), Costinot et al. (2015), and Lashkaripour and Lugovskyy (2021), who derive theories that link optimal tariffs to market shares and trade elasticities.

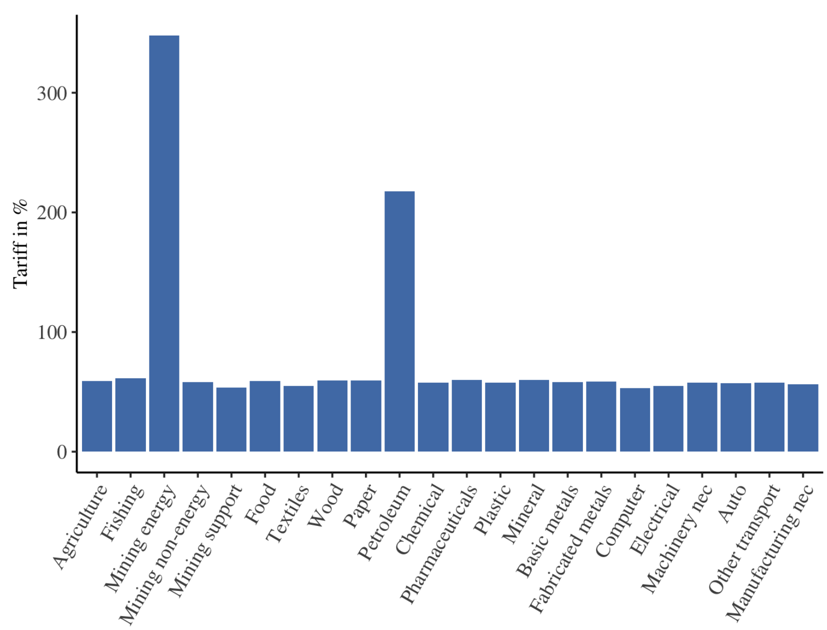
Figure 4: **Cost-Efficient Sanctions in the EU for Different ρs, $\rho \in [0.4, 1.0]$**

(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the EU under cost-efficient sanctions against Russia that vary by the level of willingness to pay for them. ρ ranges from 0.4 to 1.0. Figure 3a plots the cost-efficient sanctions on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors by different levels of willingness to pay for sanctions, ρ. Figure 3b plots the percentage change in imports in the EU for different sectors by different levels of willingness to pay for sanctions, ρ.

Figure 5: **Cost-Efficient Sanctions in the EU for** $\rho = 0.6$



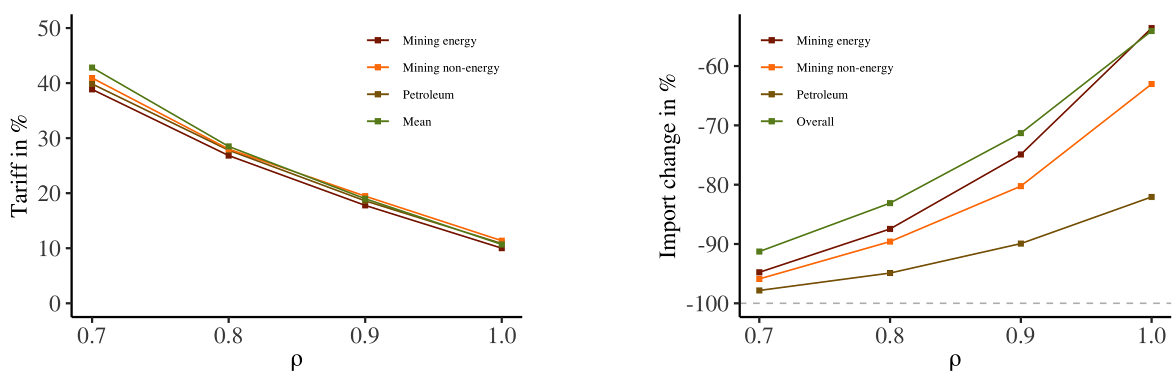
Description: This figure shows the cost-efficient sectoral tariffs that the EU imposes on Russia at $\rho = 0.6$ – the EU is willing to pay \$0.70 dollars for \$1 real income loss in Russia.

further, and cause more harm in Russia. Appendix C.2 discusses these intuitions in detail.

The US and OSA follow the same pattern of cost-efficient sanctions, as shown in Figures 6 and 7. In both cases, cost-efficient sanctions are small and uniform across sectors for low willingness to pay for sanctions, but they still cause a large drop in trade with Russia. Figure C.5 shows that as the willingness to pay increases, US optimal tariffs increase uniformly across sectors. The reason is that, as Figure A.4a shows, the share of US expenditure on Russia is small and similar across sectors. Figure C.6 shows that for other sanctioning countries, an embargo on mining and energy sectors is optimal if they would like to pay \$1 to reduce Russia's income by \$1. If the willingness to pay rises to \$1.50, an embargo by all sanctioning countries on all Russian products is optimal.

Figure 6: **Cost-Efficient Sanctions in the US for Different ρs, $\rho \in [0.7, 1.0]$**

(a) Tariff (b) Change in Imports



Description: This figure shows the statistics of the US under cost-efficient sanctions with different levels of willingness to pay. Figure 6a plots the cost-efficient sanctions on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure 6b plots the percentage change in imports in the US for different sectors.

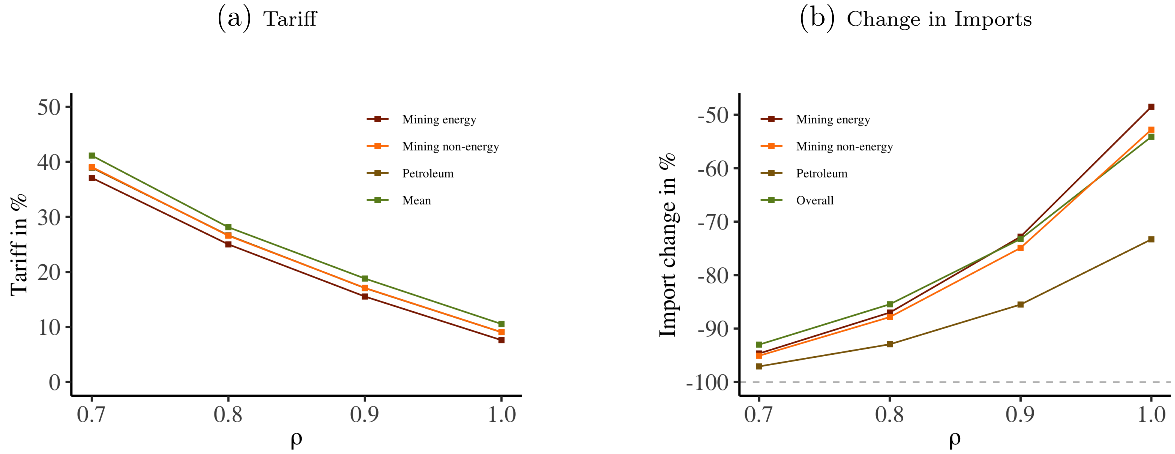
5.2 The Welfare Cost of Sanctions

5.2.1 The Welfare Cost of Sanctions for Russia

How much welfare loss can sanctions cause in Russia? To answer this question, Figure 8 shows the welfare changes for Russia and the sanctioning countries under two scenarios: with and without Russian retaliation. In the case with retaliation, similar to the sanctioning countries, Russia chooses tariffs based on Problem 15. In the case without Russian retaliation (8b), Russian tariffs are constant at the calibrated value.

As shown in Figure 8, sanctions can decrease Russian welfare by between 0.5% and 3%. Without Russian retaliation, i.e., if Russian tariffs are constant at the calibrated values, the

Figure 7: **Cost-Efficient Sanctions in the OSA for Different ρs, $\rho \in [0.7, 1.0]$**



Description: This figure shows the statistics for the OSA under cost-efficient sanctions with different levels of willingness to pay. Figure 7a plots the cost-efficient sanctions on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure 7b plots the percentage change in imports in the OSA at different sectors.

welfare loss in Russia ranges from 0.5% to 1.2%, depending on the willingness to pay of the sanctioning countries. If Russia retaliates, the welfare cost of sanctions can be as large as 3% due to the the economic size difference between Russia and the sanctioning countries. The sanctioning countries are an important sourcing origin for Russia, whereas Russia is not an important exporting destination for the sanctioning countries.[30] Because of this, restricting imports from the sanctioning countries can have little impact on the sanctioning countries' income, but it induces a large price increase and real income loss in Russia.[31]

5.2.2 The Welfare Cost of Sanctions on Sanctioning Countries

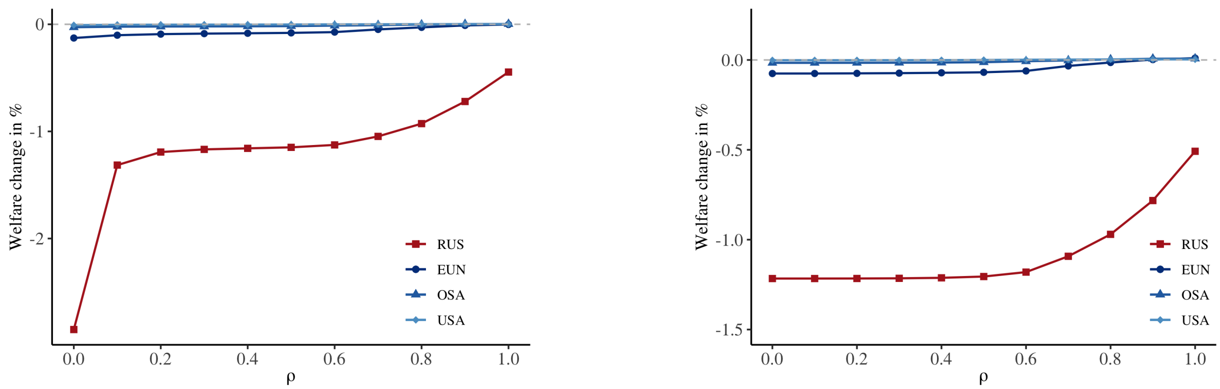
How much do sanctions cost the sanctioning countries? As shown in Figure 8, the welfare cost of sanctions is small. The sanctioning countries face a welfare loss ranging from 0.1% to 0.2%, depending on Russia's response to the sanctions. Additionally, Figure 8 highlights that imposing sanctions on Russia can benefit the sanctioning allies. If the sanctioning

[30] Russia spends 5.2% of their total expenditures on the sanctioning countries. The sanctioning countries sell 0.2% of their output to Russia. See Figures A.4c and A.4d.

[31] This finding also indicates that, as long as Russia cares about domestic welfare ($\rho_{RUS} \geq 0.1$), Russia should not impose high retaliatory tariffs on the sanctioning countries, and the consequences of sanctions are similar both with and without Russian retaliation. In Section 5.5.2, we elaborate on this point further. We show that the sanctioning countries' optimal tariffs are not significantly affected by Russia's retaliation strategies.

Figure 8: **Welfare Changes with and without Russian Retaliation**

(a) With Russian Retaliation (b) Without Russian Retaliation



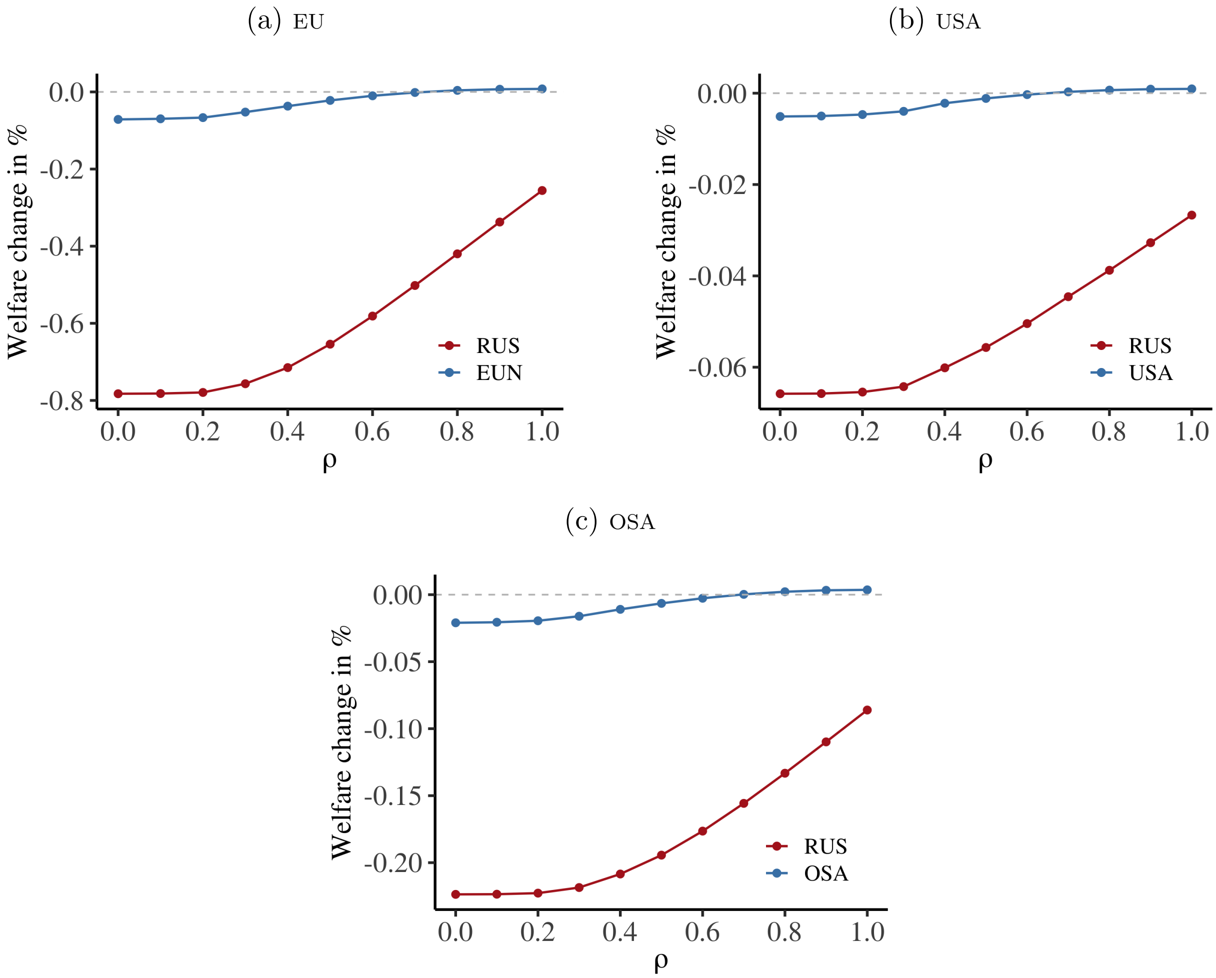
Description: This figure shows the welfare change by the different levels of willingness to pay for sanctions, ρ, under two variations of the model discussed in Section 3. Figure 8a displays the welfare changes for Russia, the EU, the OSA, and the US when Russia also changes its tariffs to affect the welfare of the sanctioning countries. Figure 8b displays the welfare change in Russia, the EU, the OSA, and the US under the assumption that Russia keeps its tariffs constant. Welfare refers to the equilibrium real income. Changes are calculated by comparing the resulting equilibrium from the new tariffs to the equilibrium with initial, pre-sanction tariffs.

allies are not willing to pay for sanctions but choose tariffs on Russia to maximize their own welfare, i.e., $\rho = 1$, their welfare increases by 0.01%, 0.003%, and 0.003% in the EU, US, and OSA, respectively. Given the sanctioning allies' significant size and wealth advantage over Russia, they can alter the terms of trade in their favor, which harms Russia's economy while benefiting the sanctioning countries.

This finding is especially significant because it emphasizes the impact of revoking Russia's MFN status, which was one of the initial sanction measures imposed on Russia. With the implementation of this new regime, countries that are part of the WTO have the freedom to impose arbitrary tariffs on Russia. Therefore, even if these countries do not intend to harm Russia's economy, they can still inflict severe losses on Russia by selecting tariffs that enhance their own welfare.

To understand which of the sanctioning countries can have a greater impact on Russia, we consider the case where the EU, the US, and the OSA individually set tariffs to target Russia's real income. For simplicity, we assume that Russia keeps its tariffs constant. Figure 9 shows the welfare changes for Russia and the sanctioning countries under unilateral sanctions. Each of the three sub-figures plots the counterfactual equilibrium in which one country chooses

Figure 9: **Welfare Changes with Individual Sanctions**



Description: This figure shows the welfare change for different willingness to pay for sanctions, ρ, under the equilibrium tariffs of the model with individual sanctions. Figure 9a shows the welfare change if the EU chooses tariffs on Russia to maximize 14 while all the other countries hold tariffs constant. Figure 9b shows the welfare change if the US chooses tariffs on Russia to maximize 14 while all the other countries hold tariffs constant. Figure 9c shows the welfare change if the OSA chooses tariffs on Russia to maximize 3 while all the other countries hold tariffs constant. Welfare refers to the equilibrium real income. Changes are calculated comparing the equilibrium to the current tariffs.

tariffs on Russian imports based on Problem 14, while Russia and all the other countries keep their tariffs constant.

According to Figure 9, the EU is the sanctioning group most affected by sanctions against Russia. If $\rho = 0$, i.e., tariffs against Russia are chosen to minimize Russian welfare, the EU has a welfare loss of 0.1%. The US and OSA have a welfare loss of only 0.01% and 0.02%. The reason is that the EU trades the most with Russia.

The EU is also the trade partner that can cause the largest welfare damage to Russia. The EU alone can reduce welfare in Russia from 0.26% to 0.78%, whereas US sanctions can only reduce Russian welfare by no more than 0.1%.

5.3 Sanctions and the Rest of the World

In this section, we study how the ROW is affected and, in turn, affects the cost-efficient sanctions against Russia. First, we show that countries not imposing sanctions benefit from lower priced goods from Russia and higher priced goods sold to the sanctioning allies. Furthermore, if the ROW joined the allies in imposing sanctions, even a low willingness to pay for sanctions would result in an embargo on Russia's oil and energy sectors.

5.3.1 Effect of Sanctions on Non-Sanctioning Countries

Figure 10a shows that the ROW increases its exports in response to sanctions imposed on Russia. As countries increase barriers against Russia, sanctioning countries substitute imports from Russia with imports from the ROW. This phenomenon, known as the trade diversion effect, causes an increase in ROW exports.[32]

Imports by Russia from the ROW has a non-monotonic relation with the willingness to pay for sanctions. Because Russia is imposing high tariffs against the sanctioning allies, Russia reduce imports from them and increase imports from the ROW. But, for high willingness to pay for sanctions, Russian income decreases with the sanctions being imposed by the Allies, which leads to a decrease in imports from the ROW.

Figure 10b shows that sanctions against Russia increase imports by the ROW. As the sanctioning allies and Russia impose tariffs on each other, the prices of exported goods in both countries decrease, which motivates the ROW to import more of these goods. However, this effect is not monotonous. High willingness to pay for sanctions causes tariffs to raise the marginal cost of production in Russia, leading to lower imports by the ROW.

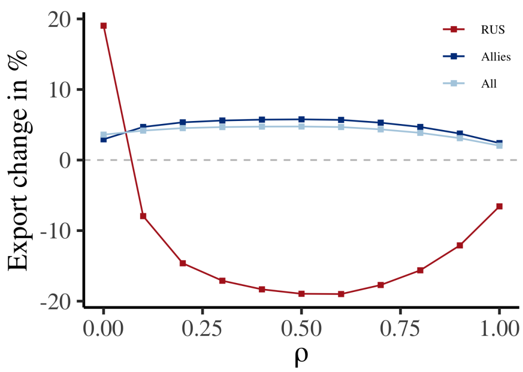
Trade sanctions increase welfare for the ROW, as shown in Figure 10c. The ROW benefits from the sanctions because it positively impacts their terms of trade. The trade diversion

[32]Because Russia suffers from a large income loss even for small willingness to pay for sanction, the effect of trade diversion only dominates when $\rho = 0$ and Russia closes its border for trade with the allies. Since there is a stronger demand for ROW's exports from Russia at highest willingness to pay for sanctions, ROW's exports to the allies are diverted to Russia. Therefore, at high willingness to pay for sanctions, ROW's exports to the allies do not increase as much.

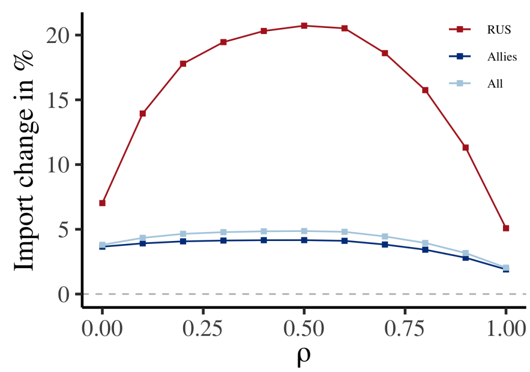
effect results in an increase in the price of exported goods, while the price of imported goods decreases. This leads to an overall increase in welfare for the ROW.

Figure 10: **Effect of Cost-Efficient Sanctions in the ROW**

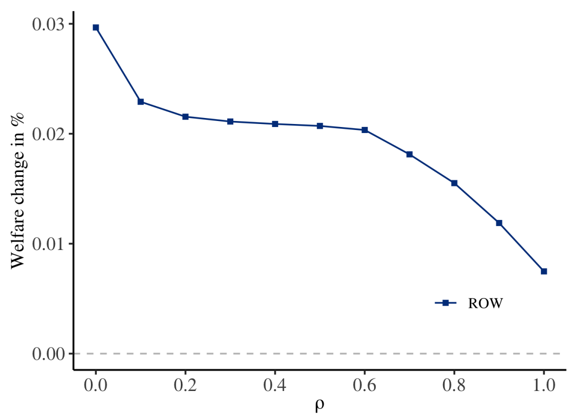
(a) Change in Exports



(b) Change in Imports



(c) Welfare



Description: This figure shows the statistics for the ROW under cost-efficient sanctions against Russia that vary by the level of willingness to pay for sanctions. We assume that the ROW keeps all its tariffs constant. ρ ranges from 0.4 to 1.0. Figure 10a plots the percentage change in exports from the ROW to the sanctioning allies and to Russia, and the overall change in exports. Figure 10b plots the percentage change in imports by the ROW from the sanctioning allies and from Russia, and the overall change in imports. Figure 10c plots the percentage change in welfare in the ROW.

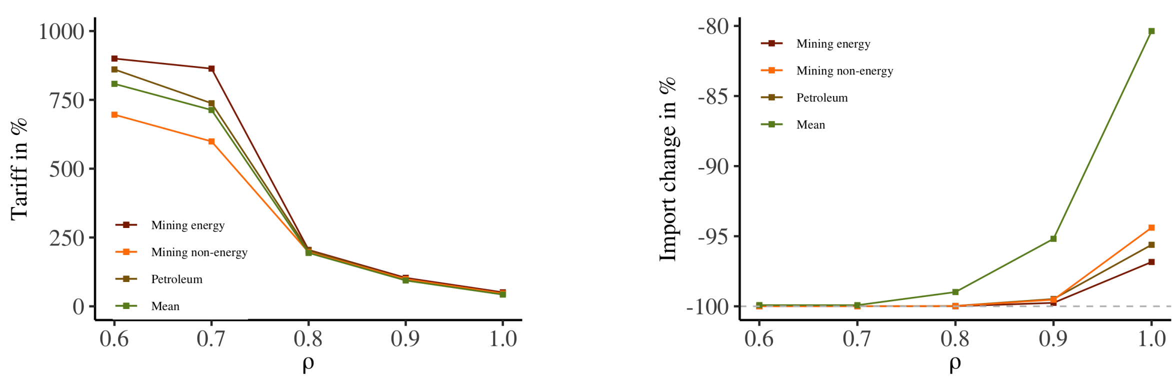
5.3.2 Larger Coalition

What would happen to the cost-efficient sanctions if a larger coalition of countries joined the current group of sanctioning allies? To answer this question, in this section, we calculate the cost-efficient sanctions when the ROW joins the sanctioning allies. Our findings reveal that if the ROW were to join the sanctions, the EU and other sanctioning allies could impose an embargo on Russia even with low willingness to pay for sanctions. Additionally, the welfare effects of these sanctions on Russia would increase significantly.

If the ROW joined the sanctioning allies, the EU could impose even higher tariffs on Russia for any willingness to pay for sanctions, as shown in Figure 11. When Russia still has the ROW to trade with, the impact of each individual sanctioning country on Russia's welfare is limited because Russia can redirect its trade to other countries that have not imposed sanctions. This reduces the benefits of imposing higher sanctions on Russia. However, if other countries are already imposing high tariffs on Russia, each individual country that joins the sanctions will have a significant impact on Russia's remaining trade. This increases the potential benefits of imposing sanctions on Russia and leads to an overall increase in the level of sanctions.

Figure 11: **Cost-Efficient Sanctions in the EU for Different ρs if the ROW Joins the Sanctioning Allies,** $\rho \in [0.6, 1.0]$

(a) Tariff (b) Change in Imports

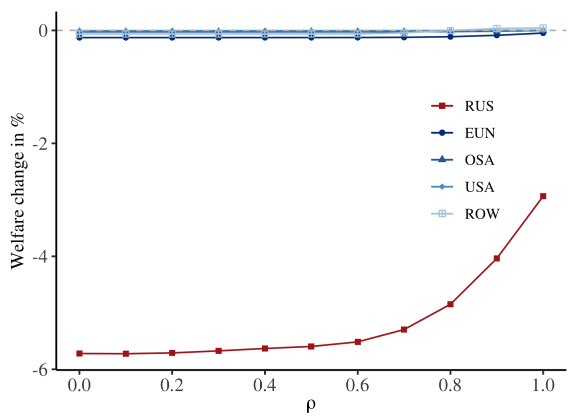


Description: This figure shows the statistics for the EU under cost-efficient sanctions against Russia that vary by the level of willingness to pay for sanctions. We assume that all countries join the sanctions against Russia and that Russia retaliates. ρ ranges from 0.6 to 1.0. Figure 3a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors by different levels of willingness to pay for sanctions, ρ. Figure 3b plots the percentage change in imports in the EU for different sectors by different levels of willingness to pay for sanctions, ρ.

According to Figure 12, sanctions would have a much greater impact on the Russian economy if the ROW joined the sanctioning allies. The welfare cost of sanctions for Russia would go from 2% up to 6%, depending on the willingness to pay for sanctions. Two forces cause the increase in the welfare effect of sanctions. First, when all countries impose sanctions against Russia, all of Russia's exports are disrupted. Second, because Russia also retaliates against all countries in the world, Russian imports are also affected. Together, these two forces dramatically amplify the impact of sanctions against Russia.

Figure 12 also shows that if countries were allowed to set their tariffs on Russia to maximize their own welfare, Russian welfare would decrease by 2.5%. This is because countries would manipulate the terms of trade jointly, leading to a significant drop in the price of Russia's exported goods. This demonstrates that, to some extent, countries can increase their own welfare while reducing Russia's welfare. Therefore, policies that permit countries to impose arbitrary tariffs on Russia, such as revoking Russia's MFN status, can have significant welfare implications for Russia.

Figure 12: **Welfare Changes if the ROW Joins the Sanctioning Allies with Russian Retaliation**



Description: This figure shows the welfare change for different levels of willingness to pay for sanctions, ρ, under the equilibrium tariffs of the model. In this specification, the ROW and the sanctioning allies are imposing sanctions against Russia. Figure 9a shows the welfare change if the EU chooses tariffs on Russia to maximize 14 while all the other countries hold tariffs constant. Figure 9b shows the welfare change if the US chooses tariffs on Russia to maximize 14 while all the other countries hold tariffs constant. Figure 9c shows the welfare change if the OSA chooses tariffs on Russia to maximize 3 while all the other countries hold tariffs constant. Welfare refers to the equilibrium real income. Changes are calculated comparing the equilibrium to current tariffs.

5.4 Political Weights

In this section, we calculate cost-efficient sanctions if the sanctioning countries target politically relevant sectors instead of the Russian economy as a whole. We show that an embargo on the Russian mining and energy sectors is optimal, even when there is a low willingness to pay for sanctions.

Government's Problem We assume now that the sanctioning countries want to target particular sectors in Russia according to their political relevance. Let $G_R^{pol}(\tau)$ be the politically weighted welfare in Russia and τ the vector of tariffs imposed by all countries. Formally, the politically weighted welfare is given by

$$G_R^{pol}(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}) = \sum_{j=1}^{J} \lambda^j \frac{I_R^j(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}{P_R^C(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}, \tag{16}$$

where λ^j is the political weight of sector j and $\frac{I_R^j(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}{P_R^C(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}$ is real income in sector j.[33]

The best response of sanctioning country n can now be formulated as the following:

$$g_n^{pol}(\boldsymbol{\tau_{-nR}}) \in argmax_{\{\boldsymbol{\tau_{nR}}\}} \rho G_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}) - (1-\rho) G_R^{pol}(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}), \tag{17}$$

s.t. Equilibrium Conditions 5-12,

where ρ is the willingness to pay for sanctions targeting politically relevant sectors.

Calibration We calibrate political weights to reflect the revenue share of companies owned by individuals sanctioned by the EU, UK, or US. First, we collect the names of the Russian individuals who had been sanctioned by the EU, UK, and US by March 10, 2022.[34]. Those are part of the Russian political elite, called oligarchs, which are believed to support the current regime. We also acquire the names of the companies that they own. Second, we collect the names, sales, and industries of the top 100 Russian companies by revenue from RBC 500, a website that publishes ratings for Russian companies, and match them to the list of sanctioned people.[35] Third, we connect the industry names used in RBC 500 to OECD

[33]Real income in sector j is measured with $\frac{L_R^j(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})}{L_R} \frac{I_R(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}{P_R^C(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}$, where $\frac{L_R^j(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}})}{L_R}$ is Russia's employment share in sector j, and $\frac{I_R(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}{P_R^C(\tau_{\mathbf{nR}}, \tau_{\mathbf{-nR}})}$ is real income. In this model, sector j's employment share is also the sector's share in Russian GDP. In Appendix Section B.2, we rewrite this optimal sanction problem in changes.

[34]The source is an article by the Guardian: `https://www.theguardian.com/world/2022/mar/04/russia-oligarchs-business-figures-west-sanction-lists-us-eu-uk-ukraine`

[35]The RBC 500 rating has been published since 2015. The rating identifies the largest Russian companies in terms of net revenue. The rating involves companies owned by Russian individuals and legal entities, regardless of their registration in Russia or abroad. The main source of the financial indicator comes from consolidated financial statements. In the case of no available consolidated financial statements, indicators are estimated.

ICIO sectors. In the last step, we calculate, for each OECD ICIO sector, the share of sales by major Russian companies owned by oligarchs in the sector's total sales (output). We use these shares as our political weights, λ_{Rj}.

Table 3: **Summary Statistics for Political Weights**

Sector	**# Firms owned by Oligarchs**	**Oligarch Share (λ_{Rj})**
Agriculture	2	4.89%
Mining energy	11	47.56%
Mining non-energy	6	57.57%
Petroleum	7	57.84%
Chemical	5	41.47%
Basic metals	7	12.79%
Machinery n.e.c.	1	14.31%
Manufacturing n.e.c.	1	9.75%
Service	32	8.82%

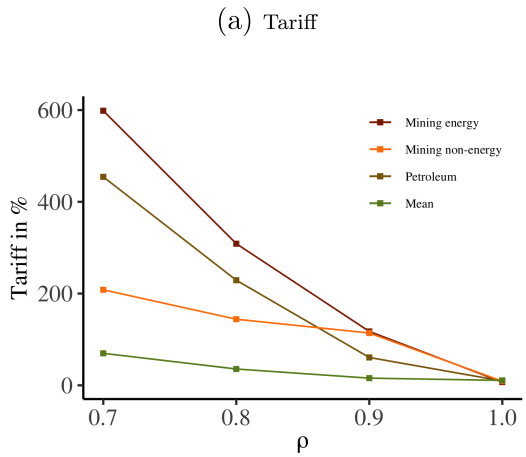
Description: This table presents the summary statistics for the political weights. The table shows, in each sector, the number of top 500 Russian firms owned by Russian oligarchs and the revenue share generated by these firms. We omit the sectors without major oligarch-owned firms.

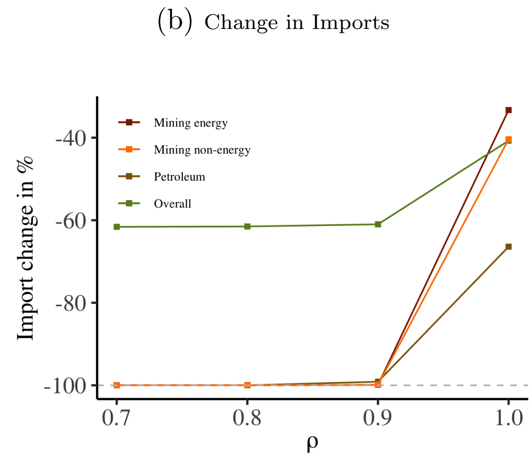
Table 3 shows the summary statistics of political weights computed using the Russian oligarchs' share of revenue in each sector. Nine out of 23 sectors have oligarch-owned firms, of which the petroleum sector has the highest political weight at 57.84%, indicating that over half of the revenue in this sector is generated by firms owned by oligarchs.

Results Even for countries with a low willingness to pay for sanctions, an embargo on the Russian mining and energy sectors would be the most cost-efficient sanction, according to the results shown in Figure 13. If the EU is willing to pay \$0.10 for each \$1 drop in Russian income, i.e., $\rho = 0.9$, tariffs should be concentrated in the mining and energy sectors. This is because these are the sectors with the highest concentration of firms owned by Russian oligarchs. Moreover, tariffs would be high enough to decrease imports of mining and energy products from Russia by almost 100%.

Figures C.7 and C.8 show the optimal sanction tariffs and resulting import changes by the US and the OSA. Similar to the EU, for a low willingness to pay for sanctions, i.e., \$0.10 to reduce Russian real income by \$1, an embargo on mining and energy sector imports from

Figure 13: **Cost-Efficient Sanctions with Political Weights in the EU for Different ρs, $\rho \in [0.7, 1.0]$**





Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay when the EU uses the political weights described in 3. Figure 4a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure 4b plots the percentage change in imports in the EU for the different sectors.

Russia would be optimal.[36]

5.5 Robustness

In this section, we show that the cost-efficient sanctions that we derive are robust to four alternative model specifications. First, we replace the trade elasticities that we estimated with those of Caliendo and Parro (2015). Second, we consider alternative retaliation strategies by Russia. Third, we calibrate the model using estimates of the long-run trade elasticity. Forth, we consider alternative production functions, allowing for a very high complementarity between inputs. In all these scenarios, we still find that cost-efficient sanctions are homogeneous across sectors, around 30% for small willingness to pay for sanctions and that an embargo in oil and gas should be imposed for large enough willingness to pay.

[36] Figures C.7 and C.8 also show that if the US and the OSA only target politically relevant sectors in Russia, total imports will increase. The reason is that they have incentives to lower tariffs on the products from Russia that are not politically relevant, such that Russian employment and output can be reallocated from the politically relevant sectors to these other sectors. As the mining and energy sectors do not account for a major share of these countries' imports from Russia, a combination of high tariffs on mining and energy sectors and low tariffs on other sectors can lead to an increase in total imports.

5.5.1 Caliendo and Parro (2015) Trade Elasticities

We show that the cost-efficient sanctions are robust if we replace the sectoral trade elasticities that we estimate using the difference-in-differences strategy with the estimates of Caliendo and Parro (2015). This is because, as we show in Figure A.5a, these two sets of elasticities are positively correlated.[37]

Figures C.9 to C.12 show the sanctioning countries' optimal strategies under these elasticities. If they would like to pay \$0.10 for a \$1 decline in Russia's welfare, the optimal tariffs should equal, on average, about 15%. Compared to the our estimated trade elasticities, lower willingness to pay for sanctions can justify a mining and energy sector embargo under Caliendo and Parro (2015) trade elasticities. A petroleum sector embargo by the EU is optimal if the willingness to pay is as low as \$0.10 to reduce Russian real income by \$1. If the EU's willingness to pay rises to \$0.70, an embargo on all mining and energy sectors is optimal. As Figure A.5a shows, Caliendo and Parro (2015) trade elasticities are higher than ours on average, and especially so for the energy sectors. Given the willingness to pay for sanctions, higher trade elasticities provide the sanctioning countries with incentive to impose higher tariffs because they can divert more exports away from Russia and harm its income more.

Similar to Figure 4, if the sanctioning countries are willing to pay \$1.50 for a \$1 reduction in Russia's welfare, an embargo on Russian imports in all sectors is optimal.

5.5.2 Russian Retaliation Strategies

The cost-efficient sanctions are also robust to Russian retaliation strategies. The reason is that, as Russia is a relatively small export destination for the sanctioning countries (see Figure A.4c), Russia's retaliation on the sanctioning countries' exports should not strongly affect the latter group's output, income, or incentive to impose sanctions.[38] In this section, we consider two alternative strategies of Russian retaliation: in solving Problem 15, Russia always sets its retaliation tariff to maximize its own real income ($\rho_{RUS} \equiv 1$) and to minimize

[37] The correlation is 0.57.

[38] This is also corroborated by Figure 8, which shows that the sanctioning countries' real income is not significantly affected by ρ – the willingness to pay to minimize the opponent's real income in both the the sanctioning countries and Russia.

the sanctioning countries' real income ($\rho_{RUS} \equiv 0$).

Figures C.13 to C.18 show the sanctioning countries' optimal tariffs and the associated import changes, with $\rho_{RUS} \equiv 1$. Figures C.19 to C.24 show the same set of variables for $\rho_{RUS} \equiv 0$. Similar to Section 5 where ρ_{RUS} is equal to that of the sanctioning countries, for low willingness to pay to sanction Russia ($0.10 for a $1 real income drop in Russia), the sanctioning countries should optimally impose tariffs of about 20% on all sectors. If the sanctioning countries would like to pay $0.7 of their real income to reduce Russian real income by $1, an embargo on mining and energy sectors would be optimal for the EU. For willingness to pay higher than $1.50, a embargo on all Russian products by all sanctioning countries would be optimal.

5.5.3 Long-Run Trade Elasticity

Sanctions, like other trade policies, typically last for an extended period. Therefore, the relevant trade elasticity for calibrating the model is the long-run trade elasticity. In Appendix C.3, we estimate the long-run trade elasticity and recalibrate the model. We find that, as expected, the short-run trade elasticity is much smaller than the long-run counterpart. Furthermore, the trade elasticity obtained in Section 2.5 does not differ statistically from the long-run trade elasticity. Using the long-run trade elasticities, we demonstrate that it would still be optimal for the EU to impose an embargo on Russian mining and energy sectors with a sufficiently high willingness to pay for sanctions. Moreover, the results are not quantitatively different from the baseline calibration because the elasticity estimated in Section 2.5 is close to the long-run trade elasticity.

5.5.4 CES Production Function

The elasticity of substitution between inputs plays a crucial role in the impact of sanctions. For example, if petroleum can be readily substituted for other inputs, imposing sanctions on Russia would have a limited impact on domestic production. In this section, we demonstrate that our main findings remain valid for a range of elasticities of substitution across inputs.

For this section, we assume that production is given by

$$Y_n^j = A_n^j \left((e_n^j)^{\frac{1}{\rho}} (L_n^s)^{\frac{\rho-1}{\rho}} + \sum_{k=1}^{J} (f^{j,k})^{\frac{1}{\rho}} (M_n^{j,k})^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \tag{18}$$

where A_n^j is the TFP of sector j in country n, L_n^s is the labor demand by sector s, and $M_n^{j,k}$ is the quantity of sector k output used by sector j. ρ denotes the elasticity of substitution across inputs. e_n^j and $f^{j,k}$ are labor- and input-augmenting technology parameters.

Figure 14 shows the results of the model using the production function given by equation 18 and a calibrated elasticity of substitution of 0.66, as estimated by de Souza and Li (2021).[39] Overall, the patterns of cost-efficient tariffs are still the same. Even for low willingness to pay for sanctions, the EU should reduce trade with Russia through a tariff ranging from 20% to 30%, depending on the willingness to pay for sanctions. If ρ is below 0.6, i.e., the EU is willing to pay \$0.70 dollars for each \$1 drop in Russian income, the EU should impose an embargo on the Russian petroleum and mining energy sectors.

In the Appendix, Figure C.26 explores the cost-efficient sanctions with an even lower elasticity of substitution between inputs of 0.1. The qualitative results remain consistent, with an optimal embargo on the Russian petroleum and mining energy sectors for ρ below 0.6. When willingness to pay for sanctions is low, the cost-efficient sanctions are homogeneous across sectors and effectively decrease trade with Russia.

6 Conclusion

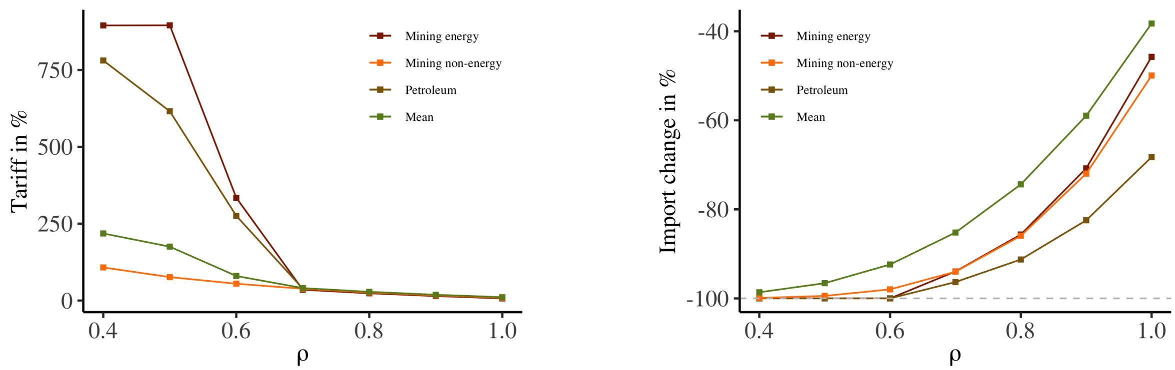
In this paper, we study how countries should optimally impose import sanctions. We investigate how these sanctions depend on countries' willingness to pay for sanctions, trade shares, and trade elasticities. We develop a model of tariff competition that features multiple countries, multiple sectors, and input-output linkages. Countries weigh the objectives of maximizing their own income and diminishing their opponent's income, and respond optimally to other countries' tariff strategies.

The Russian invasion of Ukraine has caused significant casualties and economic damage,

[39] Oberfield and Raval (2021) finds similar elasticity of substitution across inputs.

Figure 14: **Cost-Efficient Sanctions in the EU for Different ρs with CES Production Function**

(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay for sanctions. The production function is as described in 18 and the elasticity of substitution between labor and materials is calibrated to 0.66, as in de Souza and Li (2021). Figure 14a plots the cost-efficient tariff on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure 14b plots the percentage change in imports in the EU for different sectors.

and threatened global stability and economic prosperity. We apply the model to study the cost-efficient sanctions on Russia. Using the difference-in-differences empirical strategy developed in de Souza and Li (2021) and drawing on global AD investigations and tariffs from the Global Anti-dumping Database (Bown 2005), we first document that tariffs on imports from Russia strongly decrease Russian total exports and the sanctioning countries' total imports of the targeted products. Using the same empirical strategy, we estimate the model's trade elasticities for each sector.

We find that if the sanctioning countries would like to pay \$0.10 of real income to diminish Russian real income by \$1, the sanctioning tariffs should be about 20% and be similar across sanctioning countries and across sectors. If the sanctioning countries' willingness to pay rises to \$0.7, the EU should impose an embargo on the Russian energy and mining sectors. If the willingness to pay increases to \$1.50, an embargo on all sectors is close to optimal.

We also find that sanctions by the EU can lead to larger real income loss in Russia, compared to those by the US and other sanctioning allies. Russian retaliation slightly increases the welfare loss in the sanctioning countries. However, it leads to substantially larger welfare loss in Russia.

Furthermore, if sanctions target the sectors that are politically relevant, a global embargo on Russia's mining and energy sectors is optimal even when willingness to pay for sanctions is low.

Many countries have implemented trade sanctions against Russia. With these analyses, we propose a rationale as to why the observed sanctions have differed across countries and sectors. We provide a toolbox that helps policy makers to optimally impose sanctions and restore peace in the region, as they trade off between undermining Russia's capacity to continue its war and the cost to domestic welfare.

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A Empirics

A.1 Summary Statistics

Table A.1 shows the summary statistics for AD investigations targeting Russia. During the sample period (1995-2020), Russia faced 393 AD investigations, of which 298 (75%) concluded with an affirmative ruling. 150 products that Russia exported faced AD investigations, of which 112 were subject to tariff increases.[40] Twenty countries imposed AD tariffs on Russia. Conditional on an investigation that led to an AD tariff increase, the average tariff was 123% and the median tariff was 43%. Figure A.1a shows the number of AD investigations and affirmative investigations by year. Figure A.1b shows that, conditional on an investigation with an affirmative ruling, the average AD tariff was the highest on the metal and machinery sectors.

Table A.3 shows the summary statistics, by country, for the AD investigations targeting Russia. The US conducted the most AD investigations, followed by the EU, Canada, and Ukraine. Conditional on an affirmative investigation, the AD tariff rate imposed by the US was the highest (52.63%).

Table A.2 shows the summary statistics for AD investigations that all countries imposed on their trade partners. There was a total of 15,131 AD investigations, of which 10,370 (68%) concluded with an affirmative ruling; 1,585 products faced AD investigations, of which 1,298 were subject to tariff increases. Conditional on an investigation that led to an AD tariff increase, the average tariff was 128% and the median tariff was 55%. Figure A.2a shows the number of global AD investigations and affirmative investigations by year. Figure A.2b shows that, on the world level, conditional on an investigation with an affirmative ruling, the average AD tariff was the highest on the mining (non-energy), mining support, and automobile sectors. Tables A.4 and A.5 show the summary statistics for global AD investigations by the investigating country and the exporting country.

[40] A product refers to an HS 6-digit code.

Table A.1: **Statistics for AD Investigations Targeting Russia**

	Tariff Increase	**No Tariff Chg**	**All**
# Investigations	298	105	393
# Products	112	74	150
# Countries	20	11	20
Avg. Tariff	1.23	0	0.90
Med. Tariff	0.43	0	0.33

Notes: This table presents the statistics for the AD investigations targeting Russia between 1995 and 2020. Each investigation was conducted on a product from Russia. The average and median tariffs are the simple average and the median across investigations. The investigation-level tariff is computed in ad-valorem terms.

Table A.2: **Statistics for Global AD Investigations**

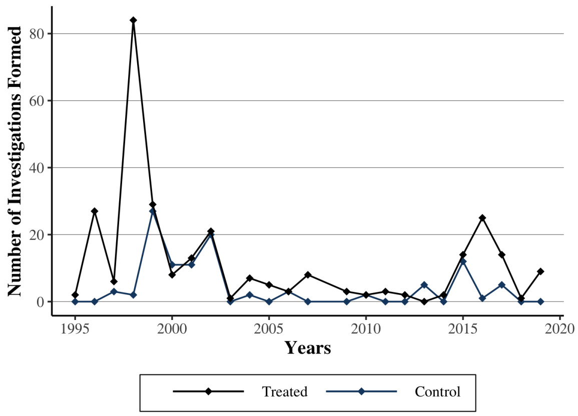
	Tariff Increase	**No Tariff Chg**	**All**
# Investigations	10370	4761	15131
# Products	1298	808	1585
# Countries inv	31	31	31
# Countries exp	95	89	106
Avg. Tariff	1.28	0	0.88
Med. Tariff	0.55	0	0.29

Notes: This table presents the statistics for the AD investigations targeting Russia between 1995 and 2020. Each investigation was conducted on a product from Russia. The average and median tariffs are the simple average and the median across investigations. The investigation-level tariff is computed in ad-valorem terms.

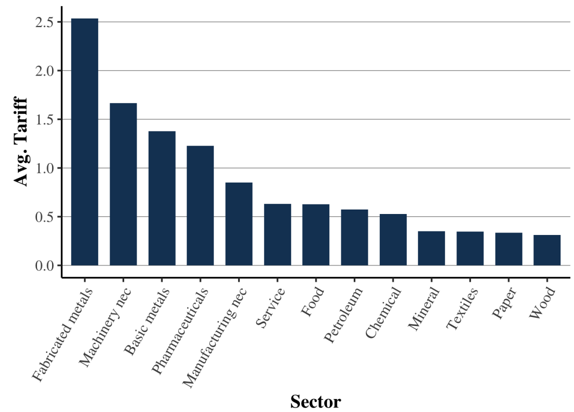
A.2 Additional Figures and Tables

Figure A.1: **Summary Statistics for AD Investigations Targeting Russia**

(a) Number of AD Investigations by Year



(b) Ave. AD Tariff Rate by Sector



Description: This figure shows the summary statistics for the AD investigations and AD tariffs targeting Russia. The left panel shows the number of AD investigations with affirmative and negative rulings by year. The right panel shows, by sector, the average tariff rate across AD investigations conditional on an affirmative ruling. The same sector classification is used as in the 2018 OECD Inter-country Input-output Database (OECD ICIO 2018). The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

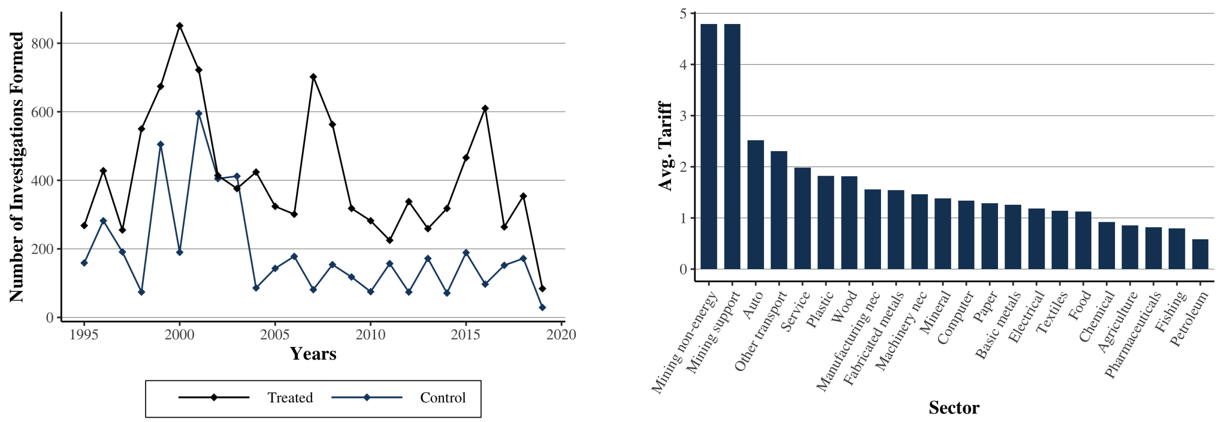
Table A.3: **AD Investigations that Targeting by Country**

	Investigations		**Treated**		**All**	
Country	**# Investigations**	**% Treated**	**Avg. Tariff**	**Med. Tariff**	**Avg. Tariff**	**Med. Tariff**
United States	76	52.63%	4.97	3.13	2.62	1.57
European Union	68	82.35%	0.54	0.35	0.45	0.33
Canada	43	79.07%	1.44	0.87	1.14	0.86
Ukraine	32	90.63%	0.39	0.34	0.36	0.32
India	25	48.00%	0.71	0.68	0.34	0.00
Argentina	22	63.64%	0.82	0.60	0.52	0.60
China	22	100.00%	0.26	0.18	0.26	0.18
Philippines	21	42.86%	0.15	0.15	0.06	0.00
Venezuela	15	100.00%	0.64	0.64	0.64	0.64
Mexico	12	83.33%	0.49	0.34	0.41	0.30
Indonesia	11	100.00%	0.35	0.29	0.35	0.29
Pakistan	9	100.00%	0.29	0.28	0.29	0.28
Turkey	9	44.44%	0.17	0.10	0.08	0.00
Colombia	7	100.00%	1.35	0.50	1.35	0.50
Brazil	6	66.67%	0.24	0.29	0.16	0.16
South Korea	5	100.00%	0.25	0.30	0.25	0.30
South Africa	5	100.00%	0.78	0.78	0.78	0.78
Taiwan	3	33.33%	0.39	0.39	0.13	0.00
Australia	1	100.00%	0.29	0.29	0.29	0.29
Peru	1	100.00%	0.07	0.07	0.07	0.07

Description: This table presents summary statistics for the AD investigations targeting Russia by the country that initiated the investigation. The table shows the number of investigations, the fraction of the investigations that led to a tariff increase, the average tariff rate conditional on an affirmative investigation, and the average tariff rate of all investigations. The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

Figure A.2: **Summary Statistics for Global AD Investigations**

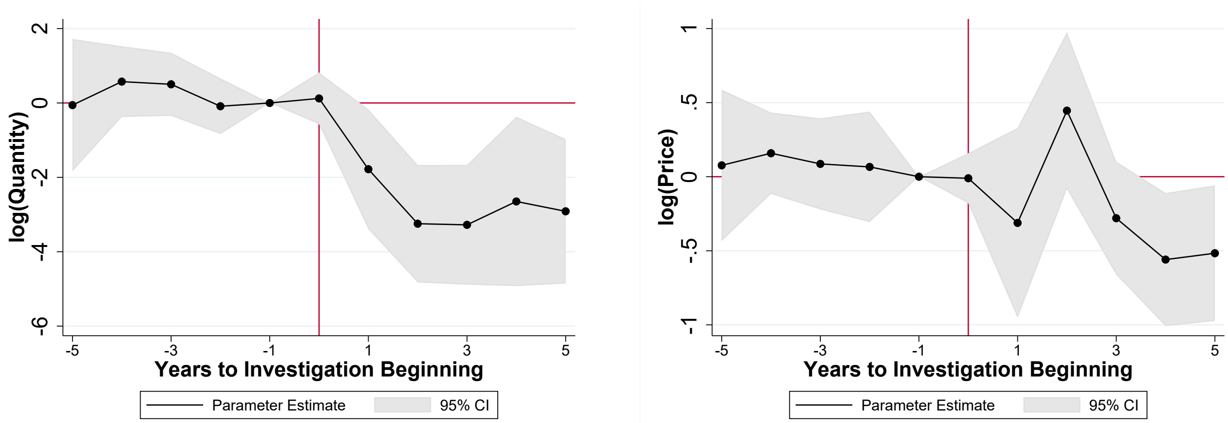
(a) Number of AD Investigations by Year (b) Ave. AD Tariff Rate by Sector



Description: This figure shows the summary statistics for the AD investigations and AD tariffs that all countries imposed on their trade partners. The left panel shows the number of AD investigations with affirmative and negative rulings by year. The right panel shows, by sector, the average tariff rate across AD investigations conditional on an affirmative ruling. The same sector classification is used as in the 2018 OECD ICIO. The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

Figure A.3: **Impact of AD Tariffs on Quantity and Price**

(a) Quantity (b) Price



Description: This figure shows the dynamic impact of AD tariffs on the quantity and price of imports using Model 2. The impact on yearly import quantity and price is plotted on the y-axis. The number of years to the beginning of the investigation is plotted on the x-axis. The import quantity is measured with HS 6-digit level metric tons imported from Russia by the country that initiated the AD investigation. HS 6-digit level price is measured with the value per metric ton. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020. The sample includes the product-origins that faced at least one AD investigation. The shaded area contains the 95% confidence interval. Standard errors are clustered at the product-country level.

Table A.4: **Global AD Investigations by Investigating Country**

	Investigations		Treated		All	
Country	**# Investigations**	**% Treated**	**Avg. Tariff**	**Med. Tariff**	**Avg. Tariff**	**Med. Tariff**
United States	3611	66.46%	2.17	0.90	1.44	0.37
India	1997	81.47%	0.80	0.51	0.65	0.50
European Union	1875	60.27%	0.92	0.56	0.56	0.23
Canada	1250	63.76%	1.91	1.09	1.22	0.49
Argentina	885	71.75%	1.24	0.62	0.89	0.50
Brazil	681	48.31%	1.42	0.76	0.69	0.00
Turkey	652	75.31%	1.59	0.45	1.20	0.29
China	624	98.40%	0.44	0.29	0.43	0.29
Australia	544	64.34%	0.28	0.15	0.18	0.07
Sourh Africa	383	63.71%	0.54	0.45	0.34	0.28
South Korea	366	68.03%	0.32	0.28	0.22	0.15
Indonesia	320	65.63%	0.27	0.21	0.18	0.11
Peru	310	64.19%	2.35	0.44	1.51	0.29
Mexico	275	83.64%	1.41	0.81	1.18	0.75
Pakistan	259	81.08%	0.39	0.28	0.32	0.22
Russia	164	59.76%	0.34	0.23	0.20	0.15
Malaysia	150	55.33%	0.19	0.13	0.11	0.06
Colombia	132	52.27%	1.93	0.77	1.01	0.10
Venezuela	120	84.17%	1.42	2.04	1.19	0.95
New Zealand	102	33.33%	1.05	0.58	0.35	0.00
Taiwan	96	51.04%	0.44	0.22	0.22	0.14
Ukraine	91	91.21%	0.89	0.45	0.81	0.41
Israel	83	46.99%	2.24	1.18	1.05	0.00
Philippines	44	40.91%	0.31	0.15	0.13	0.00
Trinidad and Tobago	28	82.14%	1.76	1.92	1.44	1.92
Chile	26	57.69%	0.31	0.23	0.18	0.10
Japan	19	89.47%	0.38	0.40	0.34	0.29
Jamaica	16	93.75%	0.51	0.22	0.48	0.22
Uruguay	10	30.00%	0.63	0.55	0.19	0.00
Costa Rica	9	77.78%	0.98	0.13	0.76	0.13
Ecuador	9	11.11%	0.30	0.30	0.03	0.00

Description: This table presents summary statistics for the global AD investigations by the country that initiated the investigation. The table shows the number of investigations, the fraction of the investigations that led to a tariff increase, the average tariff rate conditional on an affirmative investigation, and the average tariff rate of all investigations. The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

Table A.5: **Global AD Investigations by Exporting Country**

	Investigations		Treated		All	
Country	**# Investigations**	**% Treated**	**Avg. Tariff**	**Med. Tariff**	**Avg. Tariff**	**Med. Tariff**
China	3791	79.87%	2.01	0.99	1.60	0.61
South Korea	1258	62.80%	0.50	0.24	0.32	0.08
Taiwan	837	71.92%	0.97	0.37	0.70	0.24
Japan	689	64.01%	0.98	0.60	0.63	0.29
India	628	63.85%	1.80	0.40	1.15	0.15
United States	522	72.22%	0.84	0.47	0.61	0.36
Indonesia	498	69.48%	0.67	0.50	0.46	0.20
Thailand	442	72.85%	0.57	0.33	0.41	0.20
Brazil	407	69.78%	1.04	0.73	0.73	0.37
Russia	393	73.54%	1.23	0.43	0.90	0.33
Viet Nam	349	65.04%	2.82	0.76	1.84	0.26
Malaysia	327	64.83%	0.49	0.29	0.32	0.15
Germany	307	65.80%	0.65	0.39	0.43	0.21
Ukraine	295	83.39%	1.17	0.68	0.98	0.47
France	266	45.49%	0.97	0.60	0.44	0.00
South Africa	255	73.33%	1.07	0.79	0.79	0.38
Turkey	239	45.61%	1.04	0.46	0.47	0.00
European Union	224	78.57%	0.65	0.40	0.51	0.35
Italy	180	68.89%	0.89	0.45	0.61	0.18
Spain	171	51.46%	0.81	0.46	0.42	0.07
United Kingdom	165	73.33%	1.14	0.77	0.84	0.49
Mexico	162	75.31%	0.93	0.56	0.70	0.37
Romania	149	79.87%	1.13	0.66	0.91	0.43
Hong Kong	134	48.51%	0.88	0.63	0.42	0.00
Canada	130	49.23%	0.40	0.28	0.20	0.00
Pakistan	127	66.93%	0.31	0.33	0.21	0.12
Singapore	119	66.39%	0.59	0.36	0.39	0.17
Argentina	116	44.83%	0.92	0.85	0.41	0.00
Kazakhstan	104	84.62%	1.90	0.81	1.61	0.77
Belgium	101	63.37%	0.54	0.41	0.34	0.24
Slovakia	97	61.86%	1.03	0.62	0.64	0.24
Australia	96	51.04%	1.43	0.70	0.73	0.29
Netherlands	94	62.77%	0.47	0.12	0.30	0.05
Egypt	83	20.48%	0.20	0.20	0.04	0.00
New Zealand	74	8.11%	0.14	0.11	0.01	0.00
Saudi Arabia	73	28.77%	0.53	0.30	0.15	0.00
Chile	71	73.24%	0.56	0.28	0.41	0.14
United Arab Emirates	70	77.14%	0.85	0.56	0.66	0.37
Peru	60	48.33%	0.49	0.50	0.23	0.00
Austria	57	66.67%	1.01	0.54	0.67	0.54
Bulgaria	57	94.74%	1.65	0.63	1.57	0.63
Poland	57	75.44%	0.69	0.51	0.52	0.43
Iran	54	55.56%	0.41	0.29	0.23	0.15
Macao	53	5.66%	0.23	0.23	0.01	0.00
Sweden	43	39.53%	0.44	0.27	0.17	0.00
Venezuela	40	20.00%	2.07	1.44	0.41	0.00
Belarus	39	66.67%	2.44	1.09	1.63	0.49
Israel	37	54.05%	0.47	0.53	0.26	0.34
Macedonia	36	69.44%	2.38	1.26	1.65	0.63
Hungary	34	50.00%	1.14	1.57	0.57	0.07
Philippines	33	69.70%	1.05	0.45	0.73	0.45
Finland	30	53.33%	1.10	0.41	0.59	0.12
Czechia	28	82.14%	1.71	0.91	1.40	0.78
Oman	22	59.09%	0.58	0.46	0.34	0.09
Greece	21	80.95%	0.89	0.55	0.72	0.45
Uruguay	21	42.86%	0.44	0.34	0.19	0.00
Switzerland	20	35.00%	1.37	0.72	0.48	0.00
Luxembourg	20	0.00%			0.00	0.00
Lithuania	18	33.33%	0.13	0.11	0.04	0.00
Colombia	15	66.67%	0.38	0.28	0.25	0.28
Moldova	14	50.00%	9.48	11.07	4.74	0.20
Sri Lanka	13	76.92%	0.30	0.25	0.23	0.25
Portugal	13	76.92%	0.98	1.03	0.76	0.59
Denmark	12	83.33%	2.27	1.67	1.89	0.76
Malawi	12	100.00%	1.10	1.10	1.10	1.10
Croatia	11	90.91%	0.69	0.53	0.63	0.46
Trinidad and Tobago	11	45.45%	0.43	0.56	0.20	0.00
Bahrain	10	0.00%			0.00	0.00
Libya	10	20.00%	1.03	1.03	0.21	0.00
Norway	10	80.00%	0.33	0.38	0.27	0.32
Dominican Republic	9	88.89%	0.22	0.22	0.20	0.22
Ireland	9	88.89%	0.13	0.08	0.11	0.08
Paraguay	9	100.00%	0.28	0.28	0.28	0.28
Bangladesh	6	100.00%	0.27	0.31	0.27	0.31
Estonia	6	66.67%	0.40	0.40	0.27	0.06
Faroe Islands	6	50.00%	0.55	0.55	0.27	0.27
Liechtenstein	6	0.00%			0.00	0.00
Guatemala	5	20.00%	0.52	0.52	0.10	0.00
Latvia	5	100.00%	0.14	0.17	0.14	0.17
Bosnia and Herzegovina	4	75.00%	0.34	0.28	0.25	0.28
Nepal	4	100.00%	0.18	0.18	0.18	0.18
North Korea	4	0.00%			0.00	0.00
Qatar	4	100.00%	0.45	0.45	0.45	0.45
Cuba	3	66.67%	0.21	0.21	0.14	0.21
Slovenia	3	33.33%	0.46	0.46	0.15	0.00
Uzbekistan	3	33.33%	0.13	0.13	0.04	0.00
Algeria	2	100.00%	0.13	0.13	0.13	0.13
Georgia	2	100.00%	0.38	0.38	0.38	0.38
Kyrgyzstan	2	100.00%	0.26	0.26	0.26	0.26
Kuwait	2	100.00%	0.20	0.20	0.20	0.20
Laos	2	0.00%			0.00	0.00
Nigeria	2	100.00%	0.40	0.40	0.40	0.40
Serbia	2	100.00%	0.29	0.29	0.29	0.29
Armenia	1	100.00%	0.37	0.37	0.37	0.37
Costa Rica	1	0.00%			0.00	0.00
Ecuador	1	100.00%	0.04	0.04	0.04	0.04
Jordan	1	100.00%	0.34	0.34	0.34	0.34

Description: This table presents summary statistics for the global AD investigations by the exporting country. The table shows the number of investigations, the fraction of the investigations that led to a tariff increase, the average tariff rate conditional on an affirmative investigation, and the average tariff rate of all investigations. The AD data are from the Global Anti-dumping Database. The sample runs from 1995 to 2020.

Table A.6: **Summary Statistics of Diff-in-Diff Regression by Sector**

Sector	No. Obs	No. Prods	No. Importer	No. Exporter	Mean Ave Tariff	Mean Log Value	Sd. Ave Tariff	Sd. Mean Log Value
Agriculture	1959	10	6	7	0.03	8.68	0.07	6.70
Fishing	304	5	2	3	0.01	4.66	0.05	9.12
Mining non-energy	124	3	2	2	0.03	5.98	0.07	3.52
Mining support	72	3	2	2	0.03	6.35	0.08	3.43
Food	6048	87	21	37	0.03	4.95	0.07	7.46
Textiles	22568	212	18	30	0.03	-2.96	0.07	10.24
Wood	3629	64	15	25	0.03	2.08	0.07	9.53
Paper	8738	97	20	38	0.03	2.60	0.07	9.01
Petroleum	10041	140	19	45	0.04	2.86	0.08	9.00
Chemical	25126	259	23	61	0.04	3.04	0.07	8.79
Pharmaceuticals	784	21	11	12	0.05	6.38	0.09	5.81
Plastic	8502	100	22	32	0.03	4.42	0.07	8.19
Mineral	4415	69	22	29	0.04	3.18	0.08	8.27
Basic metals	100308	203	21	58	0.03	-0.48	0.07	10.15
Fabricated metals	5039	90	22	31	0.04	5.24	0.08	7.56
Computer	11945	111	21	38	0.03	4.30	0.07	8.15
Electrical	7533	95	22	33	0.03	4.25	0.07	8.61
Machinery n.e.c.	13712	229	24	44	0.04	5.37	0.08	7.60
Auto	1148	29	13	14	0.04	6.18	0.08	7.73
Other transport	1986	40	13	13	0.04	5.85	0.08	7.70
Manufacturing n.e.c.	35834	353	27	52	0.03	4.88	0.07	7.90
Service	1559	29	8	19	0.04	1.62	0.08	9.96

Description: This table presents summary statistics for the variables used in the difference-in-differences regressions used to estimated sectoral trade elasticities (Model (3)). The AD data are from the Global Anti-dumping Database. The sample runs from 1995 to 2020.

Table A.7: **Effect of AD Tariffs on Imports from Russia**

Dependent Variable	Log Value			
	(1)	(2)	(3)	(4)
AD Tariff	-4.295**	-4.295**	-4.468**	-3.966*
	(1.890)	(1.917)	(1.992)	(2.004)
Observations	1,534	1,534	1,534	1,638
R-squared	0.807	0.807	0.804	0.688
Product X Importer	X	X	X	
Importer X Year	X	X	X	
Number of AD committees	X	X		X
After AD investigation	X	X	X	X
Product				X
Importer				X
Year				X
Dummy for AD committee			X	
Cluster	Product X Importer	4-digit X Importer	Product X Importer	Product X Importer
Robust standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Description: This table presents the impact of AD tariffs imposed on Russia by other countries on the log of imports from Russia by the country that initiated the AD investigation. We study HS 6-digit level imports. Imports are measured in FOB, current dollar value terms. The coefficients are estimated with Model 1. Different columns include different combinations of fixed effects and controls. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

Table A.8: **Effect of AD Tariffs on Total Exports**

Dependent variable	Log Total Exports			
	(1)	(2)	(3)	(4)
AD Tariff	-1.577**	-1.577*	-1.445*	-1.013
	(0.726)	(0.796)	(0.741)	(0.989)
Observations	1,534	1,534	1,534	1,638
R-squared	0.804	0.804	0.803	0.657
Product X Importer	X	X	X	
Importer X Year	X	X	X	
Number of AD committees	X	X		X
After AD investigation	X	X	X	X
Product				X
Importer				X
Year				X
Dummy for AD committee			X	
Cluster	Product X Importer	4-digit X Importer	Product X Importer	Product X Importer

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the impact of AD tariffs imposed on Russia by other countries on the log of HS 6-digit level total exports by Russia to all destinations. The coefficients are estimated with Model 1. Total exports refers to total exports of the HS 6-digit level product by Russia to all destinations; these exports are of the same 6-digit products for which other countries initiated an AD investigation on Russia. Different columns include different combinations of fixed effects and controls. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

Table A.9: **Effect of AD Tariffs on Total Imports**

Dependent Variable	Log Total Imports			
	(1)	(2)	(3)	(4)
AD Tariff	-1.867**	-1.867**	-1.890**	-1.499*
	(0.743)	(0.764)	(0.826)	(0.871)
Observations	1,534	1,534	1,534	1,638
R-squared	0.839	0.839	0.837	0.738
Product X Importer	X	X	X	
Importer X Year	X	X	X	
Number of AD committees	X	X		X
After AD investigation	X	X	X	X
Product				X
Importer				X
Year				X
Dummy for AD committee			X	
Cluster	Product X Importer	4-digit X Importer	Product X Importer	Product X Importer

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the impact of AD tariffs imposed on Russia Russia by other countries on the log of HS 6-digit level total imports by another country from all origins. The coefficients are estimated with Model 1. Total imports refers to the total imports of the HS 6-digit level product from all origins by the country that initiated an AD investigation on Russia; these imports are of the same 6-digit products on which the AD tariffs have been imposed. Different columns include different combinations of fixed effects and controls. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

Table A.10: **Effect of AD Tariffs on Trade Diversion**

VARIABLES	(1) Log Exports to Other Destinations	(2) Log Imports from Other Origins	(3) Log Imports of Other Products
AD Tariff	0.202	0.112	-0.214
	(0.525)	(0.372)	(0.344)
Observations	1,063	1,062	1,064
R-squared	0.888	0.908	0.901
Fixed Effects	Product X Importer, Importer X Year, Number of AD committees, After AD investigation		
Cluster	Product X Importer		

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Description: This table presents the impact of AD tariffs imposed on Russia by other countries on the trade diversion to other destinations, origins, and products, estimated with Model 1. *Log Exports to Other Destinations* denotes the log of exports of HS 6-digit level products by Russia to all destinations except the country that imposed the AD tariff on the same 6-digit product from Russia (for which an AD investigation was initiated). *Log Imports from Other Origins* denotes the log of HS 6-digit level imports by the country that imposed the AD tariff on the same 6-digit product from Russia (for which an AD investigation was initiated). *Log Imports of Other Products* denotes the imports from Russia of all HS 6-digit level products within the same HS 2-digit category except the HS 6-digit product that faces an AD investigation by another country. The import data are from the United Nations Comtrade Database, acquired through the BACI Database of CEPII (Gaulier and Zignago 2010). The AD data are from the Global Anti-dumping Database (Bown 2005). The sample runs from 1995 to 2020.

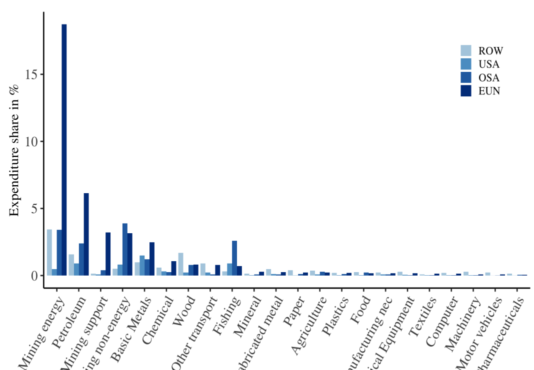
Table A.11: **OECD ICIO Sectors and International Standard Industrial Classification (ISIC) Revision 4 Sectors**

Sector	**OECD ICIO**	**ISIC Rev. 4**
Agriculture	Agriculture, hunting, forestry	1-2
Fishing	Fishing and aquaculture	3
Mining energy	Mining and quarrying, energy producing products	5-6
Mining non-energy	Mining and quarrying, non-energy producing products	7-8
Mining support	Mining support service activities	9
Food	Food products, beverages and tobacco	10-12
Textiles	Textiles, textile products, leather and footwear	13-15
Wood	Wood and products of wood and cork	16
Paper	Paper products and printing	17-18
Petroleum	Coke and refined petroleum products	19
Chemical	Chemical and chemical products	20
Pharmaceuticals	Pharmaceuticals, medicinal chemical and botanical products	21
Plastic	Rubber and plastics products	22
Mineral	Other non-metallic mineral products	23
Basic metals	Basic metals	24
Fabricated metals	Fabricated metal products	25
Computer	Computer, electronic and optical equipment	26
Electrical	Electrical equipment	27
Machinery n.e.c.	Machinery and equipment, nec	28
Auto	Motor vehicles, trailers and semi-trailers	29
Other transport	Other transport equipment	30
Manufacturing n.e.c.	Manufacturing nec; repair and installation of machinery and equipment	31-33
Service	Electricity, gas, steam and air conditioning supply	35
	Water supply, sewerage, waste management and remediation activities	36-39
	Construction	41-43
	Wholesale and retail trade; repair of motor vehicles	45-47
	Land transport and transport via pipelines	49
	Water transport	50
	Air transport	51
	Warehousing and support activities for transportation	52
	Postal and courier activities	53
	Accommodation and food service activities	55-56
	Publishing, audiovisual and broadcasting activities	58-60
	Telecommunications	61
	IT and other information services	62-63
	Financial and insurance activities	64-66
	Real estate activities	68
	Professional, scientific and technical activities	69-75
	Administrative and support services	77-82
	Public administration and defence; compulsory social security	84
	Education	85
	Human health and social work activities	86-88
	Arts, entertainment and recreation	90-93
	Other service activities	94-96
	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97-98

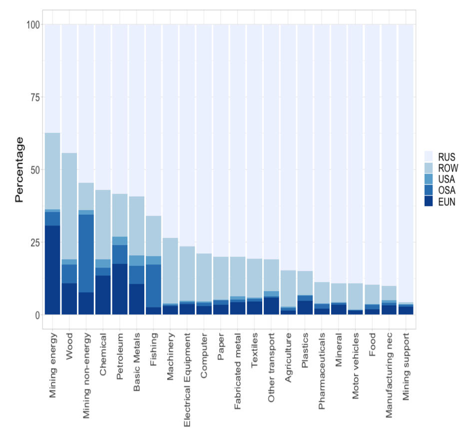
Description: This table shows the relationship between the OECD ICIO sectors that we consider and the International Standard Industrial Classification (ISIC) Rev. 4 sectors.

Figure A.4: **Trade Statistics with Russia by Sector**

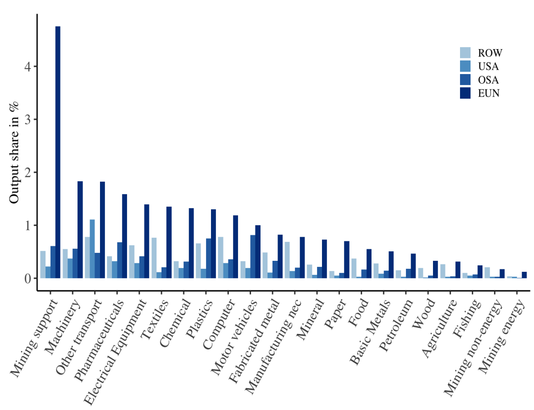
(a) Other Countries' Expenditure Share



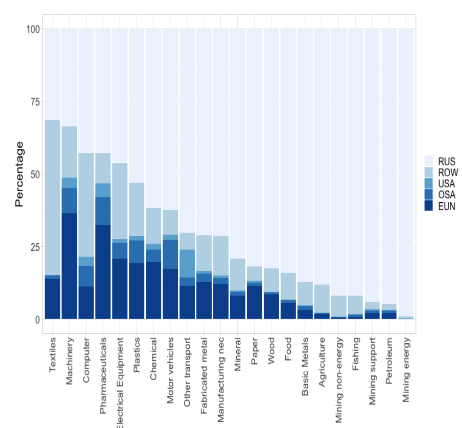
(b) Russia's Share of Output



(c) Other Countries' Share of Output



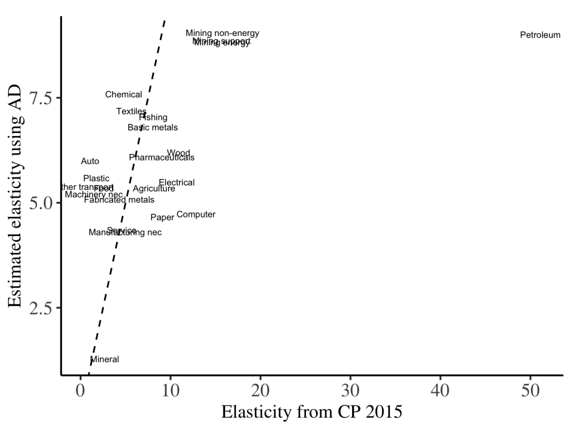
(d) Russia's Expenditure Share



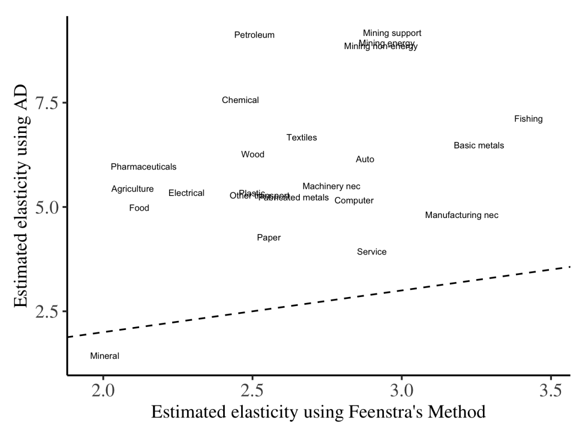
Description: This figure shows, by country and sector, the trade statistics with Russia. Figure A.4a shows Russia's share of total expenditure on the sector's products. Figure A.4b shows the share of output sold to each country in Russia's sectoral total output. Figure A.4c shows the share of output sold to Russia in other countries' sectoral total output. Figure A.4d show other countries' shares in Russia's total expenditure on the sector's product.

Figure A.5: **Correlation between Trade Elasticities Estimated with Diff-in-Diff and the Estimated Values (1) in Caliendo and Parro (2015) and (2) that We Estimate with the Feenstra (1994) Method**

(a) Correlation with Caliendo and Parro (2015) elasticities



(b) Correlation with the elasticities that we estimate with the Feenstra (1994)



Description: This figure shows the sector-level trade elasticities that we estimate with the difference-in-differences method and those estimated in the literature. The left panel shows the correlation between our elasticities and those that Caliendo and Parro (2015) find. The right panel shows the correlation between our elasticities and those we estimate using the Feenstra (1994) method at the same level of sectors.

B Model

B.1 Equilibrium in Changes

Using the "exact hat algebra" technique popularized by Dekle et al. (2007), we can express the equilibrium conditions in terms of changes from the baseline equilibrium, given changes in tariffs $\{\hat{t}^j_{ni}\}_{j,n,i}$ ($\hat{t}^j_{ni} = (1+\tau^{j'}_{ni})/(1+\tau^j_{ni})$):

$$\hat{c}^j_n = (\hat{w}_n)^{\gamma^j_n} \prod_{k=1}^{J} (\hat{P}^k_n)^{\gamma^{k,j}_n} \tag{B.1}$$

$$\hat{P}^j_n = \left[\sum_{i=1}^{N} \pi^j_{ni} (\hat{t}^j_{ni} \hat{c}^j_i)^{-\theta^j} \right]^{-1/\theta^j} \tag{B.2}$$

$$\hat{\pi}^j_{ni} = \left(\frac{\hat{c}^j_i \hat{t}^j_{ni}}{\hat{P}^j_n} \right)^{-\theta^j} \tag{B.3}$$

$$X^{j'}_n = \sum_{k=1}^{J} \gamma^{j,k}_n \sum_{i=1}^{N} \frac{\pi^{k'}_{in}}{t^{k'}_{in}} X^{k'}_i + \alpha^j_n I'_n \tag{B.4}$$

$$I'_n = \hat{w}_n w_n L_n + D'_n + \sum_{j=1}^{J} \sum_{i=1}^{N} \tau^{j'}_{ni} \frac{X^{j'}_n \pi^{j'}_{ni}}{t^{j'}_{ni}} \tag{B.5}$$

$$\hat{w}_n = \sum_{j=1}^{J} \gamma^j_n \sum_{i=1}^{N} X^{j'}_i \frac{\pi^{j'}_{in}}{t^{j'}_{in} w_n L_n}, \tag{B.6}$$

To compute the counterfactuals, we only need data on bilateral trade shares π^j_{ni}, the share of value added in production γ^j_n, value added $w_n L_n$, incumbent tariffs τ^j_{ni}, the share of intermediate consumption $\gamma^{k,j}_n$, and sectoral trade elasticity θ^j.

We follow Ossa (2014) and Caliendo and Parro (2015) to construct a trade flow matrix without trade imbalance using the approach introduced in Dekle et al. (2007). All later calculations of welfare changes given counterfactual tariffs will treat this purged trade flow data as the factual equilibrium.

Equilibrium in Changes Given Tariff Changes *Given changes in tariffs $\{\hat{t}^j_{ni}\}_{j,n,i}$, an equilibrium is defined as changes in sectoral prices, $\{\hat{P}^j_n\}_{n,j}$, and wages, $\{\hat{w}_n\}_n$, such that*

1. *Firms maximize profit (Equation B.1);*

2. The price index satisfies Equations B.2 and B.3;

3. The goods markets clear, satisfying Equations B.4 and B.5;

4. The labor market clears, satisfying Equation B.6;

Tariff Competition with Equilibrium in Changes Following the notations in Section 3.6, we denote changes in the sectoral tariffs that country n imposes on Russia with $\hat{\mathbf{t}}_{\mathbf{nR}}$, and all other tariffs–changes in tariffs imposed on Russia by all countries except country n and those that country n imposes on all other countries except Russia with $\hat{\mathbf{t}}_{-\mathbf{nR}}$.

The change in country n's welfare equals the following:

$$\hat{G}_n(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}) = \frac{\hat{I}_n(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})}{\hat{P}_n^C(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})}, \tag{B.7}$$

where $\hat{I}_n(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})$ denotes the change in country n's income and $\hat{P}_n^C(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})$ denotes the change in country n's consumer price index.

Conditional on $\hat{\mathbf{t}}_{-\mathbf{nR}}$, the objective of sanctioning country n is to both maximize its own welfare (real income, or GNI) and minimize Russian welfare in the counterfactual equilibrium:

$$\begin{aligned} g_n(\hat{\mathbf{t}}_{-\mathbf{nR}}) \in argmax_{\{\hat{\mathbf{t}}_{\mathbf{nR}}\}} \rho G_n \hat{G}_n(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}) - (1-\rho) G_R \hat{G}_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}), \\ \text{s.t. Equilibrium Conditions B.1-B.6,} \end{aligned} \tag{B.8}$$

where G_n and G_R denote country n's and Russia's real income in the baseline equilibrium. We calibrate them to the country's purchasing power parity (PPP) adjusted GNI in 2018, the same year as the OECD ICIO data.[41]

Russia, when it retaliates, maximizes a weighted average of its own welfare and minimiz-

[41] The data source is the World Bank. See `https://data.worldbank.org/indicator/NY.GNP.MKTP.PP.CD?locations=1W-EU-RU-US`.

ing the allies' welfare, both in the counterfactual equilibrium:

$$g_R(\hat{\mathbf{t}}_{-\mathbf{RS}}) \in argmax_{\{\hat{\mathbf{t}}_{\mathbf{RS}}\}} \rho G_R \hat{G}_R(\hat{\mathbf{t}}_{\mathbf{RS}}, \hat{\mathbf{t}}_{-\mathbf{RS}}) - (1-\rho) \sum_{n \in S} \frac{G_n \hat{G}_n(\hat{\mathbf{t}}_{\mathbf{RS}}, \hat{\mathbf{t}}_{-\mathbf{RS}})}{N_S} \tag{B.9}$$

s.t. Equilibrium Conditions B.1-B.6

Equilibrium in Changes with Sanctions *Given changes in all tariffs except what the sanctioning countries impose on Russia and Russia imposes on sanctioning countries,* $\{\hat{t}^j_{ni}\}_{j,n,i} \setminus \{\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{\mathbf{Rn}}\}_{n \in \mathbf{S}}$*, an equilibrium with optimal sanctions is given by tariffs imposed on Russia by sanctioning countries,* $\{\hat{\mathbf{t}}_{\mathbf{nR}}\}_{n \in \mathbf{S}}$*, tariffs imposed on the sanctioning countries by Russia,* $\{\hat{\mathbf{t}}_{\mathbf{Rn}}\}_{n \in \mathbf{S}}$*, a set of sectoral prices,* $\{\hat{P}^j_n\}_{n,j}$*, and wages,* $\{\hat{w}_n\}_n$*, such that*

1. *Given tariffs* $\{\hat{t}^j_{ni}\}_{j,n,i}$*,* $\{\{\hat{P}^j_n\}_{n,j}, \{\hat{w}_n\}_n\}$ *is an equilibrium;*

2. *Sanctioning countries and Russia optimally choose changes in their tariffs:*

$$\hat{\mathbf{t}}_{\mathbf{nR}} = g_n(\hat{\mathbf{t}}_{-\mathbf{nR}}), \forall n \in \mathbf{S}$$
$$\hat{\mathbf{t}}_{\mathbf{RS}} = g_R(\hat{\mathbf{t}}_{-\mathbf{RS}})$$

B.2 Equilibrium in Changes with Political Weights

Here, we rewrite the sanctioning countries' problem in changes if they target the politically relevant sectors in Russia. The change in Russia's politically weighted welfare is equal to the following:

$$\hat{G}^{pol}_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}) = \sum_{j=1}^{J} \frac{\lambda^j L^j_R}{\sum_{s=1}^{S} \lambda^s L^s_R} \hat{L}^s_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}) \frac{\hat{I}_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})}{\hat{P}^C_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})}, \tag{B.10}$$

where $\frac{\lambda^j L^j_R}{\sum_{s=1}^{S} \lambda^s L^s_R}$ denotes the politically weighted initial employment share of sector j in Russia. The politically weighted welfare increases if the whole economy's real income, $\frac{\hat{I}_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})}{\hat{P}^C_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}})}$, increases and if employment/value added increases more in the sectors that have higher political weights. At the same time, if other countries would like to target the politically related sectors, on top of reducing the whole economy's real income, they can also set tariffs to reduce employment/value added in the politically related sectors.

Similar to Problem B.8, the objective of sanctioning country n is to both maximize its own welfare and minimize Russia's real income in the politically connected sectors:

$$g_n^{pol}(\hat{\mathbf{t}}_{-\mathbf{nR}}) \in argmax_{\{\hat{\mathbf{t}}_{\mathbf{nR}}\}} \rho G_n \hat{G}_n(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}) - (1-\rho) G_R^{pol} \hat{G}_R^{pol}(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{-\mathbf{nR}}), \tag{B.11}$$
$$\text{s.t. Equilibrium Conditions B.1-B.6,}$$

where $G_R^{pol} = \sum_{j=1}^{J} \lambda^j \frac{L_R^j}{L_R} G_R$ represents Russia's politically weighted real income in the initial equilibrium. We calibrate λ^j to Russia's political weights, $\frac{L_R^j}{L_R}$ to Russia's sectoral employment shares, and G_R to Russia's GNI.

Just as for Problem B.9, we assume that Russia retaliates by maximizing the weighted average of its own welfare and negative impact on the sanctioning countries' welfare.

C Quantitative

C.1 Sectoral Trade Statistics with Russia

In Figure A.4, we highlight two findings from analyzing the sanctioning countries' trade statistics with Russia. First, Russia's exports of mining and energy products to the EU are important for both the EU's consumption and Russia's production. Mining and energy sector products from Russia account for about 20% of the EU's total expenditure on these products (Figure A.4a), and exports of these products to the EU account for more than a quarter of Russia's total output (Figure A.4b). This suggests that among all sanctioning countries, the EU should carry a heavy weight.[42] If the EU sanctions mining and mining products from Russia, it may cause significant economic losses in Russia, but it may also hurt the EU's welfare.

[42] The EU accounts for 36% of Russia's total exports (5% of Russia's total output) and 39% of Russia's total imports (4% of Russia's total expenditure). The US accounts for 4% of Russia's total exports (1% of Russia's total output) and 5% of Russia's total imports (0.5% of Russia's total expenditure). Other sanctioning countries account for 12% of Russia's total exports (2% of Russia's total output) and 11% of Russia's total imports (1% of Russia's total expenditure).

Second, the sanctioning countries are a major importing origin for Russia. However, Russia is not a major exporting destination for the sanctioning countries. Figure A.4d shows that, in terms of its imports from the sanctioning countries, Russia spends about 50% of its total expenditure on machinery and pharmaceutical sector products, and more than a quarter of its total expenditure on electrical equipment and chemicals. However, the share of exports to Russia in the sanctioning countries' sectoral output never exceeds 5% (Figure A.4c). This suggests that tariff retaliation by Russia may not cause substantial harm to the income of sanctioning countries. Rather, it can significantly reduce Russia's welfare. If Russia cares about its own welfare, it is optimal to not impose high retaliatory tariffs.

C.2 Cost-Efficient Sanctions and Fundamentals

To study the relationship between optimal sectoral tariffs imposed on Russia and the fundamental differences across sectors, we use the following regression:

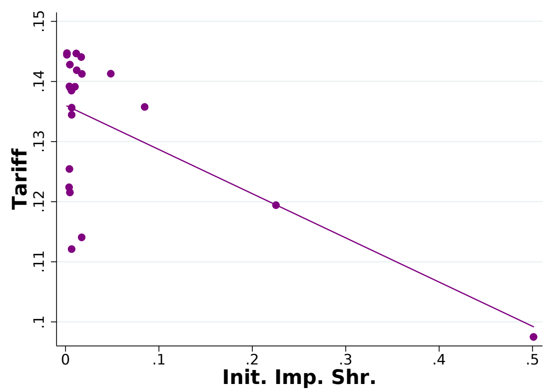
$$\tau_{s,\rho} = \beta_{\sigma,\rho}\sigma_s + \beta_{ups,\rho} upstreamness_s + \beta_{imp,\rho} ImpShr_s + \epsilon_{s,\rho}, \tag{C.1}$$

where $\tau_{s,\rho}$ is the optimal tariff imposed by the EU on sector s imports from Russia when EU's willingness to pay is governed by ρ. σ_s is the trade elasticity of sector s. $upstreamness_s$ measures sector s's upstreamness Antràs et al. (2012) – the average number of sectors one dollar of sector s output goes through until it reaches the final consumer. $ImpShr_s$ is the share of imports from Russia in total sector s's imports by the EU in the baseline economy. To make each variable comparable, they are normalized to have a mean of 0 and a variance of 1.

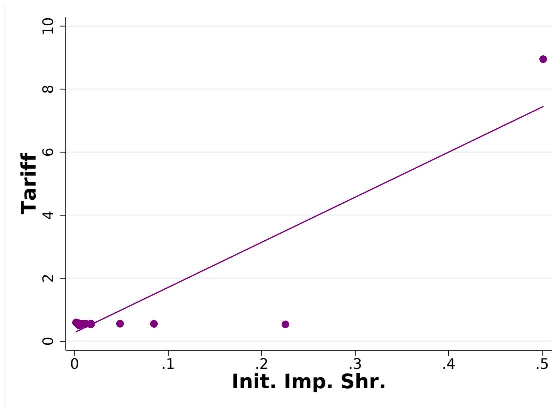
In Figure C.1, we plot the raw correlations between optimal sectoral tariffs by the EU and individual sector characteristics for $\rho = 1$ and $\rho = 0.6$. In Figure C.2, we plot how the partial correlations change with ρ. For low willingness to pay for sanctions, i.e., when ρ is large, higher tariffs should be set on sectors that have small import shares, have lower trade elasticities, and are more downstream. For example, when $\rho = 1$, a sector whose import share is 1 standard deviation smaller should be targeted by a tariff that is 0.5 standard deviation higher. Similarly, a sector whose trade elasticity is 1 standard deviation larger

Figure C.1: **Correlations between Sectoral Cost-Efficient Sanctions and Fundamentals**

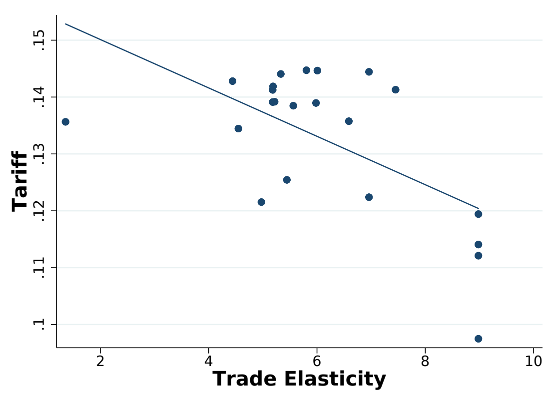
(a) Tariffs and Initial Import Share, $\rho = 1$



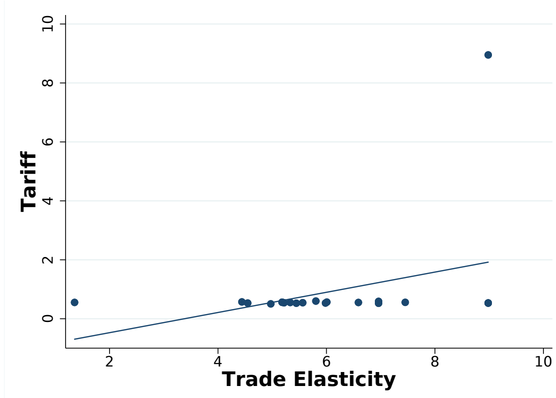
(b) Tariffs and Initial Import Share, $\rho = 0.6$



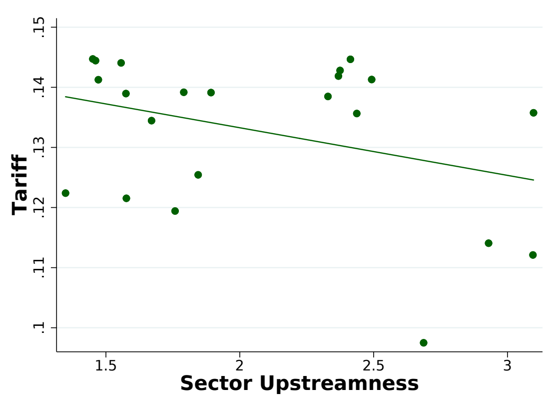
(c) Tariffs and Trade Elasticity, $\rho = 1$



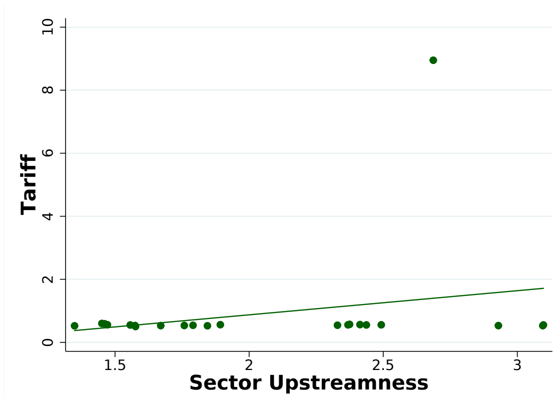
(d) Tariffs and Trade Elasticity, $\rho = 0.6$



(e) Tariffs and Upstreamness, $\rho = 1$



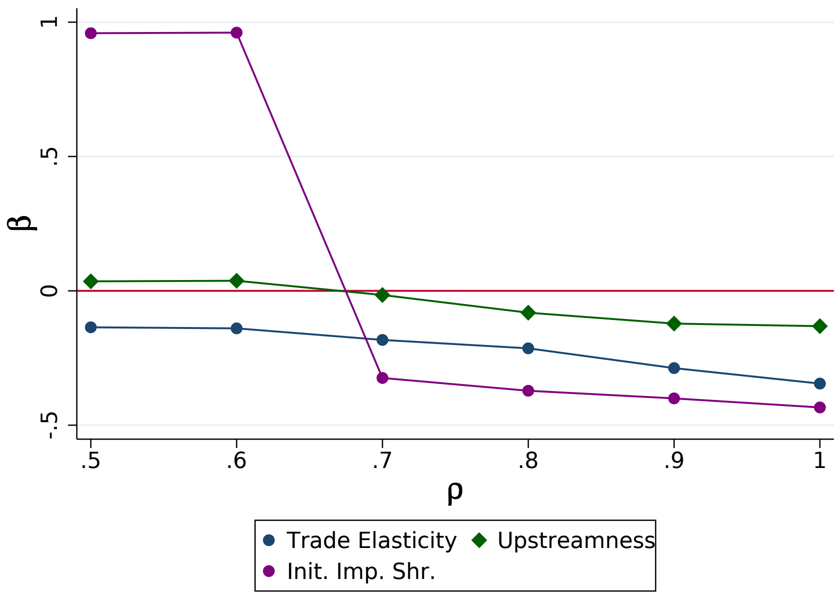
(f) Tariffs and Upstreamness, $\rho = 0.6$



Description: This figure shows the correlations between the optimal sectoral tariffs imposed on Russia by the EU and different sector-level fundamentals under $\rho = 0$ and $\rho = 0.6$.

should face a tariff that is 0.4 standard deviation lower. These relationships change when ρ falls below 0.7, i.e., when the EU places greater weight on punishing Russia. When there is higher willingness to pay, sectors with larger import shares and higher trade elasticities are targeted with higher tariffs.

Figure C.2: **Correlations between Tariffs with Different Fundamentals for Different ρs**



Description: This figure shows the partial correlations between the optimal sectoral tariffs imposed on Russia by the EU and different sector-level fundamentals under different ρs (estimated with Equation C.1).

C.3 Short- and Long-Run Trade Elasticity

In this section, we show that our results are robust to calibrating the model to the long-run trade elasticities.

Calibration We modify Equation 3 to allow for different trade elasticities in the short and long run. Specifically, we estimate the equation:

$$\begin{aligned} y_{p,d,o,t} =& \theta^{s(p)}_{\text{Before}} \tau_{p,d,o,t} \mathbb{I}_{p,c,t} \{j \text{ Yrs. to AD}, j < 0\} + \theta^{s(p)}_{\text{Short Run}} \tau_{p,d,o,t} \mathbb{I}_{p,c,t} \{j \text{ Yrs. to AD}, 0 \leq j \leq 2\} + \\ & \theta^{s(p)}_{\text{Long Run}} \tau_{p,d,o,t} \mathbb{I}_{p,c,t} \{j \text{ Yrs. to AD}, j > 2\} + X'_{p,d,o,t}\beta + \epsilon_{p,d,o,t} \end{aligned}$$

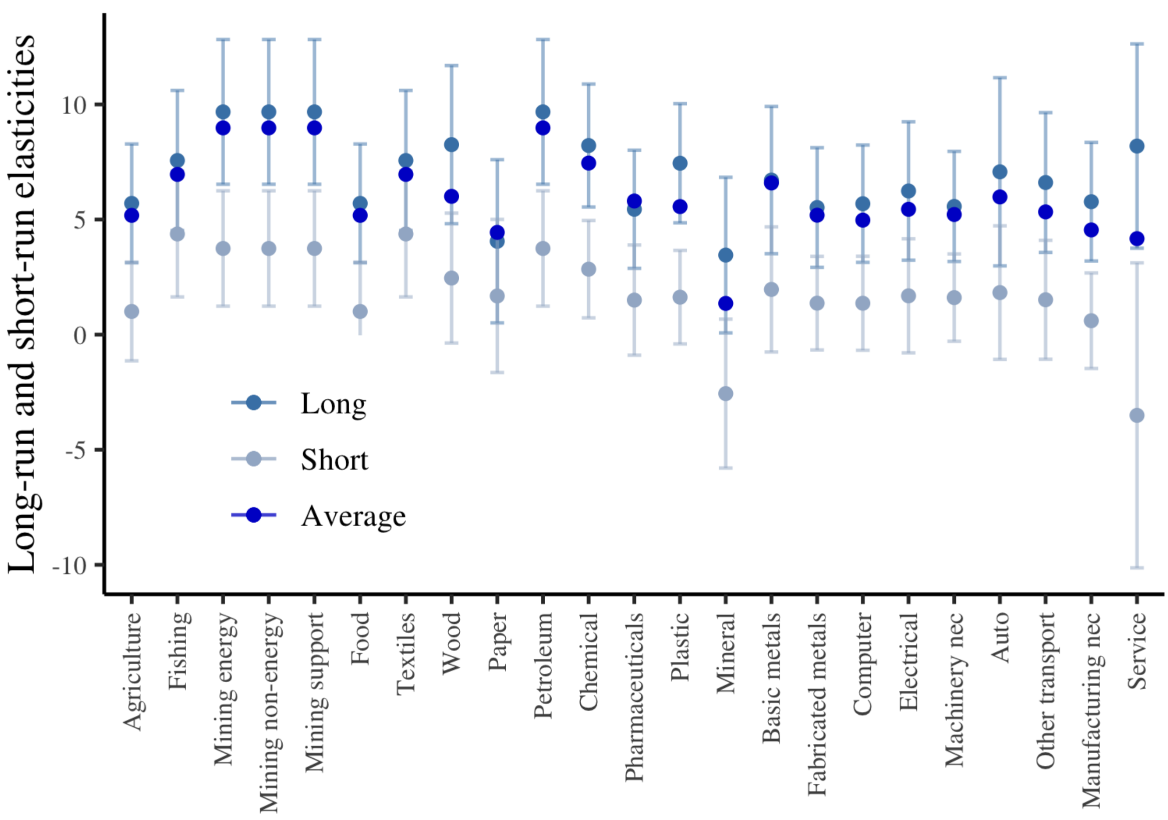
Here, $\mathbb{I}_{p,c,t} \{j \text{ Yrs. to AD}, 0 \leq j \leq 2\}$ is a dummy variable that takes the value 1 up to two years after the first AD tariff is imposed on product p from country o by country d. Similarly,

$\mathbb{I}_{p,c,t}\{j \text{ Yrs. to AD}, j > 2\}$ takes the value 1 three years after the AD tariff is imposed. All other controls are the same as in the main specification.

The parameters of interest are $\theta^{s(p)}_{\text{Short Run}}$, which captures the short-term effect of tariffs after they are imposed, and $\theta^{s(p)}_{\text{Long Run}}$, which captures the long-term effect of tariffs. We compare product-origin pairs that were subject to an AD investigation and had a tariff imposed (the treatment group) to those that were subject to an AD investigation without a tariff being imposed (the control group).

Figure C.3 shows the estimates of the short- and long-run trade elasticities, along with the average trade elasticity estimated in section 2.5. As anticipated, the short-run trade elasticity is smaller than the long-run trade elasticity. In general, the average trade elasticity we estimated in Section 2.5 is close to the long-run trade elasticity.

Figure C.3: **Estimates of the Long- and Short-Run Trade Elasticities**

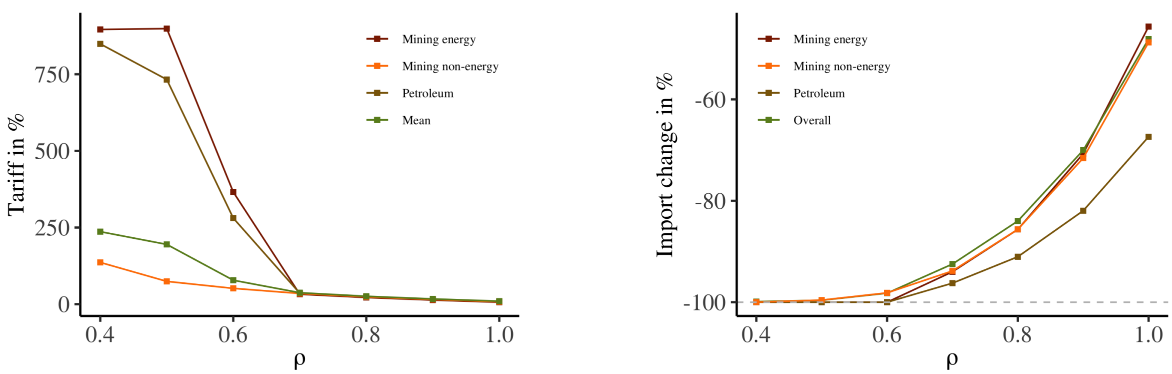


Description: This figure shows sectoral trade elasticities in the short run (from year 0 to year 2), in the long run (from year 3 to year 5), and the average.

Results Using long-run trade elasticities, an embargo on the Russian mining and energy sectors is still the cost-efficient policy when there is high enough willingness to pay for sanctions, according to the results shown in Figure C.4. Overall, the estimated sanctions are similar to the baseline results.[43]

Figure C.4: **Cost-Efficient Sanctions with Long-Run Elasticities in the EU for Different ρs,** $\rho \in [0.4, 1.0]$

(a) Tariff (b) Change in Imports



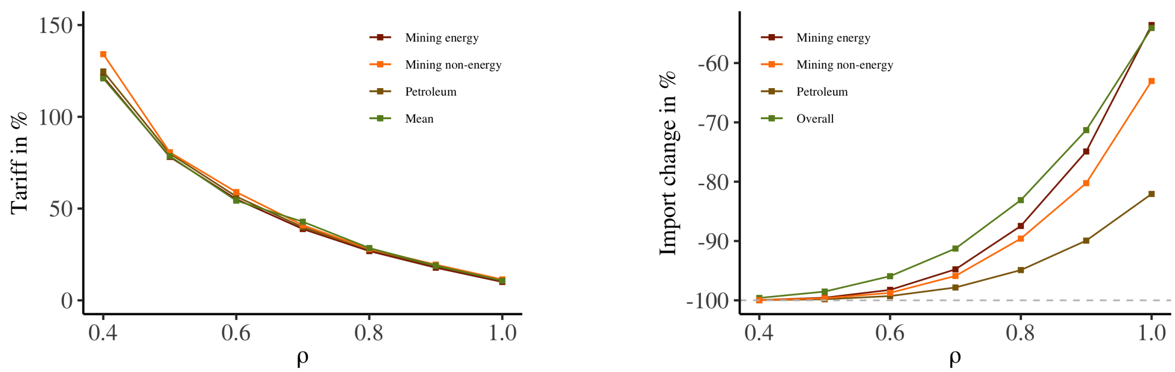
Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay with long-run elasticities, as described in C.3. Figure C.4a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.4b plots the percentage change in imports in the EU for different sectors.

[43]Figure C.25 in the Appendix displays the cost-efficient tariffs using short-run trade elasticities.

C.4 Other Figures and Tables

Figure C.5: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the US,** $\rho \in [0.4, 1]$

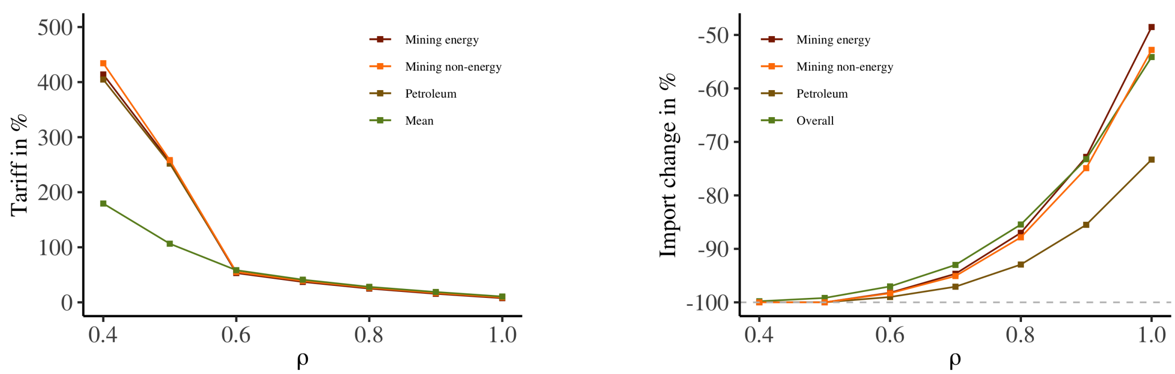
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the US under cost-efficient sanctions with different levels of willingness to pay. Figure C.5a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.5b plots the percentage change in imports in the US at different sectors.

Figure C.6: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the OSA,** $\rho \in [0.4, 1]$

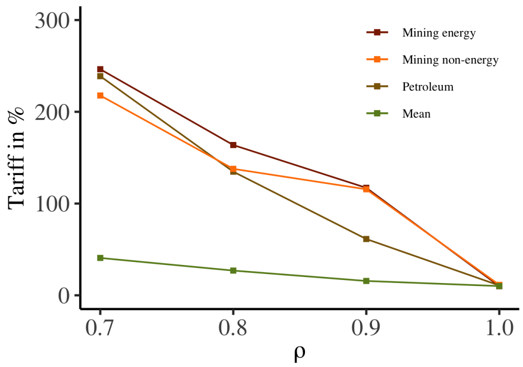
(a) Tariff (b) Change in Imports



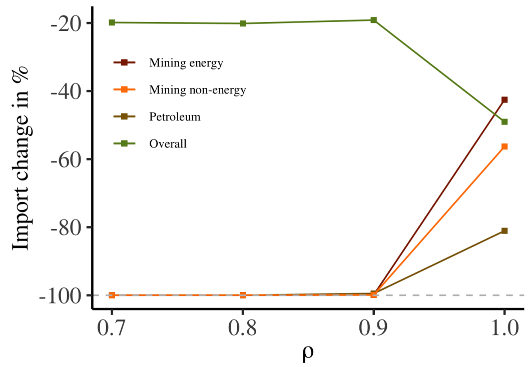
Description: This figure shows the statistics for the OSA under cost-efficient sanctions with different levels of willingness to pay. Figure C.6a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariffs across sectors for different willingness to pay for sanctions, ρ. Figure C.6b plots the percentage change in imports in the OSA for different sectors.

Figure C.7: **Cost-Efficient Sanctions with Political Weights for Different Levels of Willingness to Pay in the US,** $\rho \in [0.7, 1]$

(a) Tariff



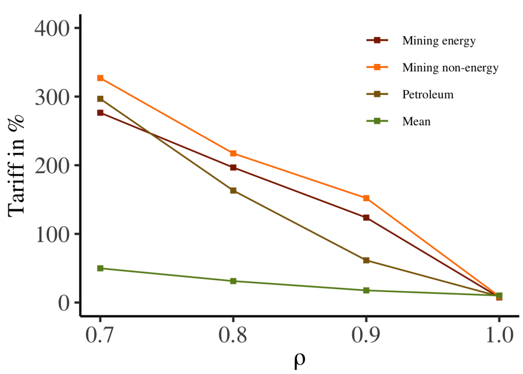
(b) Change in Imports



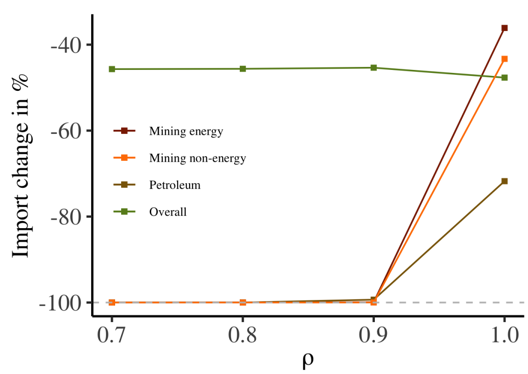
Description: This figure shows the statistics for the US under cost-efficient sanctions with different levels of willingness to pay when the US uses political weights, as described in Table 3. Figure C.7a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.7b plots the percentage change in imports in the US for different sectors.

Figure C.8: **Cost-Efficient Sanctions with Political Weights for Different Levels of Willingness to Pay in the OSA,** $\rho \in [0.7, 1]$

(a) Tariff



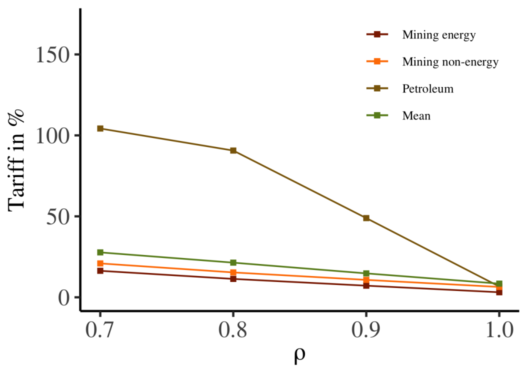
(b) Change in Imports



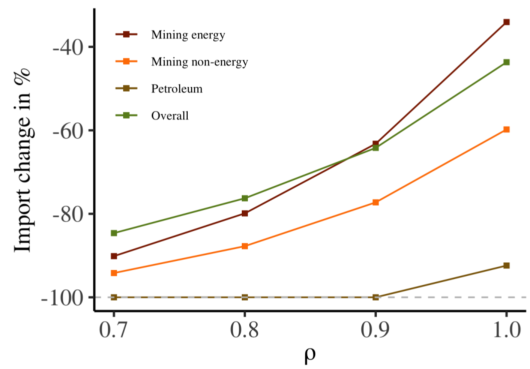
Description: This figure shows statistics for the OSA under cost-efficient sanctions with different levels of willingness to pay when the OSA uses political weights, as described in Table 3. Figure C.8a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.8b plots the percentage change in imports in the OSA for different sectors.

Figure C.9: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the EU, $\rho \in [0.7, 1]$ and Caliendo and Parro (2015) trade elasticities**

(a) Tariff



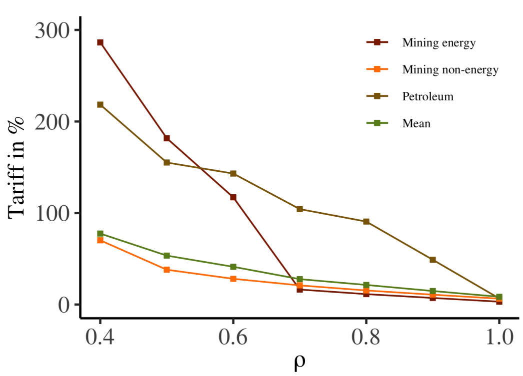
(b) Change in Imports



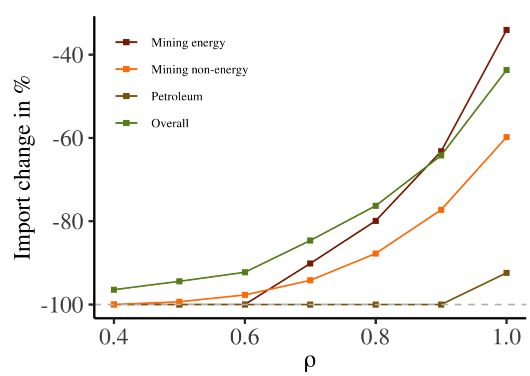
Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay. Figure C.9a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.9b plots the percentage change in imports in the EU for different sectors.

Figure C.10: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the EU, $\rho \in [0.4, 1]$ and Caliendo and Parro (2015) trade elasticities**

(a) Tariff



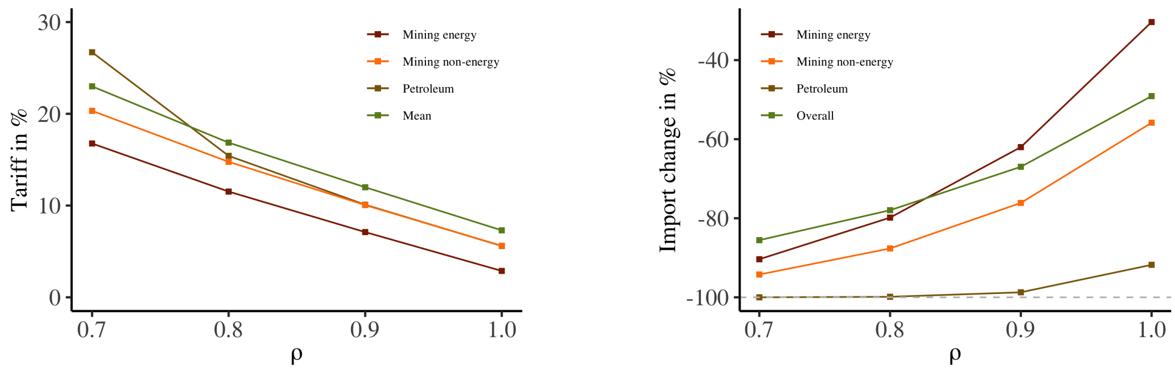
(b) Change in Imports



Description: This figure shows the statistics of the EU under cost-efficient sanctions with different levels of willingness to pay. Figure C.10a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.10b plots the percentage change in imports in the EU for different sectors.

Figure C.11: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the OSA, $\rho \in [0.7, 1]$ and Caliendo and Parro (2015) trade elasticities**

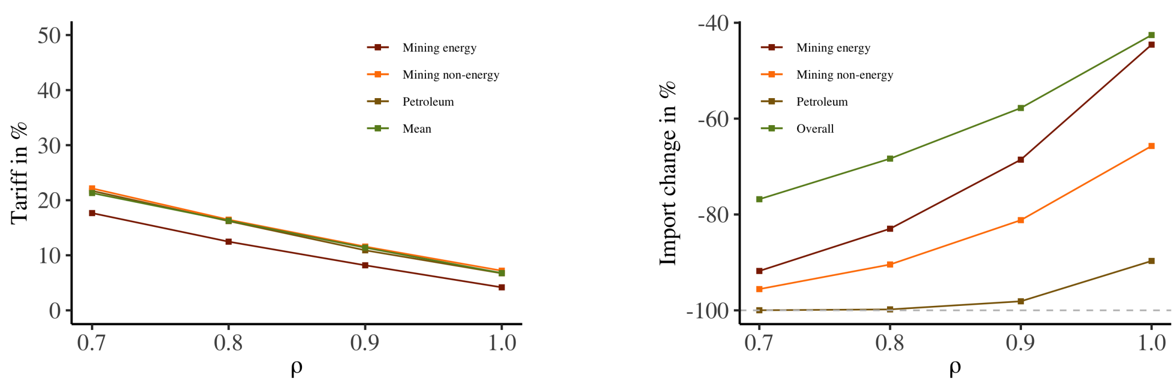
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the OSA under cost-efficient sanctions with different levels of willingness to pay. Figure C.11a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.11b plots the percentage change in imports in the OSA for different sectors.

Figure C.12: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the US, $\rho \in [0.7, 1]$ and Caliendo and Parro (2015) trade elasticities**

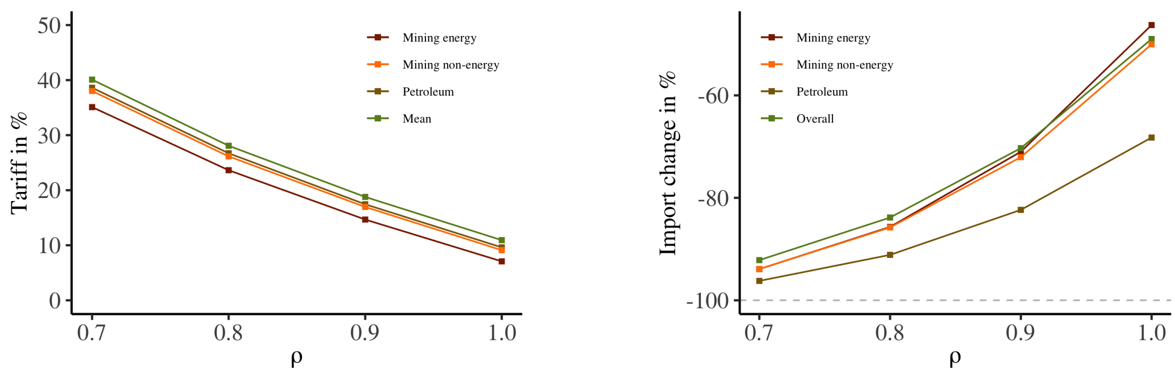
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the US under cost-efficient sanctions with different levels of willingness to pay. Figure C.12a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.12b plots the percentage change in imports in the US for different sectors.

Figure C.13: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the EU, $\rho_{\textbf{Sanction}} \in [0.7, 1]$ and $\rho_{RUS} \equiv 1$**

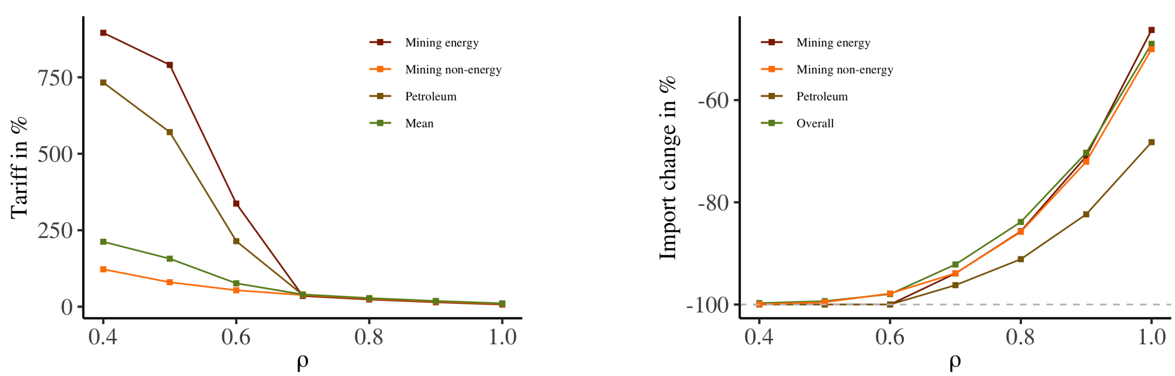
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay. Figure C.13a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.13b plots the percentage change in imports in the EU for different sectors.

Figure C.14: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the EU, $\rho_{\textbf{Sanction}} \in [0.4, 1]$ and $\rho_{RUS} \equiv 1$**

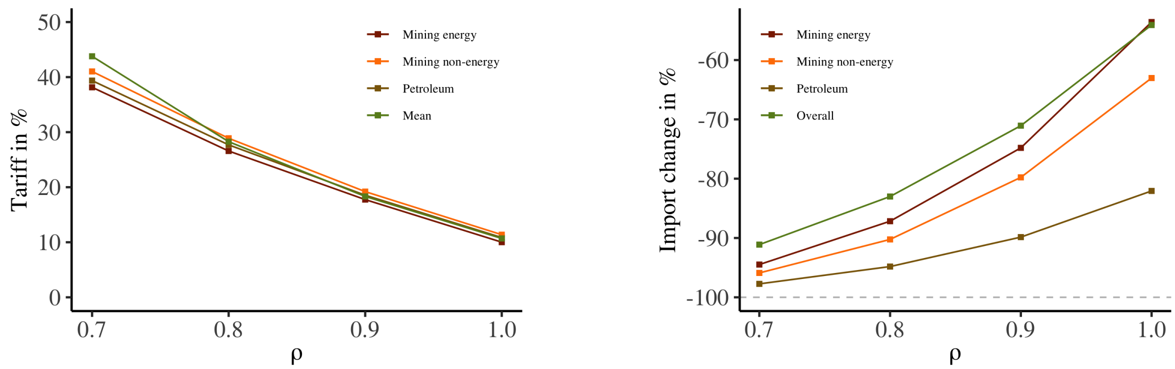
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay. Figure C.14a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.14b plots the percentage change in imports in the EU for different sectors.

Figure C.15: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the US, $\rho_{\textbf{Sanction}} \in [0.7, 1]$ and $\rho_{RUS} \equiv 1$**

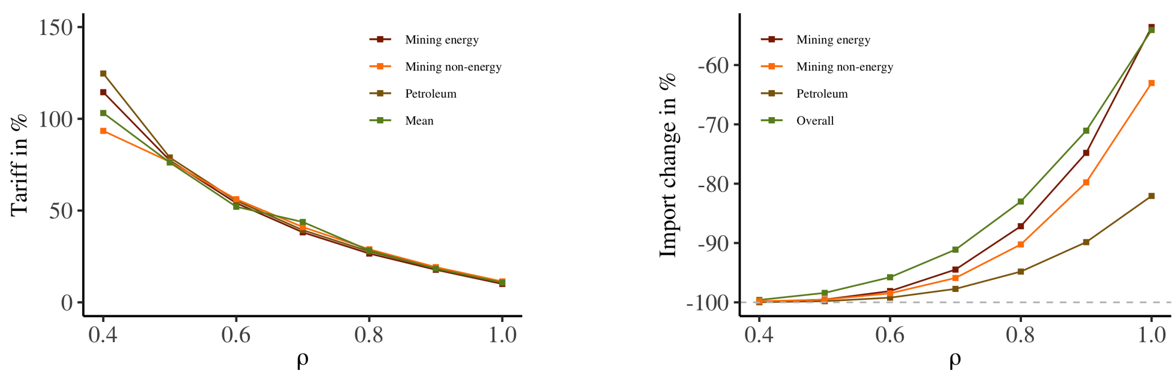
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the US under cost-efficient sanctions with different levels of willingness to pay. Figure C.15a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.15b plots the percentage change in imports in the US for different sectors.

Figure C.16: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the US, $\rho_{\textbf{Sanction}} \in [0.4, 1]$ and $\rho_{RUS} \equiv 1$**

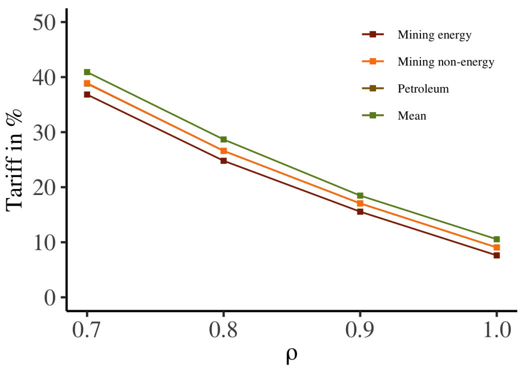
(a) Tariff (b) Change in Imports



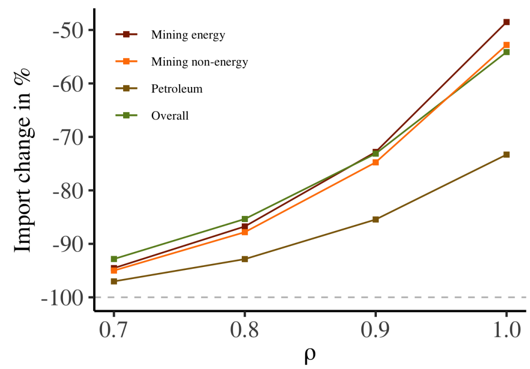
Description: This figure shows the statistics of the US under cost-efficient sanctions with different levels of willingness to pay. Figure C.16a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.16b plots the percentage change in imports in the US for different sectors.

Figure C.17: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the OSA, $\rho_{\textbf{Sanction}} \in [0.7, 1]$ and $\rho_{RUS} \equiv 1$**

(a) Tariff



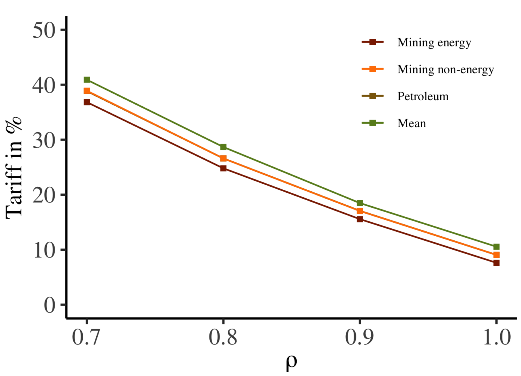
(b) Change in Imports



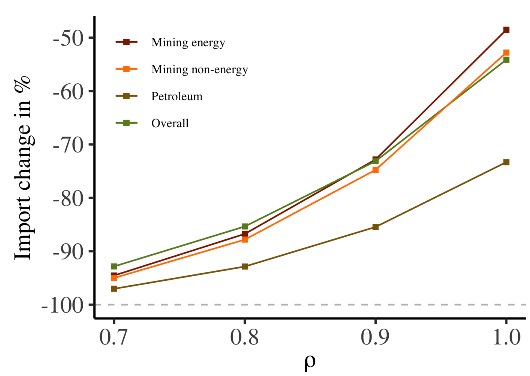
Description: This figure shows the statistics of the OSA under cost-efficient sanctions with different levels of willingness to pay. Figure C.17a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.17b plots the percentage change in imports in the OSA for different sectors.

Figure C.18: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the OSA, $\rho_{\textbf{Sanction}} \in [0.4, 1]$ and $\rho_{RUS} \equiv 1$**

(a) Tariff



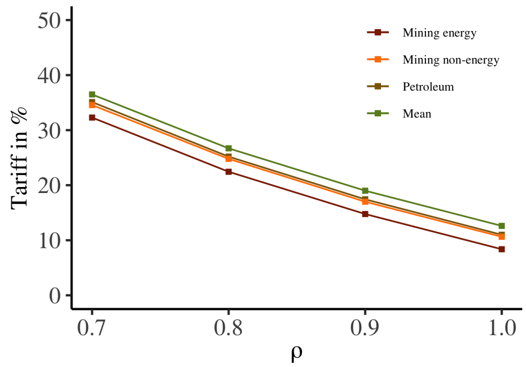
(b) Change in Imports



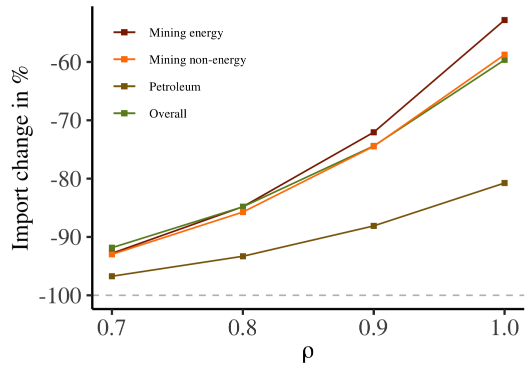
Description: This figure shows the statistics for the OSA under cost-efficient sanctions with different levels of willingness to pay. Figure C.18a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.18b plots the percentage change in imports in the OSA for different sectors.

Figure C.19: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the EU, $\rho_{\textbf{Sanction}} \in [0.7, 1]$ and $\rho_{RUS} \equiv 0$**

(a) Tariff



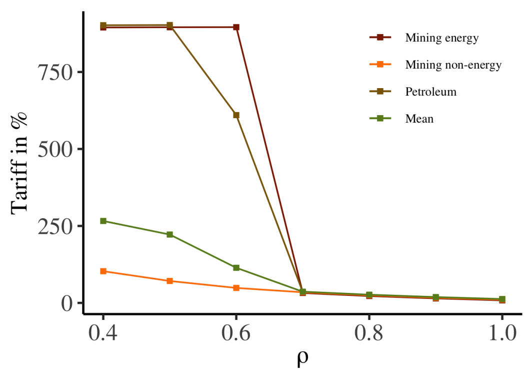
(b) Change in Imports



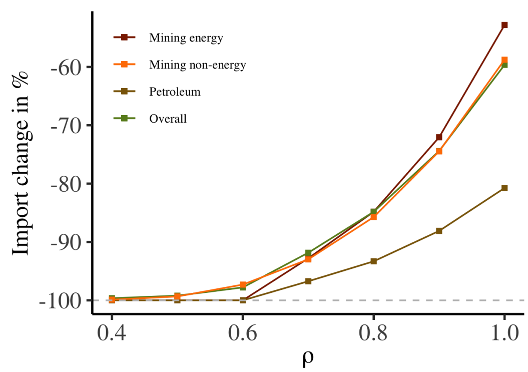
Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay. Figure C.19a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.19b plots the percentage change in imports in the EU for different sectors.

Figure C.20: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the EU, $\rho_{\textbf{Sanction}} \in [0.4, 1]$ and $\rho_{RUS} \equiv 0$**

(a) Tariff



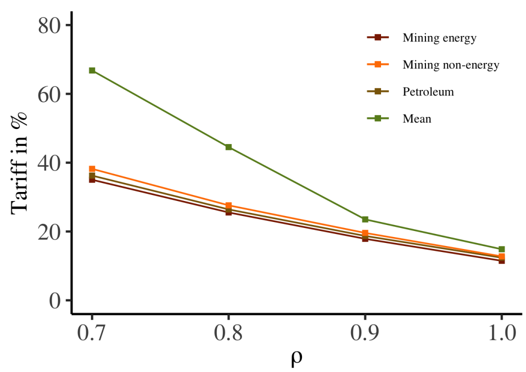
(b) Change in Imports



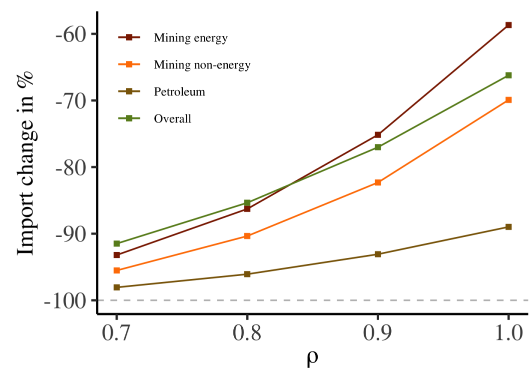
Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay. Figure C.20a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.20b plots the percentage change in imports in the EU for different sectors.

Figure C.21: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the US, $\rho_{\textbf{Sanction}} \in [0.7, 1]$ and $\rho_{RUS} \equiv 0$**

(a) Tariff



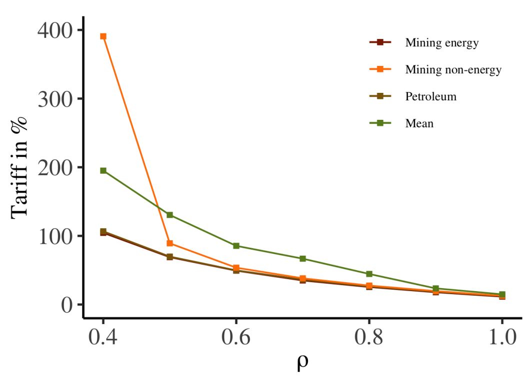
(b) Change in Imports



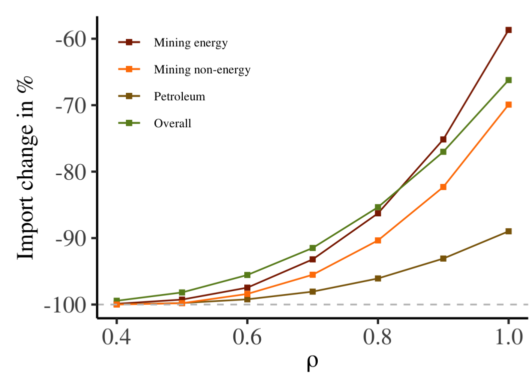
Description: This figure shows the statistics for the US under cost-efficient sanctions with different levels of willingness to pay. Figure C.21a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.21b plots the percentage change in imports in the US for different sectors.

Figure C.22: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the US, $\rho_{\textbf{Sanction}} \in [0.4, 1]$ and $\rho_{RUS} \equiv 0$**

(a) Tariff



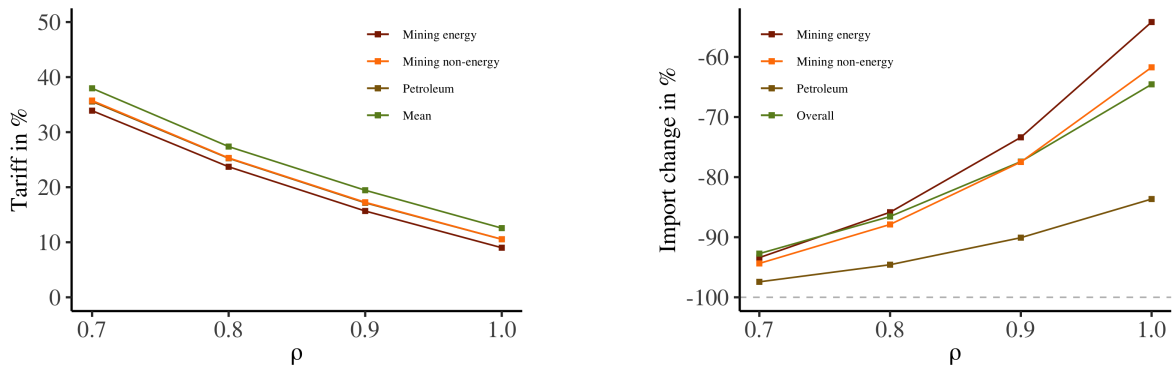
(b) Change in Imports



Description: This figure shows the statistics of the US under cost-efficient sanctions with different levels of willingness to pay. Figure C.22a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.22b plots the percentage change in imports in the US for different sectors.

Figure C.23: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the OSA,** $\rho_{\textbf{Sanction}} \in [0.7, 1]$ **and** $\rho_{RUS} \equiv 0$

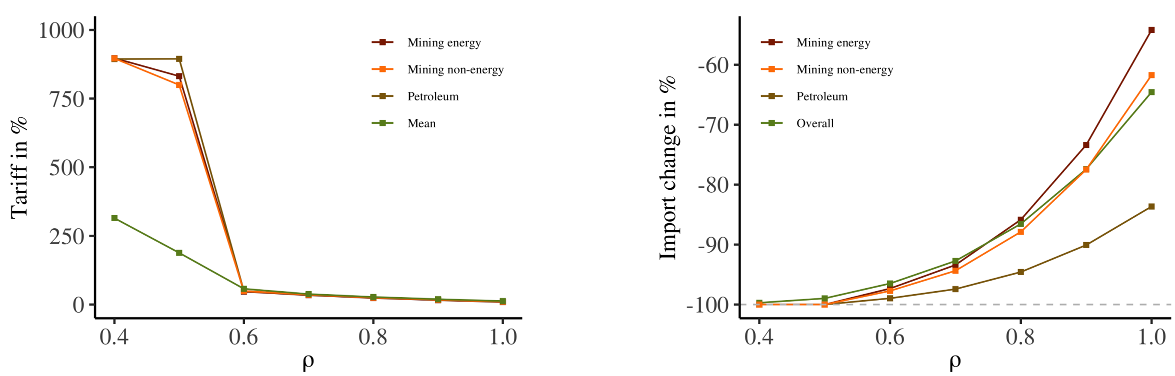
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics of the OSA under cost-efficient sanctions with different levels of willingness to pay. Figure C.23a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.23b plots the percentage change in imports in the OSA for different sectors.

Figure C.24: **Cost-Efficient Sanctions for Different Levels of Willingness to Pay in the OSA,** $\rho_{\textbf{Sanction}} \in [0.4, 1]$ **and** $\rho_{RUS} \equiv 0$

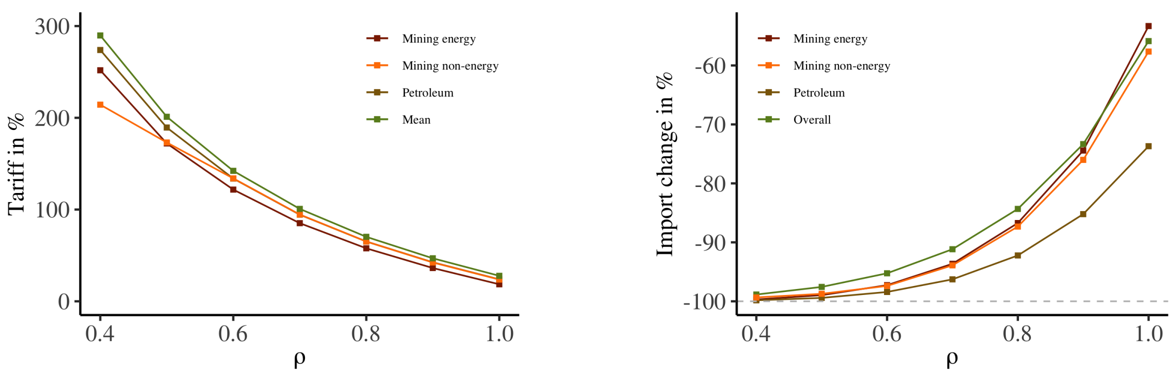
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics of the OSA under cost-efficient sanctions with different willingness to pay. Figure C.24a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.24b plots the percentage change in imports in the OSA for different sectors.

Figure C.25: **Cost-Efficient Sanctions with Short-Run Elasticities in the EU for Different ρs, $\rho \in [0.4, 1.0]$**

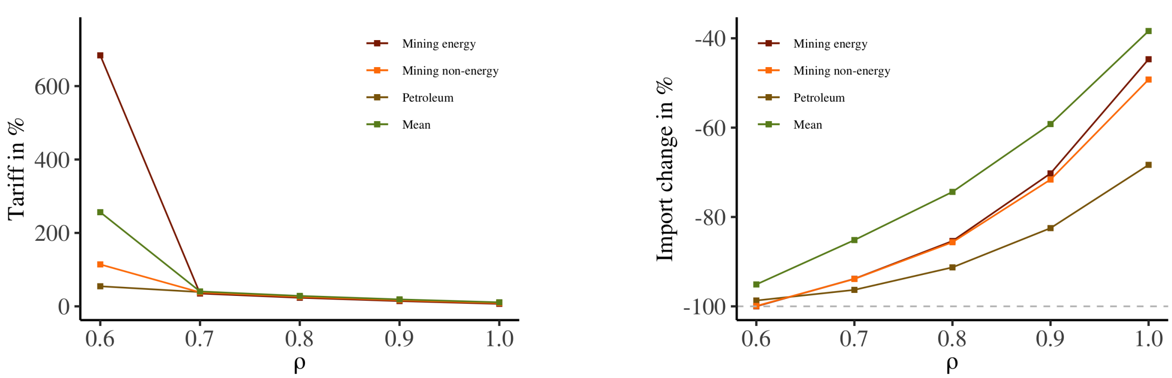
(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay with short-run elasticities described in C.3. Figure C.25a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.25b plots the percentage change in imports in the EU for different sectors.

Figure C.26: **Cost-Efficient Sanctions in the EU for Different ρ's with CES Production Function and Low Elasticity of Substitution**

(a) Tariff (b) Change in Imports



Description: This figure shows the statistics for the EU under cost-efficient sanctions with different levels of willingness to pay for sanctions. The production function is described in 18 and the elasticity of substitution between labor and materials is calibrated to 0.1. Figure C.26a plots the cost-efficient tariffs on mining energy, mining non-energy, petroleum, and the average unweighted tariff across sectors for different levels of willingness to pay for sanctions, ρ. Figure C.26b plots the percentage change in imports in the EU for different sectors.

C.5 Sanctioning Countries' Real Income Does not Decrease

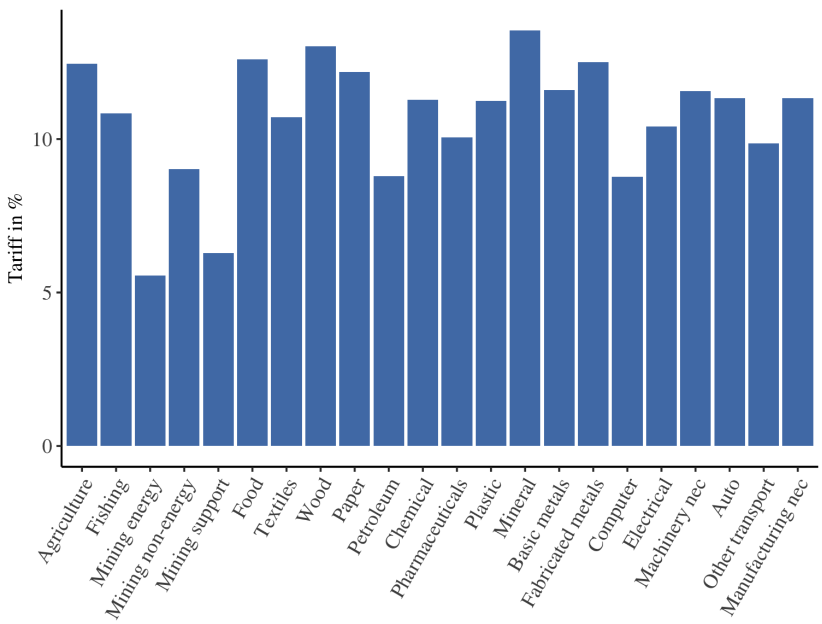
In this section, we study the cost-efficient sanctions with which the sanctioning countries' real income does not decrease, but they minimize the real income in Russia. The sanctioning country n's problem (in changes) is the following. Conditional on all other tariffs except those country n imposes on Russia, $\hat{\mathbf{t}}_{\mathbf{-nR}}$, the objective of country n is:[44]

$$
\begin{aligned}
g_n(\hat{\mathbf{t}}_{\mathbf{-nR}}) \in argmin_{\{\boldsymbol{\tau_{n,R}}\}} G_R \hat{G}_R(\hat{\mathbf{t}}_{\mathbf{nR}}, \hat{\mathbf{t}}_{\mathbf{-nR}}), \\
\text{s.t. Equilibrium Conditions B.1-B.6,} \\
\hat{G}_n(\boldsymbol{\tau_{nR}}, \boldsymbol{\tau_{-nR}}) \geq 1
\end{aligned}
\tag{C.2}
$$

Figure C.27 shows cost-efficient sanctions by the EU that satisfy Problem C.2. These tariffs are similar to those when the sanctioning country has low willingness to pay to sanction Russia. The tariffs are low (about 10%) on average and similar across sectors. As the EU does not want to decrease its own real income, lower tariffs should be imposed on energy extraction and petroleum sectors.

[44]We assume that Russia's retaliation strategy is to set tariffs on the sanctioning countries to maximize Russia's welfare; it follows Problem 15 where we set $\rho_{RUS} = 1$.

Figure C.27: **Cost-Efficient Sanctions with No Decrease in EU Welfare**



Description: This figure shows the cost-efficient sectoral tariffs that the EU imposes on Russia when the EU solves Problem C.2: the EU minimizes Russian welfare but requires that its own welfare does not decrease.