UNIVERSITÀ CATTOLICA del Sacro Cuore

**DIPARTIMENTO DI POLITICA ECONOMICA**

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**Abstract**

This study employs a gravity model to investigate the impact of sanctions on trade of mineral commodities (HS 6-digit level) from 2009 to 2020, employing a dataset encompassing flows from 239 exporter countries to 38 OECD members. Main results highlight that: (i) a substantial trade disruption is evident, marked by an immediate 90 percent reduction, with a growing impact observed over time; (ii) sanctions-busting appears effective only in the very short term, albeit with weak supporting evidence; (iii) sender countries experience a decline in trade not only with target countries but also with third-party nations (negative network effect). When scrutinizing by world regions and HS chapters, the evidence becomes nuanced. It appears that sender North American countries demonstrate the capability to replace imports from target countries with alternative suppliers, while EU countries experience a clear-cut trade disruption. When examining different HS chapters, findings indicate that sanctions lead to a reduction in trade of mineral commodities classified under chapters 26 and 27, but not in those under chapter 25. As for sanctions-busting, it appears to be evident for commodities under chapter 26. Yet, sender countries importing commodities under chapter 25 appear to be able to shift to other sources whereas sender countries importing commodities under chapter 27 experience a substantial trade disruption.

**JEL classification:** F100, F130, F140, F500, F510, N400, N500.

**Keywords:** Trade Sanctions; Mineral sector; Industrial raw materials; Gravity Model; Trade disruption; Trade diversion; Sanctions - Busting.

## *1 Introduction*

In response to Russia's invasion of Ukraine in February 2022, many countries imposed extensive economic sanctions on Russia. These sanctions represent some of the most comprehensive measures ever applied to a major economic power. This has ignited significant interest in using sanctions as a foreign policy tool and understanding their effectiveness.

Sanctions, as defined by Morgan et al. (2023), are "restrictive policy measures" taken by one or more countries to limit their relations with a target country with the aim of persuading that country to change its policies or address potential violations of norms and international conventions. Negative sanctions encompass punitive actions implemented by a sending state to inflict economic harm on a target state. In fact, negative economic sanctions serve as an alternative foreign policy tool to war. In the face of interstate hostilities, negative sanctions are employed to compel antagonistic regimes to comply with the directives of one or more states.

The aim of this article is to assess the impact of trade sanctions on the trade of industrial raw materials within the mineral sector during the period 2009-2020. In an economic perspective, economic sanctions disrupt extant economic interactions or impede the establishment of new ones. Specifically, trade sanctions can take various forms to restrict or prohibit trade, such as embargoes, import or export bans, or other trade barriers. By design, trade sanctions diminish the volume of trade between the sender and target. Nevertheless, their impact extends to third countries as well. Furthermore, the trade disruption caused by sanctions may yield a significant impact on global commodity prices.

Nevertheless, trade sanctions do not determine trade disruption only. Van Bergeijk (1994a,b, 1995) elucidates the emergence of sanctions-busting and negative network effects as consequential outcomes of sanctions. In fact, they might determine trade diversion through mechanisms aimed at circumventing sanctions (namely the sanctions-busting). In such cases, sanctions give rise to trade patterns between target countries and third countries that are not implicated in the sanctioning framework. Nevertheless, sender countries may also seek to augment trade volumes with third parties as a means of replacing the target countries in their trade partnerships. For example, when the U.S. imposed a comprehensive embargo on Nicaragua, European nations continued to maintain trade relations, and Canada even facilitated Nicaragua's relocation of its foreign trade office from Miami to Toronto in an attempt to facilitate circumvention of the sanctions. The insightful work by Early (2015) provides an in-depth examination of sanctions-busting. In summary, the evidence surrounding sanctions-busting is somewhat intricate, as a substantial number of states engage in trade-based sanctions evasion.

Critical factors to evaluate the likelihood of sanctions-busting are whether the sanctions are 1) partial or comprehensive; 2) unilateral or multilateral. Unilateral and partial sanctions hold limited effectiveness, as sanctions-busting readily occurs, thereby hindering the effective isolation of the target country. Partial yet multilateral sanctions may prove more effective provided there is effective coordination within the international community. In scenarios involving total but unilateral sanctions, both negative network effects and the phenomenon of sanctions-busting become apparent. It is evident that in the presence of multilateral sanctions, the emergence of sanctions-busting is less likely.

As noted above, trade diversion represents just one facet of altered trade patterns. In reality, sanctions can be so far-reaching that they lead to generalized trade disruption, a phenomenon referred to as negative network effects. In empirical terms, negative network effects result in a decrease in trade flows not only between sender and target countries but also involving third countries. Moreover, they lead to a

decrease in imports from both the target country and alternative sources.

In this article, we assess the impact of trade sanctions on OECD imports of minerals. Specifically, we exploit data for 63 industrial raw commodities within the mineral sector, corresponding to the Harmonized System (HS) subheading level of detail (i.e., six digits), sourced from 239 exporters during the period 2009-2020.

The focus on minerals is motivated by several compelling factors. Firstly, the surge in economic growth and industrialization has led to a heightened demand for minerals in the long-run. Stuermer (2017) exploits a dataset including a sample of 12 industrialised countries and three recent fast-industrializing countries (China, India, Brazil) from 1840 to 2010 to investigate the long-run demand for mineral commodities. The impact of GDP per capita on long-run demand of minerals is clear-cut albeit heterogenous with regard to specific commodities. Additionally, as investigated in Islam et al. (2022) the transition towards clean energy sources has further augmented this demand, necessitating substantial quantities of minerals as essential raw materials. Secondly, as explained in Moroney and Trapani (1981) the potential for substitution for mineral-intensive industries is constrained and therefore in the case of sanctions this could constitute a significant impact on the global trade.

We employ a gravity model, which represents the prevailing empirical approach for scrutinizing international trade patterns. This model, initially introduced by Isard (1954) and further developed by Tinbergen (1962) and Linnemann (1966), explicates trade interactions between two countries by incorporating factors such as their economic scale, geographical proximity, and other pertinent variables. We augment the traditional gravity model with three dummy variables to capture: (i) the degree of trade disruption between sender and target countries; (ii) whether a sender country redirects its imports from a target country to an alternative supplier country; (iii) whether the target country diverts its exports to third countries. Both (ii) and (iii) would constitute trade diversion or sanctions-busting, albeit involving different countries.

As predicted, the baseline empirical findings show the immediate trade disruption occurring between the sender and target countries. Notably, when considering different time lags, our analysis reveals an interesting trend in the coefficient, indicating a growing impact over time. Specifically, it rises from an immediate 90 percent effect to 95 percent after four years, eventually decreasing to a 66 percent impact after five years. More intriguingly, between one and up to four years following the imposition of the sanction, there is a decrease in trade not only between the countries directly affected by the sanction but also with third countries. To be specific, a trade sanction leads to a reduction in international trade for the sender countries, ranging from approximately 27 percent after one year to approximately 46 percent after four years. Furthermore, we conducted a reiteration of the analysis, specifically highlighting the impact of sanctions on distinct minerals. It is noteworthy that when scrutinizing the data according to mineral types, both trade disruption and trade diversion manifest quantitatively distinct outcomes.

One limitation of our analysis is that our model does not account for trade effects stemming from the substitution of domestic sales. Addressing this would necessitate a model with a nested CES structure and access to domestic trade data at a level of disaggregation equivalent to that of international trade. In spite of our endeavors to evaluate the influence of trade sanctions using meticulously detailed data, trade policies exhibit substantial divergence across products and countries, and comprehensive data pertaining to intra-national trade are unavailable.

Our analysis is based on a dataset built from information covering imports of 63 raw mineral com-

modities (HS Section V) from 239 exporters to 38 OECD countries over the period 2009-2020. When analyzing the impact of trade sanctions, most contributions in the literature have considered total trade between countries. This approach, however, may not be appropriate if the objective of the analysis is to evaluate the impact of a specific policy, such as a trade sanction, which is applied at product level. In particular, the objective of the sanction (especially in the case of partial sanctions) is not so much to influence the total trade of the affected countries, but rather to target countries in some specific sectors for which the sanction is imposed.

The use of disaggregated data allows us to evaluate in which sectors or for which commodities a specific sanctioning policy has or has not been effective. This information cannot be detected if aggregate data is used. However, detailed databases on trade sanctions applied between countries at the product level are not easily accessible. In this work, we have built a dataset by combining information from the OECD Inventory of export restrictions on industrial raw materials and the Global Sanctions Database (GSDB). Section 3 explains our strategy for merging the two databases and for creating a bilateral dummy variable to indicate the presence of trade sanctions at the product level.

The paper is structured as follows: Section 2 describes the empirical strategy for estimating the impact of trade sanctions on minerals; Section 3 provides information on our dataset and some descriptive statistics, Section 4 presents and discusses the results and finally, section 5 concludes.

## 2 *Literature review*

This work contributes to the sparse literature on the economic impact of sanctions. The economic impact is crucial to predict the political success of such punitive measures (see among others Navin A. Bapat and Morgan (2013); Bonetti (1998); Pape (1997); Hufbauer et al. (1990)). In general, when delving into the economic consequences, trade sanctions have a negative impact on bilateral trade flows between the target countries and their trading partners (Felbermayr et al., 2020a,b).

In a previous study by Caruso (2003), a gravity equation is used to examine the impact of U.S. sanctions imposed during the period from 1960 to 2000. The analysis extends beyond the U.S. and the target countries, including trade flows with other G-7 nations. It is found that if the U.S. refrained from implementing unilateral negative sanctions during the present period, its trade with target countries could be approximately 60 percent higher, with even greater losses in the case of global sanctions, exceeding 80 percent. Interestingly, the absence of U.S. sanctions would lead to a 17 percent reduction in trade for other G-7 nations, indicating that U.S. sanctions inadvertently boost the exports of these countries. This highlights the need to consider these factors when evaluating the effectiveness of negative sanctions. However, it's important to note that negative network effects still occur with total sanctions, especially as the number of trade ties of the target country increases, potentially leading to sanctions-busting during the present period. Afesorgbor (2019) delves into the distinct impact of economic sanctions when they are threatened versus when they are actually imposed on international trade flows. The findings reveal qualitative and quantitative differences in the effects of threatened and imposed sanctions. Specifically, while imposed sanctions result in a reduction in trade flows between the sender and the target country, the mere threat of sanctions tends to have the opposite effect, leading to an increase in trade. A study by Larch et al. (2022) use a gravity equation to analyze the impact of sanctions on bilateral trade in the mining industry, including oil and natural gas. The study finds that sanctions have effectively hindered mining trade, with complete trade sanctions reducing bilateral mining trade by an average of 44 percent.

Mining commodities play a significant role in global trade, accounting for 20 percent of world trade, and are crucial for the economic growth of nations. Therefore, sanctions in the mining sector can significantly undermine economic activity and well-being, particularly in the sanctioned states. Doan and Tran (2023) conducted an empirical examination into the impact of economic sanctions on the exchange of cultural commodities, utilizing cross-country data encompassing 5,304 country pairs over the period spanning from 1996 to 2019. The primary empirical outcomes reveal that economic sanctions exert a stimulative effect on the trade of cultural goods. This impact exhibits heterogeneity across diverse categories of economic sanctions. Notably, military, arms, trade, and travel sanctions are observed to function as facilitators of cultural goods trade, while financial and other sanctions act as impediments. Furthermore, these effects are contingent upon the economic development level of the sanctioned countries and exhibit temporal dynamics. Other works focus on specific case-studies. Nguyen and Do (2021) examine the impact of economic sanctions imposed on the exports of the Russian Federation and the effect of Russian counter-sanctions. The authors use the data from 49 trading partners of Russia from 2011 to 2018 and employ a gravity modelling approach. The study reveals that (i) economic sanctions imposed on the Russian Federation and the corresponding counter-sanctions result in notable contractions in both the overall export and Russian import values. Specifically, the sanctions induce a decline of 25.25 percent in the Russian export values, while counter-sanctions lead to a 25.92 percent reduction in the Russian import values from the originating countries; (ii) the impacts of sanctions and counter-sanctions vary across export and import product categories. Notably, the sanctions significantly impact the Russian export of oil products, causing a substantial 36.56 percent reduction in export value, whereas the effects of the sanctions on the Russian export of non-oil products are deemed insignificant. Evenett (2002) assessed the impact of sanctions on South Africa by gauging the influence of eight developed economies' sanctions on their imports from South Africa. Notably, the presence of outliers significantly impacts the parameter estimates. Disregarding these outliers may lead to the incorrect inference that sanctions imposed by the EUropean countries had the most detrimental impact on South African exports. However, robustness checks underscore that the Comprehensive Anti-Apartheid Act enacted by the United States played the most substantial role, resulting in a one-third reduction in bilateral imports. Other studies highlight the varied economic consequences of sanctions, including impacts on GDP growth, inequality, and unemployment. Neuenkirch and Neumeier (2015) assessed the impact of UN and US sanctions using a dataset comprising 160 countries, 67 of which were subjected to economic sanctions between 1976 and 2012. The results underscore that, on average, the implementation of UN sanctions leads to a reduction of over 2 percentage points in the target state's annual real per capita GDP growth rate. These adverse effects endure for a decade, resulting in an overall decline of 25.5 percent in the target country's GDP per capita. Specifically, comprehensive UN economic sanctions, encompassing embargoes affecting nearly all economic activities, prompt a reduction in GDP growth by more than 5 percentage points. In contrast, the impact of US sanctions is notably smaller and less pronounced. The imposition of US sanctions diminishes the target state's GDP growth by 0.75–1 percentage point. This detrimental effect on growth persists for seven years, contributing to an aggregate decline in GDP of 13.4 percent. In a complementary study, Neuenkirch and Neumeier (2016) conducted an analysis of the impact of US economic sanctions on the poverty gap in target countries during the period spanning 1982 to 2011. The findings reveal a detrimental influence of US sanctions on individuals in poverty, evidenced by a 3.8 percentage point larger poverty gap in target countries compared to a control group

carefully matched in terms of observable pretreatment characteristics. Moreover, the impact of sanctions on poverty is characterized by the following features: (i) a positive correlation with the severity of sanctions, (ii) a more pronounced effect for multilateral sanctions compared to unilateral sanctions imposed solely by the United States, and (iii) a persistent nature, with the poverty gap expanding over the initial 21 years of a sanction regime. Gharehgozli (2017) estimates that sanctions reduced Iran's real GDP by more than 17 percent in the period 2011-2014. Du and Wang (2022) use a multi-country multi-sector general equilibrium model with trade, multinational production (MP), and input–output linkages. The authors calibrate the model with 44 economies and 34 sectors prior to the Russia–Ukraine war in 2022. The counterfactual analysis suggests that the economic sanctions that cut trade and MP linkages between Russia and all other economies except China would decrease the real income in Russia by 11.98 percent. Moreover, if only trade linkages are cut, the real income in Russia would decrease by 9.55 percent. Kim et al. (2023) investigate the economic costs of the UN sanctions on North Korea by exploiting a data set on North Korean firms. Findings reveal that trade sanctions cause reduced the country's manufacturing output by 12.9 percent and real income by 15.3 percent. Kelishomi and Nisticò (2022) investigate the short-run effect of economic sanctions on manufacturing employment in Iran in 2012. Sanctions resulted in a comprehensive decrease in the growth rate of manufacturing employment by 16.4 percentage points. Notably, we identify substantial asymmetric effects across industries characterized by varying ex-ante import shares. Interestingly, these effects are predominantly propelled by labor-intensive industries and sectors with a pronounced reliance on imported inputs. Moeeni (2021) undertakes an assessment of the impact of economic sanctions on children's education, leveraging the United Nations sanctions imposed on Iran in 2006 as a natural experiment. Employing a methodological approach that capitalizes on the variation in the strength of sanctions across industries and utilizing difference-in-differences with synthetic control analyses, this study reveals that the sanctions led to a decrease in children's total years of schooling by 0.1 years and a reduction in the probability of attending college by 4.8 percentage points. Additionally, households exhibited a substantial 58 percent decrease in education spending, with a particular emphasis on reductions in school tuition expenditures. Jeong (2020) examines the relationship between economic sanctions and income inequality of target states. Sanctions exhibit a noticeable impact on the income inequality of the target states. The contention is that this impact varies significantly depending on the specific sanctions employed and the economic circumstances of the targeted countries. Analyzing data from 152 countries spanning the period 1974 to 2011, the findings indicate that import sanctions contribute to an increase in inequality in labor-abundant target countries. However, this effect is not observed in labor-scarce target countries. Using a cross-country analysis of 68 target states from 1960 to 2008, Afesorgbor and Mahadevan (2016) find robust empirical evidence that the imposition of sanctions has a deleterious effect on income inequality.

## *3 Estimating the impact of trade sanctions on mineral commodities.*

In this work, we assess the change in international trade of mineral commodities stemming from trade sanctions using a gravity model. Gravity models are widely used in international trade literature, and they are an application of Newton's law of gravity. The first applications of the gravity model in international trade literature were developed by Tinbergen (1962) and Pöyhönen (1963).

In this work, we assume that country $i$ (the sender country) applies sanctions to mineral commodity $k$ from target country $j$. If, after the sanctions, country $i$ imports less of mineral commodity $k$ from

country $j$ and more from country $z$, trade diversion has occurred. In contrast, if country $i$ imports less of mineral commodity $k$ from both $j$ and $z$, trade destruction has occurred due to negative network effects (Van Bergeijk, 1995), such as changes in the world economic system (e.g., supply chain disruption) that influence the economic opportunities of countries not directly involved in the conflict.
Our gravity equation specification follows the methodology proposed by Yotov et al. (2016) and includes the following features:

1. exporter-sector-time and importer-sector-time fixed effects to account for unobservable multilateral resistance terms;

2. country-pair-sector fixed effects to consider time-invariant bilateral trade costs and mitigate endogeneity issues;

3. utilization of the Poisson Pseudo Maximum Likelihood (PPML) estimator to address heteroskedasticity in trade data and capture information within zero trade flows;

4. estimations are conducted using a dataset comprising consecutive-year data (Egger et al., 2022);

5. to address potential simultaneity problems, the dummy variables for the presence of trade sanctions are lagged by one year.

Letting $Sanction^k_{ij,t}$ denote the presence of a sanction between $i$ and $j$ on commodity $k$, we construct three dummy variables as follows:

- $Sanction^k_{ij,t}$ equal to 1 if there is a sanction applied by the sender country $i$ on commodity $k$ from target country $j$ at time $t$ and 0 otherwise. It is intended to capture the effect of sanction on trade flows between sender and target countries;

- $Sender^k_{i,z\neq j,t}$ equal to 1 if there is a sanction applied by sender country $i$ on commodity $k$ but not from $z$ at time $t$ and 0 otherwise. It is intended to capture the potential trade diversion of the sender. Specifically, it aims to determine whether the sender replaces imports from the target country with imports from an alternative source.

- $Target c \neq i,j,t^k$ equal to 1 if there is a sanction imposed to target country $j$ on commodity $k$ but not from $c$ at time $t$ and 0 otherwise. It is intended to capture whether the target country diverts its exports to third countries. In practice, it also captures the emergence of sanctions-busting.

Then we estimate the augmented gravity equation in multiplicative form using a Poisson pseudo-maximum-likelihood (PPML) estimator, commonly adopted in the recent empirical analyses (Silva and Tenreyro, 2006; Yotov et al., 2016):

$$X^k_{i,j,t} = exp[\alpha + \beta Gravity + \chi Sanction^k_{i,j,t-1} + \gamma Sender^k_{i,z\neq j,t-1} + \delta Target^k_{c\neq i,j,t-1} + \psi^k_{ij} + \phi^k_{it} + \theta^k_{jt}] \times \varepsilon^k_{ij,t} \quad (1)$$

Our gravity equation (1) allows an assessment of the trade disruption or diversion of a trade sanction: - negative estimates of $\chi$, $\gamma$ and $\delta$ are suggestive of a trade disruption; - positive estimates of $\gamma$ and/or $\delta$ and a negative coefficient of $\chi$ suggest a trade diversion.

The *Gravity* controls included in the model are the following:

- the geodesic weighted distance between country $i$ and country $j$, $Distance_{ij}$;

- the origin and destination nominal per capita GDP, in US dollars, respectively, $GDP_{i,t}$ and $GDP_{j,t}$;

- the dummy $Contiguity_{ij}$ equal to 1 if $i$ and $j$ share a land border;

- the dummy $Language_{ij}$ equal to 1 if $i$ and $j$ share the same official language;

- and finally, the dummy $Colony_{ij}$ equal to 1 if $i$ and $j$ are linked by colonial ties.

We inflate our specification including a set of dummies for country-pair-sector fixed effects, $\delta_{ij}^{k}$, importer-time-sector fixed effects, $\phi_{it}^{k}$, and exporter-time-sector fixed effects, $\theta_{jt}^{k}$ to control for unobservable and/or imperfectly measured variables and recover the multilateral resistance terms (Head and Mayer, 2014; Fally, 2015; Campos et al., 2021).

### 3.1 Data and descriptive statistics

Our data set is built around information covering imports of 63 raw mineral commodities (HS Section V) from 239 exporters to 38 OECD countries over the period 2009–2020. The Appendix A provides a synthetic description of raw mineral commodities included in our empirical analysis.

Data on trade at the HS6 level of detail, based on the WTO definition, are from the COMTRADE database [1], which are integrated into the WITS software [2], while data for the gravity variables are from the Cepii dataset[3].

Data on sanctions are from the OECD Inventory of export restrictions on industrial raw materials and Global Sanctions Database (GSDB). The OECD databse contains information on export regulations in the raw materials sector, namely minerals, metals and wood, and records measures known to restrain export activity from 2009-2021 at the 6-digit level of HS2007 classification. The updated GSDB (2021) covers 1,101 publicly traceable, multilateral, plurilateral, and purely bilateral sanction cases over the 1950-2019 time period.

The advantage of using the first database lies in its disaggregated product-level information. On the other hand, the second database, despite aggregating data by countries, offers insights into bilateral sanctions.

We combine these two datasets by defining the dummy variable *Sanction* as 1 when the GSDB records a trade sanction imposed by an OECD country $i$ on country $j$ in year $t$, and when the OECD database registers an export prohibition or quota on good $k$ from country $j$ during the same year. This approach stems from the observation that voluntary export restrictions (VERs) often result from protectionist trade policies in importing countries, which can be equivalent to trade sanctions. Therefore, when we identify the presence of a trade sanction in both the bilaterally aggregated product-level database (GSDB) and the unilaterally disaggregated product-level database (OECD), we assign a dummy variable to the country-pair-product-year combination to indicate the presence of the trade sanction. Table 1 provides a summary of how our variable of interest, namely $Sanction_{i,j,t}^{k}$, is constructed.

[1] https://comtrade.un.org/. Accessed on 5 October 2022.

[2] http://wits.worldbank.org/witsweb/default.aspx. Accessed on 5 October 2022.

[3] http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=8. Accessed on 5 October 2022.

Table 1: Variable $Sanction^k_{i,j,t}$

| | GSDB | OECD |
|---|---|---|
| $Sanction^k_{ij,t} = 1$ when | $TradeSanction_{ij,t} = 1$ and | $ExportRestriction^k_{j,t} = 1$ |
| $Sanction^k_{ij,t} = 0$ when | $TradeSanction_{ij,t} = 1$ and | $ExportRestriction^k_{j,t} = 0$ |
| $Sanction^k_{ij,t} = 0$ when | $TradeSanction_{ij,t} = 0$ and | $ExportRestriction^k_{j,t} = 1$ |
| $Sanction^k_{ij,t} = 0$ when | $TradeSanction_{ij,t} = 0$ and | $ExportRestriction^k_{j,t} = 0$ |
| $Sanction^k_{ij,t} = 1$ when | $TradeSanction_{ij,t} = 1$ when if exp compl,imp compl | and any case |
| $Sanction^k_{ij,t} = 1$ when | $TradeSanction_{ij,t} = 1$ if exp part,imp compl | and any case |

Table 2 provides descriptive statistics of the main variables in our dataset and used in the empirical analysis.

Table 2: Descriptive Statistics

| Variable | Mean | Std. Dev. | Min | Max | N. of Obs. |
|---|---|---|---|---|---|
| $Trade^k_{ij,t}$ | 655 | 41,783 | 0 | 18.6Ml | 2,688,207 |
| $Sanction^k_{ij,t}$ | 0.003 | 0.06 | 0 | 1 | 2,688,207 |
| $Sender^k_{i,z\neq j,t}$ | 0.29 | 0.45 | 0 | 1 | 2,688,207 |
| $Target^k_{c\neq i,j,t}$ | 0.02 | 0.15 | 0 | 1 | 2,688,207 |
| $ln(Distance_{ij})$ | 8.45 | 1.03 | 2.48 | 9.88 | 2,688,207 |
| $ln(GDP_{i,t})$ | 19.83 | 1.55 | 16.37 | 23.79 | 2,688,207 |
| $ln(GDP_{j,t})$ | 18.60 | 2.01 | 10.21 | 23.79 | 2,688,207 |
| $Contiguity_{ij}$ | 0.029 | 0.17 | 0 | 1 | 2,688,207 |
| $Language_{ij}$ | 0.09 | 0.28 | 0 | 1 | 2,688,207 |
| $Colony_{ij}$ | 0.01 | 0.11 | 0 | 1 | 2,688,207 |

## *4 Facts in mineral trade.*

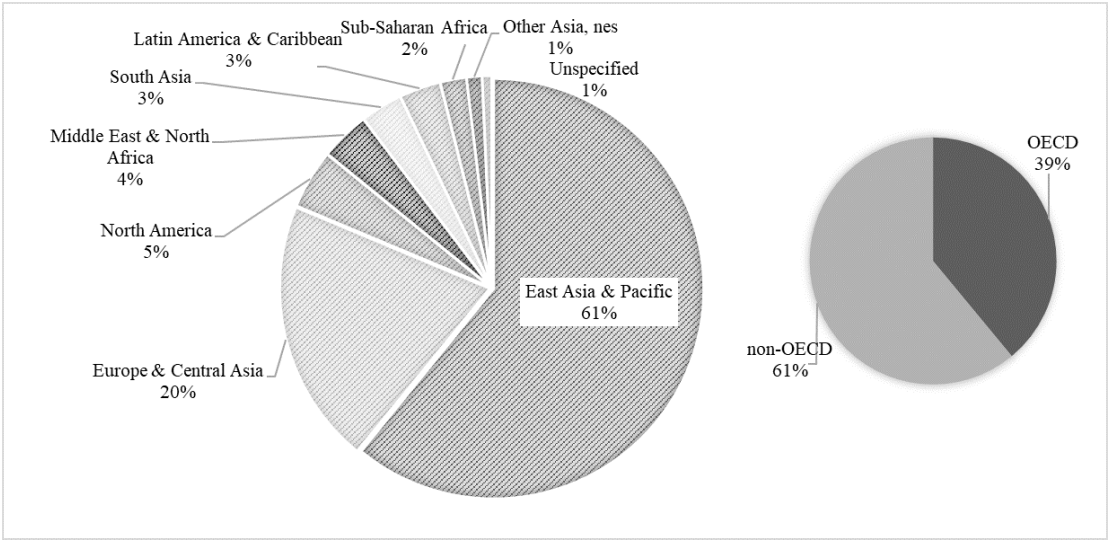
Figure 1 shows the share of the world's mineral imports across various regions. Notably, East Asia and the Pacific emerges as the largest importer of mineral commodities (accounting for the 61% of world trade in minerals), mainly driven by China's imports. It's worth mentioning that our dataset does not include China as an importer since it is not an OECD member. However, China does not impose trade sanctions on its mineral trading partners. It's important to note that China, included in the dataset as an exporter, has a *Sanction* dummy equal to 1 during the 2017-2020 period due to sanctions imposed by US.

In contrast, countries in Europe and Central Asia import 20% of mineral commodities, while North America's share stands at 5%. The OECD members included in our dataset account for approximately 40% of the world's mineral imports in the period 2009- 2020. exporters are targeted differently by im-

porters.

In our dataset, the dummy variable *Sanction* is set to 1 for sanctions imposed by countries in Europe and Central Asia on commodities from Myanmar, Armenia, Russian Federation, Ukraine, Egypt, Arab Republic, Israel, Saudi Arabia, Guinea, and Zimbabwe. In the case of North America, the *Sanction* dummy is also set to 1 for raw materials from China, as well as minerals from Indonesia, Korea, Democratic Republic, Myanmar, Vietnam, Kyrgyz Republic, Russian Federation, Turkey, Ukraine, Bolivia, Colombia, Cuba, Jamaica, Iran, Islamic Republic, Saudi Arabia, Congo, Democratic Republic, Former Sudan, Ghana, Nigeria, Sierra Leone, and South Africa. Lastly, countries in the East Asia and Pacific region, during the period under analysis, imposed sanctions on Indonesia, Korea, Democratic Republic, Russian Federation, and Ukraine.

Figure 1: World Mineral Imports: Share by regions (2009–2020)




**Note**: Elaborations on WITS (https://wits.worldbank.org/); Simple average over period 2009-2020.

Figure 2 depicts the trends in the number of sanctions and imports from 2009 to 2020. The figure reveals a striking correlation, emphasizing the significant impact of trade sanctions on mineral imports. It's evident that when the number of sanctions imposed increases, there is a corresponding decrease in imports. Conversely, during periods when the number of sanctions decreases, imports increase.

The peak of sanctions in the year 2014 is due to the sanctions imposed on Russia and Ukraine. Conversely, the noticeable reduction in recent years descends from the lifting of sanctions against Iran.

When we examine the number of sanctions imposed by various sender countries and enforced on different target in our dataset (Figure 3), a clear hierarchy emerges. The United States, the United Kingdom, and Canada are the leading sanctioning countries, often imposing sanctions on different nations, followed by EU members. On the other side, the main targets of these sanctions are Russia, Zimbabwe, Egypt, Myanmar, and Iran.

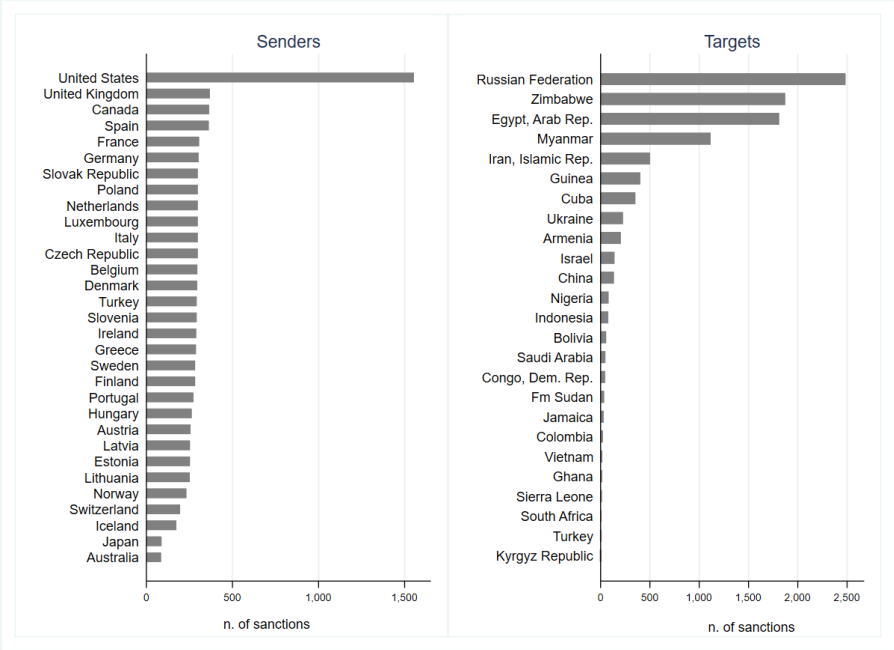
Figure 2: Trends in Sanctions and Imports (2009-2020)


**Note**: Elaborations on GSDB (https://globalsanctionsdatabase.com/), OECD (https://data.oecd.org/) and WITS (https://wits.worldbank.org/).

Turning our attention to trade of minerals, we observe a notable contrast between countries that are major mineral exporters and those that are major importers. The top OECD importer countries are Japan and South Korea. Remarkably they impose relatively few sanctions on mineral commodities. In contrast, the major sender countries, including those in North America, the UK, and EU member states, have lower levels of mineral imports (see Figure 4).

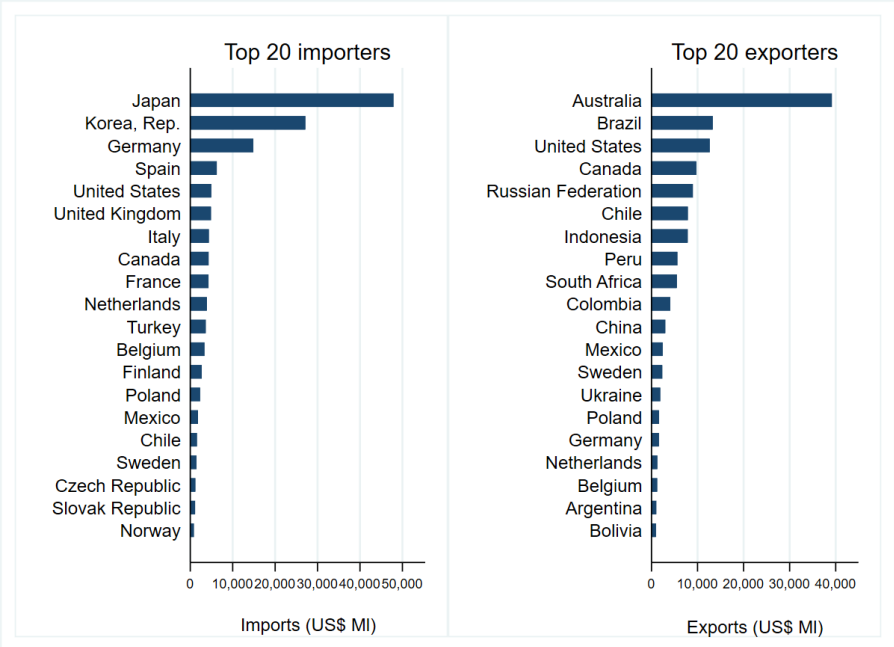
It is interesting to note Russia, despite being heavily affected by trade sanctions, remains among the top five mineral exporters whereas the other major exporters such as Australia, Brazil, the US, and Canada are not affected by trade sanctions.

Figure 3: Number of sanctions by senders and targets (2009–2020)



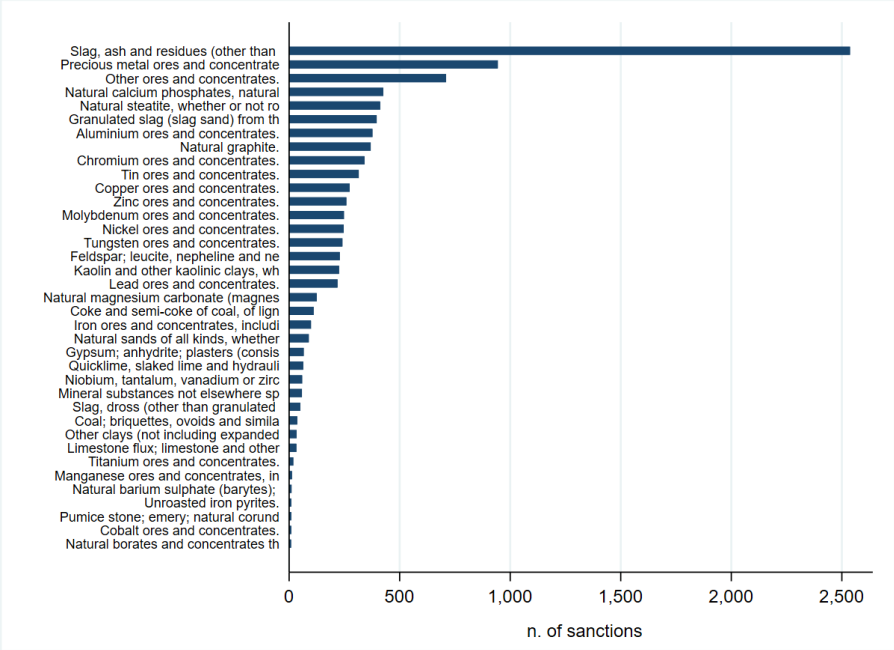

**Note**: Elaborations on GSDB (https://globalsanctionsdatabase.com/), OECD (https://data.oecd.org/).

Figure 4: The Top 20 Importing and Exporting Countries of minerals (2009–2020).




**Note**: Elaborations on WITS (https://wits.worldbank.org/).

Figure 5: Sanctioned product (HS4) (2009–2020).




**Note**: Elaborations on GSDB (https://globalsanctionsdatabase.com/), OECD (https://data.oecd.org/).

Focusing on the mineral commodities most commonly subject to trade sanctions (Figure 5), we can observe that these sanctions encompass a wide array of resources, spanning from precious metals to industrial minerals and ores. The targeted materials encompass slag, precious metal ores, non-ferrous metal ores, calcium phosphates, steatite, granulated slag, aluminum ores, natural graphite, chromium ores, and tin ores.

In particular, sanctions on slag, ash, residues, precious metal ores and concentrates, as well as other ores and concentrates, have significant implications for various countries, with the primary targets being Russia, Ukraine, Myanmar, Egypt, Guinea, and Zimbabwe.

Other commodities, such as aluminum ores and concentrates, exhibit a diverse range of destination countries. The list of target countries encompasses China, Cuba, Egypt, the Arab Republic, Guinea, Indonesia, Iran, the Islamic Republic, and Myanmar. Overall, the wide spectrum of sanction targets, both countries and products, reflects the global reach and demand within the mineral sector.

In these materials, sanctions play a pivotal role across various sectors, and trade restrictions concerning them can result in supply chain disruptions, affecting market prices, and generating economic and political consequences for both importing and exporting nations.

## 5 *Econometric results*

First, we discuss the results of the baseline gravity model, which includes bilateral distance and other gravity controls. These results are presented in Table 3. Column (1) shows the results for the full sample without any lags applied to the interest variables related to the trade sanction. In the other columns, we introduce a one-year lag (Column (2) and continue this pattern until the five-year lag (Column (5)) is

incorporated. The use of lagged values of the $Sanction^k_{ij,t}$ relies on the intuitive argument that dependent and independent variables cannot fully adjust within 1 year (Cheng and Wall, 2005).

The negative and significant coefficient of the dummy $Sanction^k_{ij,t-n}$ highlights that a sanction disrupts bilateral trade in the very short run, by around 90% (in Column (1))[4], and up to 94% after four years (Column (5)).[5]

With regard to the potential trade diversion resulting from the trade sanction, both the sender and target countries, in the presence of a sanction, attempt to divert trade towards new source countries or new recipients countries, respectively.

The coefficient of the dummy $Sender^k_{i,z\neq j,t-n}$ is negative and statistically significant. It indicates that after one year and up to four years following the imposition of a sanction, there is a reduction in trade not only between the countries involved in the sanctioning provision but also with third countries (negative network effects). Specifically, a trade sanction results in a reduction of international trade for the senders, ranging from approximately 27% after one year to around 46% after four years. There is no evidence of trade diversion. The estimated coefficient of the variable $Target^k_{c\neq i,j,t-n}$, related to the trade diversion of the target, is positive even if not statistically significant.

[4] All percentages are calculated from the formula: (exp($\hat{\beta}$)-1)x100.

[5] In Appendix C, we employ a gravity equation to estimate the trade impact of sanctions using aggregated data from the GSDB. The results consistently demonstrate a negative and statistically significant impact.

Table 3: Trade effects of trade sanctions. Model with gravity controls

| | (1) no lag ($n=0$) | (2) 1-year lag ($n=1$) | (3) 2-year lag ($n=2$) | (4) 3-year lag ($n=3$) | (5) 4-year lag ($n=4$) | (6) 5-year lag ($n=5$) |
|---|---|---|---|---|---|---|
| $Sanction^{k}_{ij,t-n}$ | -2.32*** | -2.30*** | -2.39*** | -2.54*** | -2.73*** | -2.68 |
| | (0.36) | (0.36) | (0.34) | (0.31) | (0.29) | (0.32) |
| $Sender^{k}_{i,z\neq j,t-n}$ | -0.24 | -0.31** | -0.41*** | -0.52*** | -0.62*** | -0.60 |
| | (0.16) | (0.15) | (0.16) | (0.17) | (0.17) | (0.15) |
| $Target^{k}_{c\neq i,j,t-n}$ | 0.14 | 0.11 | 0.11 | 0.13 | 0.14 | 0.11 |
| | (0.29) | (0.29) | (0.30) | (0.35) | (0.37) | (0.31) |
| $ln(Distance_{ij})$ | -0.86*** | -0.86*** | -0.86*** | -0.86*** | -0.86*** | -0.85*** |
| | (0.08) | (0.08) | (0.08) | (0.08) | (0.08) | (0.08) |
| $ln(GDP_{i,t})$ | 0.25 | 0.16 | 0.05 | -0.01 | -0.18 | 0.02 |
| | (0.16) | (0.17) | (0.18) | (0.19) | (0.25) | (0.24) |
| $ln(GDP_{j,t})$ | -0.09 | -0.04 | -0.00 | -0.01 | 0.01 | 0.07 |
| | (0.16) | (0.16) | (0.16) | (0.17) | (0.16) | (0.15) |
| $Contiguity_{ij}$ | 1.06*** | 1.05*** | 1.04*** | 1.01*** | 1.00*** | 1.00*** |
| | (0.17) | (0.18) | (0.18) | (0.18) | (0.18) | (0.19) |
| $Languange_{ij}$ | 0.52*** | 0.53*** | 0.54*** | 0.57*** | 0.57*** | 0.59*** |
| | (0.17) | (0.17) | (0.17) | (0.17) | (0.17) | (0.17) |
| $Colony_{ij}$ | 0.14 | 0.13 | 0.12 | 0.09 | 0.08 | 0.07 |
| | (0.34) | (0.34) | (0.33) | (0.33) | (0.33) | (0.33) |
| Constant | 14.29*** | 15.34*** | 16.81*** | 18.28*** | 21.43*** | 15.73*** |
| | (4.45) | (4.78) | (4.90) | (5.11) | (5.86) | (5.74) |
| $N$ | 2,688,207 | 2,462,784 | 2,237,089 | 2,009,830 | 1,784,917 | 1,559,169 |
| $R^2$ | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |

Notes: Robust standard errors clustered by country-pairs in parentheses; * $p<0.10$, ** $p<0.05$, *** $p<0.01$; Included (unreported) are importer, exporter, product, and year fixed effects.

As regards the results of the gravity variables, the coefficient of the bilateral distance between countries indicated with $Distance_{ij}$ is negative and significant, correctly capturing the larger trade costs implied by distance. As expected, the economic variables *Contiguity* and *Language*, have a positive and significant impact on bilateral trade, indicating that when two countries have a land border or share the same language, trade flows is higher; while, economic sizes ($ln(GDP_{i,t})$ and $ln(GDP_{j,t})$) and colonial ties, $Colony_{ij}$, seem to not affect trade.

To test the robustness of these results, we estimate equation (1) with the full structure of fixed effects, including importer-product-time fixed effects, exporter-product-time fixed effects, and country-pair-product fixed effects[6]. These fixed effects absorb all dimensions of the gravity variables used in the literature and allow us to account for unobserved characteristics. The results are presented in Table 4.

As the rich structure of fixed effects fully accounts for the multilateral resistance terms (Head and Mayer, 2014; Fally, 2015), we rely on the gravity framework that employs the strategy of fixed effects

[6]To avoid perfect collinearity between our variables of interest and the included fixed effects, we define product fixed effects at a more aggregate level, HS-2 digit.

and consider the results in Table 4 as our baseline results.

Across all specifications, as indicated in Table 4, we find consistent evidence of the trade sanction, denoted as $Sanction^{k}_{ij,t-n}$, exerting an adverse impact on bilateral trade between the sender and target countries. Notably, our analysis reveals an interesting trend in the coefficient, indicating a growing impact over time. Specifically, it rises from an immediate 90% effect to 95% after four years, eventually decreasing to a 66% impact after five years.

When examining the influence of trade sanctions on bilateral trade with countries not subjected to sanctions, we observe that the coefficient of the dummy $Sender^{k}_{i,z\neq j,t-n}$ is consistently negative and statistically significant across columns (2) to (5). The pattern shown in the Table 4 suggests a progressive decline in trade, ranging from 27% to 47%, as time elapses.

Table 4: Trade effects of trade sanctions. Gravity model with fixed effects

| | (1) no lag ($n=0$) | (2) 1-year lag ($n=1$) | (3) 2-year lag ($n=2$) | (4) 3-year lag ($n=3$) | (5) 4-year lag ($n=4$) | (6) 5-year lag ($n=5$) |
|---|---|---|---|---|---|---|
| $Sanction^k_{ij,t-n}$ | -2.35*** | -2.43*** | -2.66*** | -2.85*** | -2.98*** | -1.09** |
| | (0.37) | (0.37) | (0.35) | (0.33) | (0.4933) | (0.54) |
| $Sender^k_{i,z\neq j,t-n}$ | -0.24 | -0.32* | -0.42** | -0.55*** | -0.63*** | -0.61 |
| | (0.19) | (0.18) | (0.19) | (0.20) | (0.20) | (0.18) |
| $Target^k_{c\neq i,j,t-n}$ | 0.95* | 0.78 | 0.59 | 0.43 | 0.28 | 0.42 |
| | (0.58) | (0.62) | (0.70) | (0.80) | (0.82) | (0.70) |
| Constant | 11.30*** | 11.32*** | 11.34*** | 11.31*** | 11.27*** | 11.20*** |
| | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.03) |
| $N$ | 1,684,457 | 1,525,005 | 1,369,023 | 1,214,285 | 1,054,900 | 895,770 |
| pseudo $R^2$ | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.69 |

Notes: Robust standard errors clustered by country-pairs in parentheses; * $p<0.10$, ** $p<0.05$, *** $p<0.01$; Included (unreported) are importer, exporter, product, and year fixed effects.

The coefficient associated with the dummy variable $Target^k_{c\neq i,j,t-n}$, representing the impact of sanctions on trade between the target country and other non-sanctioned countries, consistently shows a positive sign. However, it is statistically significant, at the 10% level of confidence, only in column (1). This implies that the sanctioned country rapidly shifts its trade toward other countries, leading to a trade flow increase of approximately 61%.

## 5.1 Disaggregating by HS chapters

Table 5 shows the trade impact of trade sanctions on various products. For a more comprehensive analysis, Appendix D provides results for the impact on specific sanctioned products defined at the 4-HS digit level. Findings presented in Table 5 suggest that sanctions are linked to a substantial reduction in the trade of two categories: Ores, slag, and ash commodities (Chapter 26 HS classification) and Mineral Fuels, Mineral Oils, and Products of Their Distillation; Bituminous Substances; Mineral Waxes (Chapter 27 HS classification). Specifically, the estimated coefficients for these categories are -1.64 (corresponding to a trade reduction of approximately 81%) and -4.54 (corresponding to a trade reduction of approximately 99%), respectively, and they are statistically significant.

Not all raw materials are affected by trade diversion to the same extent, as highlighted in the analysis so far. Countries that impose sanctions on commodities under Chapter 25 of the HS classification, which includes "Salt; sulfur; earths and stone; plastering materials, lime, and cement" are able to source them from other countries. The estimated coefficient indicates an increase of trade of around 70%. However, for commodities classified under Chapter 27, specifically "Coal; briquettes, ovoids, and similar solid fuels manufactured from coal" and "Coke and semi-coke; of coal, lignite, or peat" (refer to Appendix D for details), there is evidence of a significant trade disruption, approximately 87%.

Table 5: Trade Effects of trade sanctions by product.

| | Chapter 25: Salt; sulfur; earths and stone; plastering materials, lime and cement | Chapter 26: Ores, slag and ash | Chapter 27: Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes |
|---|---|---|---|
| $Sanction^{k}_{ij,t-1}$ | 0.19 | -1.64*** | -4.54*** |
| | (0.46) | (0.45) | (0.42) |
| $Sender^{k}_{i,z\neq j,t-1}$ | 0.53*** | -0.20 | -2.07*** |
| | (0.13) | (0.17) | (0.59) |
| $Target^{k}_{c\neq i,j,t-1}$ | -0.27 | 1.74*** | -4.04*** |
| | (0.19) | (0.49) | (0.63) |
| Constant | 7.21*** | 10.30*** | 13.60*** |
| | (0.05) | (0.05) | (0.02) |
| $N$ | 801,553 | 702,335 | 21,087 |
| pseudo $R^2$ | 0.54 | 0.54 | 0.84 |

Notes: Robust standard errors clustered by country-pairs in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Included (unreported) are importer, exporter, product, and year fixed effects.

Concerning the diversion of target countries, the table highlights that target countries of commodities under Chapter 26 manage to supply other destination markets, achieving a trade diversion of approximately 470%. In contrast, suppliers of commodities falling under Chapter 27 experience a sharp reduction in their exports, roughly around 98%, indicating difficulties in exporting them to alternative destinations.

## 5.2 Disaggregating by world regions: the sender's perspective.

In order to test the general validity of our results, we have re-run our estimations by highlighting regional patterns.

Table 6 shows the results of trade effects from the sender's perspective. Specifically, it provides an overview of the various repercussions stemming from trade sanctions enforced by different senders ($i$) on bilateral trade ($Sanction^{k}_{ij,t-n}$). Additionally, the table highlights the effects on trade between the different senders ($i$) and third countries ($Sender^{k}_{i,z\neq j,t-n}$), as well as the effects on trade between the target countries and various OECD member destinations ($c$) that do not take part into the sanctioning mechanism ($Target^{k}_{c\neq i,j,t-n}$).

Trade sanctions from both EU member states and countries in the Asia and Pacific region have a clear and statistically significant adverse impact on trade. Particularly, when a sender is from the Asia and Pacific region, especially Japan and Australia in our sample, the negative effect becomes even more pronounced. In such cases, trade can decrease by approximately 95% when imposed by EU members and around 98% when imposed by Japan and Australia.

Sanctions enforced by the remaining European countries (in our sample, Iceland, Norway, Switzerland, and Turkey) appear to have a detrimental effect on trade in the medium to long term. Such evidence

is displayed in columns (5) and (6) and the coefficients point to an average impact of 82% decrease in trade.

Interestingly, sanctions imposed by North American countries, specifically Canada and the USA, yield a positive estimated coefficient; however, this result lacks statistical significance.

An examination of the impact of trade sanctions on trade interactions involving different senders and non-sanctioned countries, commonly referred to as the sender's trade diversion effect, reveals that North American countries applying trade sanctions demonstrate a greater ability to redirect trade flows from alternative source countries. This is evident in the consistently positive and statistically significant estimated coefficient ($Sender^{k}_{i,z\neq j,t-n}$) for North America across all model specifications (columns 1 through 6). The resulting trade diversion in North America averages around 170% over the first five years after the imposition of the sanctions.

Conversely, EU member states that impose sanctions not only experience a reduction in trade with the sanctioned countries but also a decrease in trade with other trading partners, amounting to a reduction of approximately 44%. This reduction results from the consistently negative and statistically significant coefficient ($Sender^{k}_{i,z\neq j,t-n}$) for the EU members.

On the other hand, countries under sanctions redirect their trade to different locations. Specifically, the estimated coefficients of the dummy variable $Target^{k}_{c\neq i,j,t-n}$ in Table 6 reveal that suppliers of mineral raw materials subject to sanctions witness a substantial decrease in trade with countries located in Europe, with an average decrease of -90%. They also observe a significant decrease in trade with countries in the Middle East, such as Israel in our sample, showing a decrease of approximately -100%. Simultaneously, they expand their trade ties with partners in the EU, realizing an increase of around 600%, North America, with an increase of around 300%, and the Latin America and Caribbean regions, namely Chile, Colombia, Costa Rica, and Mexico, with an increase of around 300%. Clearly, these significant increases can also be attributed to rising prices.

Table 6: Trade Effects from the Sender's Perspective

| | (1) no lag ($n=0$) | (2) 1-year lag ($n=1$) | (3) 2-year lag ($n=2$) | (4) 3-year lag ($n=3$) | (5) 4-year lag ($n=4$) | (6) 5-year lag ($n=5$) |
|---|---|---|---|---|---|---|
| $Sanction^{k}_{ij,t-n}$, **with** $i=$ | | | | | | |
| *EU* | -2.86*** | -2.84*** | -2.95*** | -2.97*** | -3.01*** | -2.87*** |
| | (0.25) | (0.28) | (0.29) | (0.27) | (0.25) | (0.29) |
| *Asia&Pacific* | -3.72*** | -4.09*** | -4.39*** | -4.56*** | -4.53*** | -4.48*** |
| | (0.22) | (0.19) | (0.14) | (0.11) | (0.10) | (0.11) |
| *Europe* | -1.00 | -0.92 | -0.76 | -0.62 | -1.56* | -1.84** |
| | (0.71) | (0.69) | (0.65) | (0.63) | (0.88) | (0.83) |
| *NorthAmerica* | 0.47 | 0.47 | 0.58 | 0.54 | 0.38 | 0.43 |
| | (0.66) | (0.72) | (0.83) | (1.04) | (1.32) | (0.1.35) |
| $Sender^{k}_{i,z\neq j,t-n}$, **with** $i=$ | | | | | | |
| *EU* | -0.42*** | -0.50*** | -0.59*** | -0.68*** | -0.73*** | -0.76*** |
| | (0.10) | (0.11) | (0.11) | (0.12) | (0.12) | (0.12) |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Asia&Pacific* | -0.21 | -0.28 | -0.45 | -0.68 | -0.85* | -0.86* |
| | (0.50) | (0.50) | (0.51) | (0.52) | (0.51) | (0.48) |
| *Europe* | -0.31 | -0.33 | -0.33 | -0.36 | -0.42 | -0.45 |
| | (0.42) | (0.41) | (0.41) | (0.41) | (0.41) | (0.42) |
| *NorthAmerica* | 1.02*** | 0.93*** | 0.91*** | 0.93*** | 0.97*** | 0.97*** |
| | (0.17) | (0.13) | (0.11) | (0.12) | (0.13) | (0.12) |
| $Target^{k}_{c\neq i,j,t-n}$, **with** $c =$ | | | | | | |
| *EU* | 1.21*** | 1.36*** | 1.58*** | 1.82*** | 2.18*** | 2.43*** |
| | (0.34) | (0.36) | (0.38) | (0.41) | (0.46) | (0.47) |
| *Asia&Pacific* | 1.06 | 0.89 | 0.68 | 0.49 | 0.24 | 0.20 |
| | (0.73) | (0.80) | (0.93) | (1.08) | (1.15) | (1.01)) |
| *Europe* | -1.40 | -1.95* | -2.52*** | -2.70*** | -2.70*** | -2.54*** |
| | (1.18) | (1.10) | (0.74) | (0.31) | (0.12) | (0.14) |
| *LatinAmerica&Caribbean* | 1.38*** | 0.70 | 0.62 | 0.74 | 1.28* | 1.56** |
| | (0.53) | (0.52) | (0.59) | (0.78) | (0.76) | (0.68) |
| *MiddleEast* | 0.34 | 0.45 | -0.03 | -0.05 | -5.26*** | -4.81*** |
| | (0.58) | (0.61) | (0.30) | (0.24) | (0.23) | (0.18) |
| *NorthAmerica* | 1.31*** | 1.35** | 1.37** | 1.41** | 1.43** | 1.39** |
| | (0.47) | (0.56) | (0.61) | (0.65) | (0.68) | (0.68) |
| Constant | 11.25*** | 11.27*** | 11.29*** | 11.25*** | 11.19*** | 11.13*** |
| | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.02) |
| *N* | 1,684,457 | 1,525,005 | 1,369,023 | 1,214,285 | 1,054,900 | 895,770 |
| pseudo $R^2$ | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |

Notes: Robust standard errors clustered by country-pairs in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Included (unreported) are importer, exporter, product, and year fixed effects.

Table 7 shows the consequences of trade sanctions from the target's perspective. It illustrates how these sanctions, $Sanction^{k}_{ij,t-n}$, affect various target countries, $j$. Furthermore, the table shows the impact on trade resulting from the redirection of trade by senders, $Sender^{k}_{i,z\neq j,t-n}$, towards other destinations not subject to sanctions, $z$.

It also highlights the effect on trade between the sanctioned countries, $j$, and various OECD member destinations not involved in the sanction agreement, thus emphasizing the different trade diversion effects among target countries, $Target^{k}_{c\neq i,j,t-n}$.

## 5.3 Disaggregating by world regions: the target's perspective.

From the target's perspective, Table 7 reveals that the most affected target countries are the exporters in the Europe and Central Asia region. Notably, Russian Federation and Ukraine are the major target countries. The coefficient of the dummy variable $Sanction^{k}_{ij,t-n}$ points to a decrease in trade ranging from 96% (in column (1)) to 97% (in column (6)). Following closely are countries in the Sub-Saharan Africa region, where the most sanctioned countries are Guinea and Zimbabwe. In this area, the initial decrease in trade is approximately 88%.

Strikingly, Middle East and North African countries, namely Egypt Arab Rep, Iran Islamic Rep., Israel, and Saudi Arabia, are experiencing an unexpected increase in trade despite sanctions, which

provides some evidence of sanction busting. This finding also raises questions about potential efforts to bypass or evade the sanctions, particularly in resource-rich areas.

Looking at the estimated coefficients of the dummy variable $Sender^{k}_{i,z\neq j,t-n}$, it becomes apparent that mineral exporters in the Middle East and North Africa regions are enjoying the most substantial gains from potential trade diversion due to sanctions. Conversely, international trade in sender countries is decreasing, particularly in Europe and Central Asia and Sub-Saharan Africa, likely due to rising mineral commodity prices.

In response to evolving global trade dynamics, target countries are actively redirecting their trade patterns. This shift is particularly evident in the East Asia and Pacific regions, where China plays a central role in global trade. The coefficients representing this trade redirection, denoted as $Target^{k}_{c\neq i,j,t-n}$, are not only statistically significant but also show a consistent upward trend over time. The same holds true for sub-Saharan African countries, which are particularly rich in natural resources. Therefore, target countries in the region could redirect their trade to meet the growing global demand for raw materials, especially minerals. This may involve the establishment of new trade relationships with countries that require these resources.

Meanwhile, trade with countries in other regions gradually decline, indicating challenges in diverting trade to alternative destinations.

Table 7: Trade Effects from the Target's Perspective

| | (1) no lag ($n=0$) | (2) 1-year lag ($n=1$) | (3) 2-year lag ($n=2$) | (4) 3-year lag ($n=3$) | (5) 4-year lag ($n=4$) | (6) 5-year lag ($n=5$) |
|---|---|---|---|---|---|---|
| $Sanction^{k}_{ij,t-n}$, **with** $j=$ | | | | | | |
| *EastAsia&Pacific* | -0.33 | -0.21 | 0.25 | 0.99 | -0.27 | 0.33 |
| | (0.60) | (0.63) | (0.68) | (0.79) | (0.93) | (0.73) |
| *Europe&CentralAsia* | -3.26*** | -3.26*** | -3.38*** | -3.40*** | -3.47*** | -3.46*** |
| | (0.25) | (0.29) | (0.29) | (0.29) | (0.26) | (0.25) |
| *LatinAmerica&Caribbean* | -0.41 | -0.38 | -0.50 | -0.56 | -0.58 | -0.56 |
| | (1.63) | (1.65) | (1.62) | (1.59) | (1.60) | (1.59) |
| *MiddleEast&NorthAfrica* | 0.94** | 0.85** | 0.79** | 0.92** | 0.94** | 0.86** |
| | (0.44) | (0.39) | (0.37) | (0.38) | (0.37) | (0.38) |
| *Sub−SaharanAfrica* | -2.11*** | -1.80* | -0.43 | -0.41 | -0.45 | -0.06 |
| | (0.79) | (0.95) | (1.06) | (1.08) | (1.06) | (1.03) |
| $Sender^{k}_{i,z\neq j,t-n}$, **with** $z=$ | | | | | | |
| *EU* | 0.10 | 0.07 | 0.07 | 0.09 | 0.05 | -0.04 |
| | (0.14) | (0.15) | (0.17) | (0.18) | (0.18) | (0.17) |
| *EastAsia&Pacific* | -0.63 | -0.70 | -0.85* | -1.08** | -1.20** | -1.14** |
| | (0.48) | (0.49) | (0.51) | (0.51) | (0.50) | (0.48) |
| *Europe&CentralAsia* | -0.58*** | -0.69*** | -0.83*** | -0.99*** | -1.04*** | -0.98*** |
| | (0.20) | (0.21) | (0.23) | (0.25) | (0.26) | (0.28) |
| *LatinAmerica&Caribbean* | 0.05 | -0.04 | -0.12 | -0.20 | -0.33 | -0.42 |
| | (0.38) | (0.35) | (0.34) | (0.34) | (0.32) | (0.30) |

| | | | | | | |
|---|---|---|---|---|---|---|
| $MiddleEast\&NorthAfrica$ | 0.62*** | 0.51** | 0.39* | 0.29 | 0.11 | -0.00 |
| | (0.21) | (0.21) | (0.22) | (0.25) | (0.27) | (0.26) |
| $NorthAmerica$ | 0.04 | -0.03 | -0.21 | -0.39 | -0.47 | -0.39 |
| | (0.28) | (0.28) | (0.28) | (0.31) | (0.33) | (0.35) |
| $SouthAsia$ | -0.88* | -0.91* | -0.92* | -0.89 | -0.80 | -0.74 |
| | (0.49) | (0.51) | (0.52) | (0.56) | (0.63) | (0.62) |
| $Sub-SaharanAfrica$ | -0.83*** | -0.85*** | -1.00*** | -0.96*** | -0.80 | -0.90*** |
| | (0.28) | (0.28) | (0.29) | (0.30) | (0.29) | (0.29) |
| $Target^{k}_{c\neq i,j,t-n}$, **with** $j=$ | | | | | | |
| $EastAsia\&Pacific$ | 2.39*** | 2.50*** | 2.74*** | 3.52*** | 3.73*** | 3.03*** |
| | (0.71) | (0.69) | (0.63) | (0.76) | (0.50) | (0.37) |
| $Europe\&CentralAsia$ | -0.61 | -1.07 | -1.42* | -1.71** | -1.82** | -1.47* |
| | (0.67) | (0.75) | (0.76) | (0.76) | (0.78) | (0.88) |
| $LatinAmerica\&Caribbean$ | -0.74 | -0.77* | -0.82* | -0.99** | -1.05*** | -1.09*** |
| | (0.53) | (0.47) | (0.43) | (0.41) | (0.39) | (0.37) |
| $MiddleEast\&NorthAfrica$ | -0.41 | -1.04*** | -0.95*** | -0.45 | -0.49 | -0.48 |
| | (0.69) | (0.36) | (0.30) | (0.49) | (0.49) | (0.52) |
| $Sub-SaharanAfrica$ | 1.59*** | 2.04*** | 3.50*** | 3.59*** | 3.70*** | 3.98*** |
| | (0.42) | (0.42) | (0.53) | (0.55) | (0.52) | (0.42) |
| Constant | 11.28*** | 11.30*** | 11.32*** | 11.29*** | 11.25*** | 11.19*** |
| | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.02) |
| $N$ | 1,684,278 | 1,524,871 | 1,368,898 | 1,214,285 | 1,054,900 | 895,770 |
| pseudo $R^2$ | 0.700 | 0.699 | 0.700 | 0.701 | 0.700 | 0.697 |

Notes: Robust standard errors clustered by country-pairs in parentheses; * $p<0.10$, ** $p<0.05$, *** $p<0.01$; Included (unreported) are importer, exporter, product, and year fixed effects.

## 6 Conclusion

This paper presents an empirical investigation on the impact of economic sanctions on the trade of mineral commodities for the period 2009-2020. By means of an augmented gravity model, we emphasize the degree of trade disruption between the sender and target countries, along with the emergence of trade diversion attributed to sanctions circumvention. First, a substantial trade disruption is evident, marked by an immediate 90 percent reduction, with a growing impact observed over time. Conversely, in the latter case, sanctions-busting appears effective only in the very short term, albeit with weak supporting evidence. Notably, this study introduces a significant novelty by examining the occurrence of trade diversion for sender countries. Unlike existing literature, we also assess whether sender countries have substituted imports from target countries with imports from third-party nations. Empirical findings unveil a complex outcome. Specifically, the general trend suggests that sender countries witness a decline in trade not only with target countries but also with third-party nations (negative network effect). Put differently, sanctions result in a broad trade disruption. Nevertheless, when scrutinizing by world regions and HS chapters, the evidence becomes considerably nuanced. In the first case, it appears that North American countries demonstrate the capability to replace imports from target countries with alternative suppliers, while EU countries experience a clear-cut trade disruption. Furthermore, when considering

the emergence of sanctions-busting, the resulting evidence is inconclusive for most regions, with the exception of MENA countries. To fact, MENA countries appear to have encountered an uptick in mineral exports despite the presence of sanctions. When examining different commodities, the findings indicate that sanctions lead to a reduction in the trade of mineral commodities classified under chapters 26 and 27, but not in those categorized under chapter 25. As for sanctions-busting, it appears to be primarily operative for commodities under chapter 26. Specifically, sender countries importing commodities under chapter 25 appear to be able to shift to other sources; while, sender countries importing commodities under chapter 27 experience a substantial trade disruption. In fact, it seems they are not able to shift to other supply channels. Target countries exporting commodities under Chapter 26 manage to supply other destination markets, achieving a trade diversion presumably due to sanctions-busting. In contrast, suppliers of commodities falling under Chapter 27 experience a sharp reduction in their exports, roughly around 98 percent.

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# APPENDIX

## A Commodity description

Table 1: Product classification

| Section V | Minerals (industrial raw materials) | HS6 code |
|---|---|---|
| Chapter 25 | Salt; sulfur; earths and stone; plastering materials, lime and cement | 250200; 250410; 250490; 250510; 250590; 250700; 250810; 251010; 251020; 251110; 251320; 251910; 251990; 252010; 252020; 252100; 252210; 252220; 252230; 252610; 252620; 252810; 252890; 252910; 252921; 252922; 252930; 253090. |
| Chapter 26 | Ores, slag and ash | 260111; 260112; 260120; 260200; 260300; 260400; 260500; 260600; 260700; 260800; 260900; 261000; 261100; 261310; 261390; 261400; 261510; 261590; 261610; 261690; 261710; 261790; 261800; 261900; 262011; 262019; 262021; 262029; 262030; 262040; 262060; 262091; 262099. |
| Chapter 27: | Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes | 270112; 270400. |

Table 2: List of countries subject to trade sanctions ($Sanction^{k}_{ij,t} = 1$)

| Senders | Freq. | Targets | Freq. |
|---|---|---|---|
| United States | 1,740 | Russian Federation | 2,483 |
| Canada | 494 | Zimbabwe | 1,872 |
| United Kingdom | 368 | Egypt, Arab Rep. | 1,810 |
| Spain | 362 | Myanmar | 1,116 |
| France | 306 | Iran, Islamic Rep. | 600 |
| Germany | 303 | Guinea | 402 |
| Czech Republic | 298 | Cuba | 384 |
| Italy | 298 | Korea, Dem. Rep. | 344 |
| Luxembourg | 298 | Ukraine | 226 |
| Netherlands | 298 | Armenia | 204 |
| Poland | 298 | Israel | 140 |
| Slovak Republic | 298 | China | 134 |
| Belgium | 296 | Nigeria | 80 |
| Denmark | 295 | Indonesia | 78 |
| Slovenia | 292 | Congo, Dem. Rep. | 60 |
| Turkey | 292 | Bolivia | 56 |
| Ireland | 289 | Saudi Arabia | 48 |
| Greece | 288 | Fm Sudan | 45 |
| Finland | 283 | Jamaica | 30 |
| Sweden | 283 | Colombia | 22 |
| Portugal | 273 | Vietnam | 17 |
| Hungary | 263 | Ghana | 15 |
| Austria | 256 | Sierra Leone | 12 |
| Estonia | 253 | South Africa | 6 |
| Latvia | 253 | Turkey | 3 |
| Lithuania | 252 | Kyrgyz Republic | 1 |
| Norway | 232 | | |
| Switzerland | 196 | | |
| Japan | 184 | | |
| Iceland | 174 | | |
| Korea, Rep. | 88 | | |
| Australia | 85 | | |
| Overall | 10,188 | | 10,188 |

# B Gravity model

Table 3: Trade effects of trade sanctions. Aggregated data

| | (1) no lag | (2) 1-year lag | (3) 2-year lag | (4) 3-year lag | (5) 4-year lag | (6) 5-year lag |
|---|---|---|---|---|---|---|
| $Sanction^k_{ij,t}$ | -2.24*** | -2.19*** | -2.25*** | -2.36*** | -2.52*** | -2.47*** |
| | (0.36) | (0.36) | (0.34) | (0.31) | (0.30) | (0.32) |
| $ln(Distance_{ij})$ | -0.86*** | -0.86*** | -0.86*** | -0.86*** | -0.86*** | -0.85*** |
| | (0.08) | (0.08) | (0.08) | (0.08) | (0.08) | (0.08) |
| $ln(GDP_{i,t})$ | 0.33* | 0.28* | 0.22 | 0.23 | 0.10 | 0.04 |
| | (0.17) | (0.17) | (0.18) | (0.19) | (0.24) | (0.25) |
| $ln(GDP_{j,t})$ | -0.08 | -0.04 | -0.01 | -0.02 | -0.01 | 0.07 |
| | (0.15) | (0.16) | (0.16) | (0.17) | (0.16) | (0.15) |
| $Contiguity_{ij}$ | 1.06*** | 1.05*** | 1.04*** | 1.01*** | 1.01*** | 1.00*** |
| | (0.17) | (0.18) | (0.18) | (0.18) | (0.18) | (0.19) |
| $Language_{ij}$ | 0.52*** | 0.53*** | 0.54*** | 0.57*** | 0.57*** | 0.59*** |
| | (0.17) | (0.17) | (0.17) | (0.17) | (0.17) | (0.17) |
| $Colony_{ij}$ | 0.14 | 0.13 | 0.12 | 0.09 | 0.08 | 0.07 |
| | (0.34) | (0.34) | (0.33) | (0.33) | (0.33) | (0.32) |
| Constant | 12.22*** | 12.62** | 13.34*** | 13.19** | 15.55** | 15.20** |
| | (4.54) | (4.94) | (5.16) | (5.54) | (6.32) | (6.34) |
| $N$ | 2,688,207 | 2,462,784 | 2,237,089 | 2,009,830 | 1,784,917 | 1,559,169 |
| pseudo $R^2$ | 0.60 | 0.60 | 0.60 | 0.60 | 0.59 | 0.59 |

Notes: Robust standard errors clustered by country-pairs in parentheses; $Sanction^k_{ij,t}$ from the GSBD; Included (unreported) are importer, exporter, product, and year fixed effects;
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

# C Trade effect of trade sanctions: industry-wise analysis

Table 4: Trade Effects of trade sanctions by product (HS4-digit).

| | (1) Estimated coefficient | (2) Standard errors |
|---|---|---|
| $Sanction^k_{ij,t-1}$: | | |
| Natural sands of all kinds (2505) | -2.80*** | (0.16) |
| Gypsum; anhydrite; plasters (2520) | -5.36*** | (0.49) |
| Natural steatite (2526) | -0.75*** | (0.25) |
| Natural borates and concentrates thereof (2528) | 7.30*** | (0.27) |
| Feldspar; leucite; nepheline and nepheline syenite; fluorspar (2529) | -0.85*** | (0.14) |
| Mineral substances not elsewhere specified or included (2530) | -0.93*** | (0.16) |
| Iron ores and concentrates (2601) | -5.21*** | (1.13) |
| Copper ores and concentrates (2603) | -2.55*** | (0.58) |
| Nickel ores and concentrates (2604) | -3.97*** | (0.84) |
| Aluminium ores and concentrates (2606) | 3.26*** | (0.57) |

| | | |
|---|---|---|
| Zinc ores and concentrates (2608) | -3.85*** | (0.75) |
| Molybdenum ores and concentrates (26013) | -8.80*** | (0.76) |
| Titanium ores and concentrates (26014) | -1.13* | (0.60) |
| Precious metal ores and concentrates (26016) | -1.80*** | (0.64) |
| Ores and concentrates (2617) | -2.21** | (1.05) |
| Slag, dross; (other than granulated slag), scalings and other waste (2619) | -2.30* | (1.34) |
| Slag and ash (2621) | -3.23*** | (0.56) |
| Coke and semi-coke; of coal, lignite or peat; retort carbon (2704) | -4.39*** | (0.37) |
| $Sender^{k}_{i,z\neq j,t-1}$: | | |
| Unroasted iron pyrites (2502) | -2.69*** | (0.53) |
| Kaolin and other kaolinic clays (2507) | 1.36*** | (0.20) |
| Natural calcium phosphates (2510) | 0.73** | (0.32) |
| Natural barium sulphate (2511) | 1.51*** | (0.54) |
| Natural magnesium carbonate (2519) | 1.08*** | (0.25) |
| Limestone flux; limestone and other calcareous stone (2521) | -0.84* | (0.52) |
| Natural steatite (2526) | 0.94*** | (0.26) |
| Iron ores and concentrates (2601) | 1.67*** | (0.29) |
| Copper ores and concentrates (2603) | 2.03*** | (0.30) |
| Nickel ores and concentrates (2604) | -1.05** | (0.44) |
| Cobalt ores and concentrates (2605) | -2.75*** | (0.78) |
| Zinc ores and concentrates (2608) | 1.04*** | (0.26) |
| Tin ores and concentrates (2609) | -5.99*** | (0.32) |
| Chromium ores and concentrates (2610) | -1.71*** | (0.36) |
| Tungsten ores and concentrates (2611) | -2.49*** | (0.42) |
| Titanium ores and concentrates (2614) | 1.45*** | (0.54) |
| Niobium, tantalum, vanadium or zirconium ores and concentrates (2615) | -0.89** | (0.40) |
| Ores and concentrates (2617) | -3.70*** | (0.32) |
| Granulated slag (slag sand) from the manufacture of iron or steel (2618) | -2.00*** | (0.22) |
| Slag, dross; (other than granulated slag), scalings and other waste (2619) | -2.63*** | (0.35) |
| Slag, ash and residues; (not from the manufacture of iron or steel) (2620) | -1.02*** | (0.27) |
| Coke and semi-coke; of coal, lignite or peat; retort carbon (2704) | -2.27*** | (0.52) |
| $Target^{k}_{c\neq i,j,t-1}$: | | |
| Unroasted iron pyrites (2502) | -10.65*** | (0.32) |
| Natural graphite (2504) | 0.89*** | (0.26) |
| Natural sands of all kinds (2505) | -2.02*** | (0.40) |
| Natural calcium phosphates (2510) | -0.93* | (0.52) |
| Natural barium sulphate (2511) | -3.09*** | (0.30) |
| Pumice stone; emery; natural corundum (2513) | -4.63*** | (1.09) |
| Natural magnesium carbonate calcareous stone (2519) | -1.58*** | (0.41) |
| Limestone flux; limestone and other calcareous stone (2521) | -5.35*** | (0.61) |
| Quicklime, slaked lime and hydraulic lime (2522) | -5.07*** | (0.32) |
| Natural borates and concentrates thereof (2528) | 4.76*** | (0.46) |
| Mineral substances not elsewhere specified or included (2530) | 0.48** | (0.20) |
| Iron ores and concentrates (2601) | 2.13** | (1.05) |
| Copper ores and concentrates (2603) | 4.11*** | (0.86) |
| Cobalt ores and concentrates (2605) | 3.39*** | (0.90) |
| Aluminium ores and concentrates(2606) | 3.03*** | (0.44) |
| Tin ores and concentrate (2609)s | -7.93*** | (1.09) |
| Tungsten ores and concentrates (2611) | -1.40*** | (0.40) |
| Molybdenum ores and concentrates (2613) | 2.09** | (0.91) |
| Titanium ores and concentrates (2614) | 3.64*** | (0.66) |
| Niobium, tantalum, vanadium or zirconium ores and concentrates (2615) | -0.94* | (0.52) |
| Ores and concentrates (2617) | -1.55* | (0.95) |
| Slag, ash and residues (2620) | 2.83*** | (0.91) |

| | | |
|---|---|---|
| Coal; briquettes, ovoids and similar solid fuels manufactured from coal (2701) | -5.11*** | (0.87) |
| Coke and semi-coke; of coal, lignite or peat; retort carbon (2704) | -4.32*** | (0.65) |
| Constant | 11.28*** | (0.03) |
| $N$ | 1,672,548 | |
| pseudo $R^2$ | 0.73 | |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Included (unreported) are importer-product-time, exporter-product-time, and country pairs-product fixed effects.
Not significant commodities not reported.

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