The potential impact of sanctions on the European and the Russian economy – a GVC approach

VAKHAL PÉTER[1]

Abstract

Globalization has woven economies together through intricate global value chains (GVCs), where countries specialize in different production stages. This interdependence can be disrupted by sanctions, potentially harming both the targeted nation and those imposing the restrictions. This study examines the impact of sanctions imposed by the European Union (EU) on GVCs in response to Russia's war on Ukraine. The common assumption is that the EU, heavily reliant on Russian energy imports, will suffer the most from these sanctions. We investigate this hypothesis by analysing quantitative data, including trade statistics, official documents, and IO models. Their focus is on how specific sectors in both the EU and Russia will be affected by the sanctions. The findings reveal a surprising asymmetry. The EU's sanctions target a much larger portion of Russian imports (70%) compared to exports (21%). This is predicted to cause a nearly 2% decline in the Russian economy, while the impact on the EU is estimated to be less than 1%. However, the burden isn't evenly distributed. Eastern EU member states with close trade ties to Russia, like Lithuania, Latvia, and Estonia, are more exposed to the negative effects. Additionally, sectors like aviation, chemicals, petroleum refining, and metals in Russia are expected to experience the most significant decline due to the sanctions. In conclusion, while the sanctions are predicted to have a more significant negative impact on the Russian economy compared to the EU, specific sectors and eastern EU member states are likely to experience economic hardship due to the disruption of GVCs.

Introduction

This study examines the impact of sanctions imposed by the European Union on global value chains due to Russia's war against Ukraine. In relation to the antecedents, topicality and conceptual foundation of the topic, it is worth mentioning that in our globalized world, the complete or partial isolation of a country strongly integrated into the international supplier network from the world economy carries extraordinary risks for both the domestic and the international economy. The isolation of an economy (even partly) from its foreign trade partners for any non-natural reason (such as an earthquake) in the 21st century could seem almost unimaginable and irrational, because even according to Ricardo's foreign trade theory, trade between countries is mutually beneficial (Costinot, 2009). In the past more than half a century, the increasing spread of global value chains (GVCs) has contributed to the continuous improvement of productivity and to the beginning of deindustrialization, i.e. the retrenchment of industrialization (Peneder & Streicher, 2018), and in some cases reindustrialization processes (Christopherson et al., 2014). The rise of GVCs was mostly favourable for emerging economies (Timmer et al., 2014), because it offered an opportunity for specialization and involvement in value chains. As a result of the processes that began in the early 2000s, the Republic of Korea, China and Mexico became the main global suppliers of final manufacturing products, and Brazil, the Republic of South Africa and Russia of raw materials (Gereffi, 2016).

[1] senior research fellow, Kopint-Tárki Institute for Economic Research
assistant professor, Corvinus University of Budapest, Dep. of Operations Research

Embedding into the global trade network (Kaplinsky, 2013) enabled rapid economic development for a large number of developing and emerging countries for two decades, although this process has now slowed down significantly (Timmer at al., 2016) or even reversed after the pandemic (Antràs, 2020). The main driving force behind the spread was that entering the global production network is significantly easier than building an independent production capacity, because it is possible to penetrate on the world market even with a very small added value, thus making it possible to conduct foreign trade even with a relatively small investment. As a result, the exports of emerging and developing countries expanded dynamically in the last two decades, which in most cases also resulted in significant economic growth.

Deep embedding in value chains is also accompanied by the development of mutual interdependence in the world economy. In supplier relations, a centre-periphery arrangement is emerged, where the relative role of peripheral countries (most often measured through the exported domestic added value / total gross export ratio) is smaller than that of countries or sectors playing a central role in the network. According to Criscuolo & Timmis (2018), this topology already suggests a clear hierarchical arrangement, in which the economic influence of the central countries is more significant than that of the others. In this constellation, it was also observed that the weight of the Central and Eastern European countries, as well as Russia and Kazakhstan, in the value chains is constantly increasing. The greater weight also results in greater dependence for the affected sectors and thus for the entire economy. This interdependence is twofold: on the one hand, it is directed downward (what the literature calls downstream), which indicates the sector's dependence on consumers of intermediate or final products, and on the other hand, it is directed upward (upstream), which expresses the need of domestic users for foreign inputs.

Of course, this interdependence is not exclusively an international phenomenon, as it also exists between domestic sectors, and in fact these relationships are much stronger. If, for whatever reason, a sector cannot fulfil its delivery obligations, the users of its products will not be able to produce in the short term either, or at most as much as the accumulated stock allows for the necessary input. The same is true the other way around: if a user - be it a producer or a final consumer - does not take over the produced products for any reason, they remain in the manufacturer's inventory until a new user buys them. All of this applies particularly to services as well.

The exact definition of the time span is extremely important. If a producer does not have an absolute monopoly position in the market, then there must be a perfect physical substitute for its product available at some markup $c \geq 0$. However, it is not or only rarely available immediately, but it can be obtained on the market. In this case, the level of dependence is low, because if the supplier or buyer cannot supply, they can be easily replaced. If there is only an imperfect substitute in the competitive market, it is not possible to perfectly replace the lost supply or demand in the short term.

In this regard, it is worth briefly discussing monopolistic market dependencies, when the producer either has the possibility to obtain raw materials from only one source (upstream dependency) or his product has only one customer (downstream dependency). In such cases, a demand or supply shock has much more severe consequences than in a perfectly competitive market. However, as a result of technological development, over a longer period of time, the monopolistic supplier-customer relationship does not develop completely. The results of technical or technological development can, in the long run, dissolve the strict dependency relationships (Götz, 1999). In this area, it is therefore worth examining the short-term risks.

The causes of upward or downward demand and supply shocks in the mentioned supplier and user channels are manifold. Up until now, disruptions in global value chains have mostly been caused by shocks that could be traced back to production losses that occurred as a result of natural disasters (Breiling, 2021). Later, supply difficulties arose due to the market turbulence caused by the coronavirus epidemic (McKinsey, 2020; Miroudot, 2020). As a result, some experts have already written about the voluntary resettlement of subsidiaries with foreign parent companies (Xu et al., 2020). And before that, Brexit, caused reactions that could lead to the disruption of the value chain structure known so far (Losoncz, 2020; Moradlou et al., 2021).

So far in modern economic history, there have only been a few cases where a sector of a country with a dominant world market share has been unable to meet its delivery obligations, thereby causing upward and downward global shocks. Such was, for example, the IT hardware supply crisis that arose during the floods in Thailand in 2011. Traces of this can still be seen today in certain segments of East Asian countries, especially small and medium-sized enterprises (SMEs) (Pathak & Olmo, 2021).

A war can also cause a shock acting in both directions, which has its effect in several steps. On the one hand, it can not only cause logistical disturbances, but can also lead to the destruction or partial destruction of physical and human infrastructure. On the other hand, the various economic and financial sanctions introduced in response to war primarily affect the economy of the attacking country, but due to their double-edged nature, they also affect the countries that initiated them. Finally, in the globalized world economy, the other countries of the world also have to reckon with the direct and indirect effects of war and sanctions. The sad economic experience of war is that since it usually takes place between neighbouring countries, regional value chains suffer the greatest damage. Often in such a way that the attacking party suffers severe economic losses even if no sanctions are imposed on him.

The study presents and analyses this described phenomenon based on sanctions initiated in response to Russia's war against Ukraine. One of its aims is to examine the impact of the imposed specific sanctions on the affected economies. Another goal is to map which countries are most exposed to the related economic shocks in the short term.
Sanctions research has specialized literature, but at the same time, there is a research gap in mapping the connections, effects and mechanisms of effects between war and value chains, which emphasizes the relevance of this paper. This study attempts to fill this gap, taking into account the limitations of statistical follow-up.
According to the initial hypothesis of the study, due to the high degree of dependence on Russian energy carriers and certain raw materials, the European economy will suffer the most serious negative effects, primarily in the short term.
The genre of the study is impact analysis, it reviews and analyses the actual and potential economic consequences of Russia's war against Ukraine and the EU sanctions given in response to it. The study itself is an impact analysis using quantitative and qualitative methods based on international and domestic literature sources, official documents, analyses of statistical data, as well as the global sectoral relations balance (input-output - IO) model that quantifies the possible effects.

The economic aspects of international conflicts and wars of a military nature

As for the economic aspects of conflicts, wars (including civil wars) are always associated with a decrease in output, which causes a recession, primarily in the attacked country, but also in the economy of the attacking party, depending on world political reactions. The medium-term effect also depends to a large extent on the level of economic development of the countries. In this connection, it is an experience worthy of attention that the conflicts that occurred in developing countries, but have already ended, did not usually derail the economy from the growth path, and in fact, reconstruction can induce considerable economic growth. The correlation between economic growth and overcoming poverty is weak, so even though a developing country recovering from the crisis can achieve spectacular economic growth, this still leaves the majority of them stuck in the poverty trap. The indebtedness of the population does not decrease (in fact, it typically increases significantly during the crisis), which can lead to the outbreak of new conflicts. However, the situation is different in developed and emeging countries, where war typically completely diverts the growth trajectory, and it is almost impossible to return to the previous levels (Cerra & Saxena, 2005). Similar conclusions can be drawn about the countries that participated in the war in Yugoslavia (then still part of it), where the recovery of the economic consequences has been going on for several decades, and the pre-war levels of development have only recently been reached again (Braddon & Hartley, 2011; Uvalic, 2010).

Countries not affected by wars and other armed conflicts typically react with sanctions, which usually take the form of the introduction of trade restrictions. These not only apply to the relationship between the sanctioning country and the sanctioned country, but also generally extend to third parties trading with the sanctioned country. These are typically the economic sanctions imposed by the US on Iran, which also apply to third-country companies trading with Iranian firms. Restrictions usually cause severe negative effects on bilateral balance of payments, but they can also have spillover effects on global value chains. The greater the economic power of the sanctioning country vis-à-vis the sanctioned one, the more significant impact it can achieve (Caruso, 2003). There is a risk that in the spirit of reciprocity, the sanctioned country will also take countermeasures, as happened, for example, in the case of the US trade sanctions against China. The mentioned trade restrictions did not achieve the otherwise rather vague goal. Similar considerations were also valid for the US sanctions imposed on major economies, including Russia, after the millennium (Hufbauer & Jung, 2020).

The international community first introduced various economic sanctions against Russia in the second half of the 2010s, after the occupation of the Crimean peninsula. With the exception of the temporarily higher consumer price index, they had a negligible impact on Russian growth, foreign trade and other macroeconomic indicators (Csontos & Udvari, 2021; Gros & Di Salvo, 2017; Gros & Mustilli, 2015). Although the restrictions were targeted, they were not comprehensive enough, and the sectoral coverage was small. According to some opinions, the excessive dependence of European countries on Russian energy carrier imports proved to be a significant restraining force, which prevented the achievement of a significant effect (Belo, 2020).

In conflicts that turn into war, the greatest destruction occurs during acts of war, as physical infrastructure (capital goods), human resources (labour) and agricultural lands are also significantly damaged. In some form, all the parameters of the production function are affected negatively, which necessarily leads to the deterioration of efficiency and productivity, and ultimately to the reduction of value-added and output. Considering only economic aspects, the

war can have at least one of the effects shown in Table 1, assuming that it is limited to the territory of only one country.

Table1: Possible economic effects of military conflicts

Attacked		**Attacker**	
Event	**Short-term impact**	**Event**	**Short-term impact**
Total or partial destruction of physical infrastructure.	Destruction of physical capital goods.	Partial destruction of military equipment and human resources	Losses in capital goods, contraction of labour supply in sector.
Civil humán erőforrások elmenekülése vagy elpusztulása, vendégmunkások elmaradása.	Tightening labour supply, drastic decline in household consumption.	Sanctions to partially restrict international financial transactions.	Freezing of financial obligations and claims of economic operators, decrease in the value of companies, temporary paralysis of domestic financial and capital markets.
Total or partial cessation of production.	Restriction of international trade.	Full or partial trade-restrictive economic sanctions.	Total or partial demand and supply shocks in the economy, weakening of the exchange rate.
Diversion of production units, labour, products and services, seizure for military purposes, conversion of production to war economy.	Total or partial failure to meet domestic and international market demand.	Diversion of production units, labour, products or services, seizure for military purposes, conversion of production to a military economy.	Total or partial failure to meet domestic and international market demand.
Increase in defence spending.	Increase in government consumption.	Increase of military spending.	Rise in government consumption.
Weakening of the exchange rate, temporary suspension of the functioning of the banking system, financial and capital markets	Hyperinflation threat.	Deterioration of the interest rate environment, increase in corporate and sovereign credit risks, liquidity problems, exchange rate weakening.	Accelerating inflation, deteriorating willingness to invest and internal balance indicators.

Source: Own collection and editing based on a large number of domestic and international literary sources

Based on Table 1, in the event of a war, outputs can primarily be expected to decrease, the extent of which is most likely proportional to the severity of the hostilities. The decline in output due to global value chains extends not only to the parties directly involved, but to almost all countries, especially those that had close direct trade relations with them. The sanctioned producers cannot deliver to the sanctioning party, production is suspended for an indefinite period, therefore they cannot receive or send products. The following scenario prevails at the domestic and international level, the extent of the drop in demand and supply depends on the actual situation.

- If the attacking country is sanctioned, some sectors and households will not have access to the foreign inputs and final products needed for production or consumption. However, the production of purely domestically produced intermediate and final products is undisturbed.
- As a countermeasure, the sanctioned country does not deliver certain inputs to the restrictive countries, and does not buy certain outputs from them. These deliveries may be delayed based on the decision of the customers and as a result of their sanctions.

The war can also cause short-term economic damage to non-sanctioned third countries by not having access to inputs and final products supplied by the parties, or by not purchasing products issued by third countries. The extent of the impact clearly depends on the magnitude of the direct and indirect relations, and on the market monopoly position of the partner countries. The clearer and stronger the competition on the world market with the countries in conflict on the supply and demand side, the easier they can be replaced, so the third country can become more independent from the events in the economic field. The more the market shifts in a monopolistic direction, the more expensive it is to replace it with another imperfect product or technological innovation. All this can be captured on the basis of the international input-output tables.

The initial situation and its possible consequences: mutual exposure and dependence based on foreign trade indicators

Before mapping the impact mechanisms and consequences of the sanctions, it worth to map the initial situation by relying on the conceptual set of the reviewed literature sources. In this context, the concept and measurement of global economic exposure or dependence and dependence should be clarified.
Due to its topic, this study in this chapter refers to the international trade positions of Russia and the EU as dependency, while exposure refers to the impact and effects of changes in certain foreign trade indicator values on the countries of the world.
Accordingly, this section discusses various foreign trade indicators. On the one hand, it examines the share of Russia and the EU in world imports in total and based on main product categories. These indicators indicate the export side's exposure and, where appropriate, dependence. On the other hand, it presents the relative weight of the EU and the mentioned countries in Russia's imports, which indicates import dependence or dependence, also in total, and broken down by main product categories. However interesting and exciting the question may be and it may colour the conclusions, the study does not address the location and role of FDI flows, which may be the subject of further research.

As far as foreign trade indicators are concerned, it can be seen from Table 2 that Russia's share in all imports of the world, the EU and large countries that determine international economic trends (China, Japan, the United Kingdom and the USA) is small. Within this, however, it is significantly above average among energy carriers: Russia accounted for more than a quarter of Chinese imports, 23.4 percent of EU imports, and 8.3 percent of British imports in 2021. In

this context, we can talk about dependency in the case of the EU. Among the dominant countries in the world economy, the USA's reliance on Russian energy carriers is the smallest (5.8 percent of imports). China's above-average relative weight in the product group of vegetable and animal oils and fats is also worth mentioning.

Table 2: Russia's share in imports of the world, the EU and four large countries in 2021 by main product categories

SITC nomenclature	World	China	EU27	Japan	UK	USA
Food and live animals	1.9%	2.3%	1.9%	2.2%	0.2%	0.9%
Beverages and tobacco	0.8%	0.5%	1.2%	0.4%	0.4%	0.1%
Crude materials, inedible, except fuels	2.5%	2.4%	7.6%	1.0%	1.8%	0.6%
Mine ral fuels, lubricants and related materials	10.3%	13.3%	29.6%	5.6%	8.6%	8.1%
Animal and vegetable oils, fats and waxes	3.0%	5.8%	1.6%	0.3%	0.0%	0.0%
Chemicals and related products, n.e.s.	1.2%	0.7%	2.5%	0.2%	0.3%	0.7%
Manufactured goods classified chiefly by material	3.2%	4.4%	8.5%	4.4%	3.1%	2.2%
Machinery and transport equipment	0.2%	0.0%	0.3%	0.0%	0.0%	0.0%
Miscellaneous manufactured articles	0.2%	0.1%	0.2%	0.0%	0.0%	0.1%
Commodities and transactions not classified elsewhere in the SITC	4.1%	0.5%	5.8%	0.2%	23.2%	0.1%
Total	2.3%	3.2%	7.0%	1.8%	3.6%	1.0%

Source: UN-COMTRADE

Russia earns significant foreign exchange earnings from the export of energy carriers. At current prices, their magnitude is estimated at $12.5 million per day for coal, $700 million for crude oil and petroleum products (diesel, gasoline, and heating oil) and $400 million for natural gas transported by pipeline. These figures may vary depending on quantities and prices.

Regarding the individual energy carriers, the 43 million tons of power plant coal imported from Russia in 2021 does not represent monopoly market exposure or dependence, it can be replaced within a few months from the world market, primarily through deliveries from Australia, Colombia and the Republic of South Africa (McWilliams et al., 2022). The port's stock of 2.6 million tons, equivalent to three months of Russian imports, helps bridge any short-term disruptions. The transition imposes significant tasks on the logistics infrastructure.

Russia is the world's largest crude oil exporter, the EU is the world's second largest crude oil importer and the number one buyer of Russian crude oil. According to the International Energy Agency, in 2021 Russia's output of 10.5 million barrels per day accounted for 14 percent of the world's crude oil production, of which 4.27 million barrels per day (60 percent) were sold in Europe. Added to this was the export of a total of 2.69 million barrels of refined products per day in 2021. The most important of these is diesel oil, whose Russian share in EU imports was 40 percent (Fattouh et al., 2022). Behind the average there are significant differences between the individual EU member states. The ratio of the net import of Russian crude oil to the total

energy consumption was almost 80 percent for Lithuania on the one hand, and 12 percent for Germany on the other hand. For this reason, any disruption of Russian deliveries would be an asymmetric supply shock for the EU.

Russia's share in the European Union's import of crude oil and petroleum products cannot be considered a monopoly market (upstream), but at most an outstanding, determining dependency. The asymmetry of interdependence relations is indicated by the fact that Russia's share in the EU's crude oil imports is smaller than the reverse, i.e. the EU's share in Russian crude oil exports. Russia has the possibility to sell its crude oil freed up as a result of a possible Western embargo in other relations, or to sell its products through an intermediary in violation of the rules of origin. All of this is highlighted by the fact that 40 percent of the revenues of the Russian budget in 2021 came from taxes on oil and natural gas, which were still much cheaper at that time. This can be considered an outstanding degree of reliance.

According to the data provided by the European Commission, the 155 billion cubic meters of natural gas imported by the European Union from Russia in 2021 (90 percent of which came via pipeline) accounted for 45 percent of the total import and 40 percent of the consumption. However, there are significant differences behind this: at one end of the scale, Russian imports were 11 percent of consumption in the Netherlands, at the other end 93-94 percent in Finland and Latvia, and in between 64 percent in Austria and 55 percent in Germany. At the same time, Russia's export dependence on natural gas is less than that of crude oil: about 40 percent of the production is sold on the foreign market, but in the latter, the dependence on the EU is prominent, around 80 percent.
Russia's role is prominent in the world export of some raw materials and metals. Russia is the main source of nickel, which is essential for steel and battery production. The country's positions are decisive in the global supply of argon and neon noble gases required for semiconductor production, as well as titanium sponge, which is part of aircraft production. The country's uranium exports are also significant (OECD, 2022). Russia is an important global supply source for aluminum used in vehicle production (the world's second largest aluminum exporter), palladium used in the production of vehicle catalysts (with an export share of 43 percent) and nickel (11 percent).

Apart from the discussed areas, Russia's embeddedness in the international division of labour, and even its dependence, is stronger in imports than in exports (Table 3). In 2020, the share of China and the European Union was around 60 percent or more in Russia's import of machinery and transport equipment, products grouped by raw material, chemicals and other processed products. According to the statistical data, China and the European Union were the main import partners of manufacturing products, including machinery and transport equipment. The above-average share of the EU in Russian imports of beverages and tobacco, foodstuffs and live animals, as well as animal and vegetable oils and fats can also be mentioned. In the former group of goods, the role of the United Kingdom and the USA cannot be neglected either. However, these are not strategic products that determine the pace of economic development in the longer term.

Table 3: The share of the EU and four large countries in Russia's imports in 2020 by main commodity groups (Russian imports of individual product groups = 100 percent)

SITC nomenclature	China	EU27	Japan	UK	USA
Food and live animals	5,3%	19,1%	0,2%	0,7%	0,8%
Beverages and tobacco	1,1%	58,1%	0,3%	8,9%	3,9%
Crude materials, inedible, except fuels	2,5%	20,5%	0,4%	0,7%	3,6%
Mine ral fuels, lubricants and related materials	1,9%	33,9%	2,8%	2,2%	1,2%
Animal and vegetable oils, fats and waxes	0,4%	14,1%	0,0%	0,2%	0,5%
Chemicals and related products, n.e.s.	14,0%	54,9%	1,5%	2,6%	7,6%
Manufactured goods classified chiefly by material	27,6%	31,4%	2,7%	0,8%	2,2%
Machinery and transport equipment	34,0%	31,8%	5,4%	1,6%	4,6%
Miscellaneous manufactured articles	37,5%	24,8%	2,1%	1,0%	4,1%
Commodities and transactions not classified elsewhere in the SITC	2,3%	40,3%	0,0%	0,4%	38,5%
Total	24,8%	33,5%	3,1%	1,5%	5,9%

Table 3 shows that the EU's share of Russia's imports of mineral fuel, lubricants and similar substances is about 30 percent. A large part of this is coal and coal derivatives from Poland (nearly 90 percent of the total Russian coal imports), as well as oil from petroleum (petroleum or kerosene, among others) from Finland.

After the collapse of the Soviet Union, Russia began to play a kind of central role in the value chain of the Baltic republics, Romania, Bulgaria and Slovakia, becoming the main supplier of added value by 1995. (At that time, the ties to Germany were not as strong as they are today). At the turn of the millennium, the European value chain (Factory Europe) emerged, parallel to this the dependence on Russian energy value chain (Amador et al., 2018).
While only 1.3 percent of the EU's total output contining Russian added value in 2011, 3.3 percent of the total Russian output came from the EU. However, the distribution of the use of Russian value-added between member states and industries is far from uniform. While Ireland and Portugal, and even Germany, use Russian value-added to an insignificant extent, in Latvia this ratio is close to 10 percent, in Bulgaria it reaches 8 percent, and in Hungary it is 5 percent. All this happens almost exclusively through energy carriers (Benkovskis et al., 2014).

Database, methodology and assumptions

Several international input-output databases are available for research purposes, their temporal and geographical coverage is quite different. For our research purposes, the most suitable IO database is the ICIO maintained by the OECD.

During the analysis, we took specific sanctions as a basis. Unfortunately, the trade policy of the European Union is extremely bureaucratic, the sanctions were adopted in several steps, not all of them were recorded in the same legislation. The regulations leave quite a lot of room for the customs authorities of the Member States, often allowing individual assessment. Despite the greatest care, we were unable to find an updated official list that itemized the products and services subject to sanctions.

The sanctions imposed by the EU can be distinguished as follows:

- Export sanctions: the ban on the export of certain products and services produced in the EU. It is important to note that a large part of the export ban applies to so-called dual-use products (suitable for both civilian and military purposes), the purpose of which is not primarily to cause economic damage, but to hinder Russian military production. However, due to civilian use, they can also cause damage to the economy.
- Import sanctions: the EU has imposed an import ban on certain products produced in Russia. Import restrictions are specifically aimed at causing economic damage.
- Financial restrictions: the disconnection of Russian banks from the SWIFT system certainly caused serious damage to the banking system, but at the same time the effect cannot be quantified, nor can it be attributed to member states. The same is true for the limitation of insurance services, which is why financial sanctions were not taken into account during the research.
- Sanctions on individuals and savings and assets held in the EU. Their purpose is primarily political, and their economic effects are small, so we do not take them into account in the study.

We identified a total of 694 items from the export sanctions, which we supplemented with the prohibition of services, of which the most well-known are logistics restrictions. In the area of import restrictions, we found 1,064 items, which were supplemented with the service prohibitions described above.

Table 4: Share of top 5 sanctioned products in 2019

Import sanctions			Export sanctions		
Product	**Share in EU import of the product**	**Share of EU in total Russian export of the product**	**Product**	**Share in total of the product**	**Share of EU in total Russian import of the product**
Petroleum oils (2709)	20%	47%	Medicaments (30049000)	3%	70%
Petroleum oils (2710)	18%	54%	Processing units (84715000)	4%	44%
Coal and briquette (2701)	41%	22%	Machines, apparatus and mechanical appliances, n.e.s. (84798997)	3%	58%
Wood and wood products (44)	6%	32%	Machines for the reception, conversion and transmission or regeneration of voice, images or other data (85176200)	2%	8%
Diamonds (7102)	14%	41%	Machinery, plant or laboratory equipment (84198998)	3%	65%

Source: UN-COMTRADE

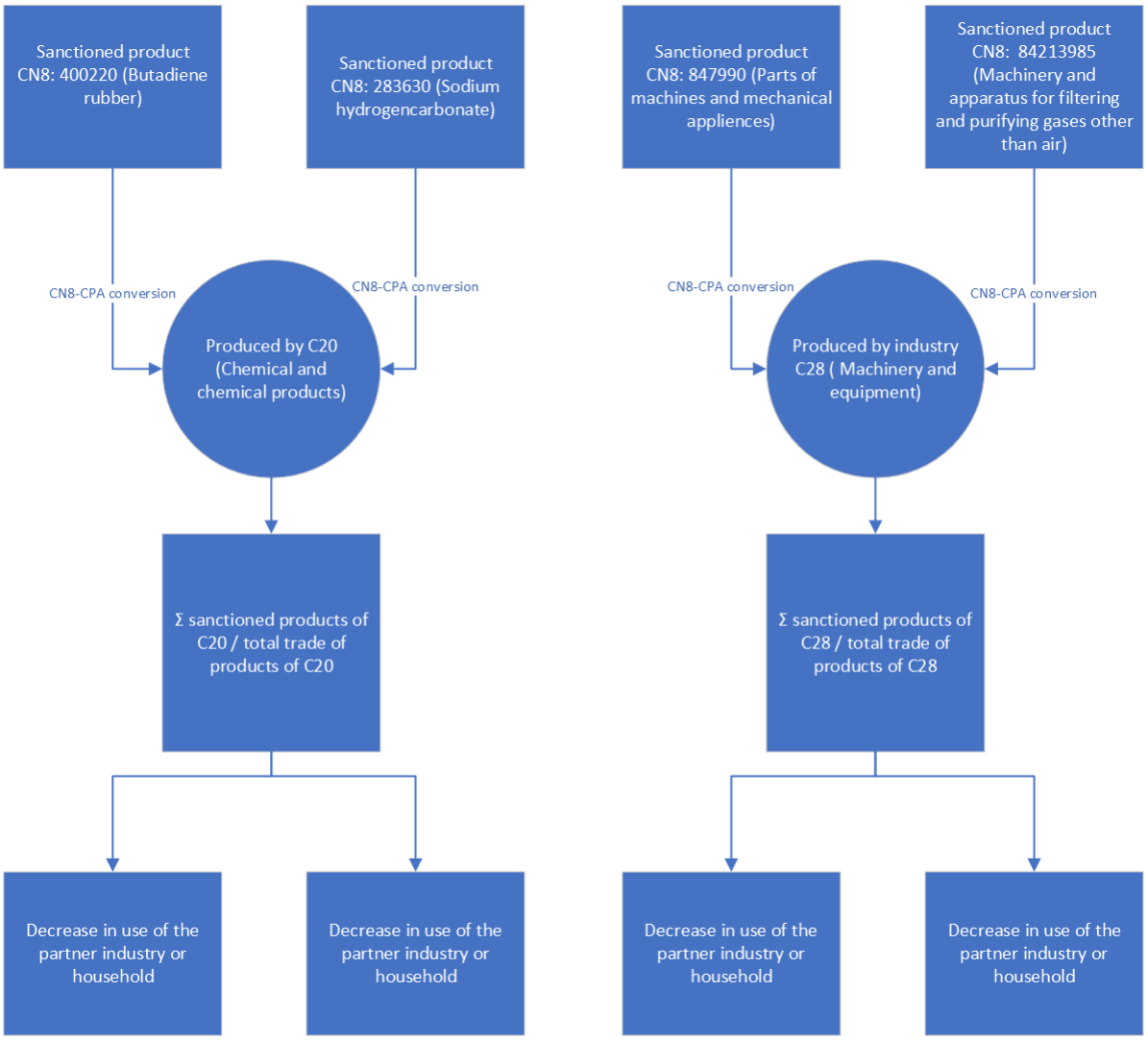
The analysis methodology is based on the observation that the sanctions list contains items based on the CN-HS nomenclature, which items can be matched to the CPA nomenclature (classification of products by activity). In this way, based on each sanction item, it can be clearly established which sector is producing one in the downstream direction. The IO database contains the users of the sectors (both intermediate users and final users), in other words, it can be determined which partner sectors are affected mostly by the sanctions.

Of course, the analysis has limitations. One of these is that, although the supplier and user sectors are known, we do not know the proportion of sanctioned products distributed among users. In this regard, we used the assumption that the sanctioned products represent the same

proportion in all sectors. We also do not know what role the sanctioned products play in production, how important they are in output and consumption. In the absence of certain intermediate products, production cannot be continued at all, but in other cases, it can even be completely abandoned. For example, the EU imposed a complete import ban on Russian caviar, which by definition does not mean a significant reduction in output of its final users. On the other hand, the European Commission ordered a ban on the export of semiconductors to Russia, which could even stop the entire production chain. Since these are not known, we assume that production will fall by the amount of the weight of the sanctioned products in the sector's use.
In this study, we also do not deal with substitutability, or with the fact that producers, violating international trade agreements, evade sanctions via an intermediary.
We also do not take into account the decrease in demand due to price increases (as happened in 2022 and 2023), the model assumes that world prices do not change.

The conversion process is summarized in the following figure.

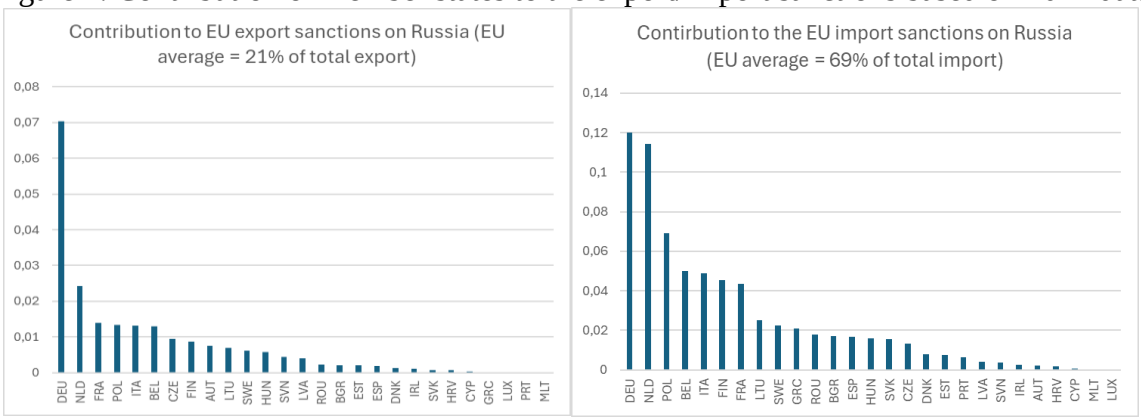
Figure 1: The process of conversion from CN-HS code to CPA



In some cases, the sanctions are not comprehensive, for example, tied to world market prices (oil price caps) or quantitative limits, and a few member states have received temporary exemptions certain cases. We could not calculate with these individual exceptions, so during the research we considered the strictest application of the imposed sanction as a reference.

Our data refer to the year 2021, before the outbreak of the war. Based on this, the European Union sanctions about 21% of the total exports to Russia. On the import side, the ratio is much higher, around 70% of products from Russia are subject to some kind of sanction. In line with the size of the economies, Germany is one of the most affected member states, followed by the Netherlands. The exposure indicator defined by us is intended to express the Gross Value Added (GVA) of certain countries of the war. The methodology is summarised in the appendix.

Figure 2: Contribution of member states to the export/import sanctions based on 2021 data



Source: Eurostat

The estimation is based on the method of partial hypothetical extraction and the detailed mathematical description can be found in the appendix.

Results

The numerical results of the model are given in the following table.

Table 5: Changes in GVA, output and final demand by country

Country	Change in GVA	Change in output	Change in final demand
AUT	-0.1%	-0.2%	-0.1%
BEL	-0.1%	-0.1%	0.0%
BGR	-0.3%	-0.4%	-0.2%
CYP	-0.2%	-0.2%	-0.1%
CZE	-0.2%	-0.3%	-0.2%
DEU	-0.2%	-0.2%	-0.1%
DNK	-0.1%	-0.1%	0.0%
ESP	-0.1%	-0.1%	0.0%
EST	-0.4%	-0.7%	-0.4%
FIN	-0.3%	-0.4%	-0.2%
FRA	-0.1%	-0.1%	0.0%
GRC	-0.1%	-0.1%	0.0%
HRV	-0.1%	-0.1%	-0.1%
HUN	-0.2%	-0.3%	-0.2%
IRL	-0.1%	-0.1%	-0.1%
ITA	-0.1%	-0.1%	-0.1%
LTU	-0.7%	-0.9%	-0.3%
LUX	-0.1%	-0.1%	0.0%
LVA	-0.7%	-0.9%	-0.4%
MLT	-0.1%	-0.1%	-0.1%
NLD	-0.1%	-0.1%	0.0%
POL	-0.1%	-0.2%	-0.1%
PRT	0.0%	-0.1%	0.0%
ROU	-0.1%	-0.1%	0.0%
RUS	**-1.7%**	**-2.2%**	**-0.5%**
SVK	-0.2%	-0.2%	-0.1%
SVN	-0.1%	-0.1%	0.0%
SWE	-0.1%	-0.1%	0.0%

Table 6: Changes in sectorial GVA in Russia and EU member states (top30)

Country	Industry	Change in GVA		Country	Industry	Change in GVA
RUS	Water transport	-15.3%		CYP	Air transport	-20.7%
RUS	Air transport	-11.7%		EST	Air transport	-17.5%
RUS	Chemical and chemical products	-8.9%		LVA	Air transport	-14.8%
RUS	Coke and refined petroleum products	-8.1%		LTU	Air transport	-14.6%
RUS	Basic metals	-7.5%		BGR	Pharmaceuticals, medicinal chemical and botanical products	-10.3%
RUS	Land transport and transport via pipelines	-6.6%		BGR	Air transport	-9.6%
RUS	Mining support service activities	-3.8%		LVA	Pharmaceuticals, medicinal chemical and botanical products	-9.3%
RUS	Warehousing and support activities for transportation	-3.1%		CZE	Air transport	-7.7%
RUS	Paper products and printing	-2.9%		FIN	Air transport	-6.3%
RUS	Water supply; sewerage, waste management and remediation activities	-2.8%		LVA	Electrical equipment	-5.8%
RUS	Other non-metallic mineral products	-2.6%		SVK	Air transport	-5.6%
RUS	Rubber and plastics products	-2.4%		EST	Computer, electronic and optical equipment	-5.2%
RUS	Mining and quarrying, energy producing products	-2.3%		LTU	Land transport and transport via pipelines	-5.2%
RUS	Administrative and support services	-2.2%		CYP	Land transport and transport via pipelines	-5.1%
RUS	Mining and quarrying, non-energy producing products	-2.1%		SVK	Pharmaceuticals, medicinal chemical and botanical products	-4.7%
RUS	Electricity, gas, steam and air conditioning supply	-1.9%		HUN	Pharmaceuticals, medicinal chemical and botanical products	-3.7%
RUS	Manufacturing nec; repair and installation of machinery and equipment	-1.9%		LVA	Land transport and transport via pipelines	-3.7%
RUS	Wood and products of wood and cork	-1.6%		MLT	Pharmaceuticals, medicinal chemical and botanical products	-3.6%
RUS	Other transport equipment	-1.2%		POL	Air transport	-3.4%
RUS	Machinery and equipment, nec	-1.2%		EST	Land transport and transport via pipelines	-3.3%
RUS	Wholesale and retail trade; repair of motor vehicles	-1.1%		ROU	Pharmaceuticals, medicinal chemical and botanical products	-3.0%
RUS	Electrical equipment	-1.0%		FIN	Basic metals	-2.7%
RUS	Financial and insurance activities	-1.0%		LVA	Warehousing and support activities for transportation	-2.6%
RUS	Fabricated metal products	-1.0%		AUT	Air transport	-2.5%
RUS	IT and other information services	-0.7%		SVN	Air transport	-2.3%
RUS	Professional, scientific and technical activities	-0.7%		EST	Basic metals	-2.3%
RUS	Real estate activities	-0.6%		POL	Pharmaceuticals, medicinal chemical and botanical products	-2.2%
RUS	Computer, electronic and optical equipment	-0.6%		LVA	Computer, electronic and optical equipment	-2.2%
RUS	Postal and courier activities	-0.5%		EST	Machinery and equipment, nec	-2.1%
RUS	Construction	-0.4%		LVA	Coke and refined petroleum products	-2.1%

Based on our model, ceteris paribus, the sanctions do not particularly adversely affect the member states of the European Union, since even the largest decline in member states does not reach 1%. In contrast, the Russian economy is falling by almost two percent. These results are not surprising, since the EU's export restrictions cannot be called overly aggressive compared to import restrictions, they affect specific products, and the Russian market is not particularly important for the EU. On the other hand, it was previously seen that the EU is one of the main trade partners for Russia, and the sanctions are significant, so the 2% decrease may even seem low. Nevertheless, European households barely feel the lack of Russian final goods, while the

Russian population is not forced to dramatically reduce its consumption. Both economies have a large internal market where producers are not sanctioned.
At the same time, a significant difference can be observed between the eastern and western member states, within which Lithuania, Latvia and Estonia are the most exposed to the adverse effects of the sanctions, as these countries have a significant Russian market share, which will most likely be lost after the introduction of restrictions.

The sanctions are painful for Russia, as the strong raw material export exposure almost shows the image of a monocultural economy, which lost one of its main partners due to the restrictions. Although some of the trade restrictions can indeed be considered more symbolic, the regulations cover all products that have brought significant revenue to the state budget. Russian aviation is suffering the biggest decline, as it is losing a large part of its passengers, and moreover, they cannot get access to suitable spare parts for their machines. Among the manufacturing sectors, the chemical industry and petroleum refining are the worst performers, both are forced to suffer a drop of 8% each due to the marked drop in European demand, but the metal industry would face a 7.5% contraction.

Summary and conclusions

Our research examines the effects of EU sanctions imposed in response to the war between Russia and Ukraine. The special feature of our analysis is that, based on the itemized list of sanctioned products, we matched the goods to the sectors that produce them, so we can estimate a downstream effect in the value chains stretching between the EU and Russia.

Our results show that the imposed sanctions harm Russia much more than Europe, primarily because trade relations in the Russia-EU relationship are not balanced. In general, it can be said that although Russia has mineral resources through which it almost has a monopoly position in certain bottlenecks, their volume is not sufficient to make the entire European economy dysfunctional. At the same time, the main purpose of the sanctions is not to ruin the Russian economy, but "merely" to hinder the further production of Russian military equipment.

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Mathematical annex

Unit vectors, unit matrices, special summation and aggregation matrices

The unit vector following conventions is arranged in a column with, $\mathbf{i}=\begin{bmatrix}1\\1\\\vdots\\1\end{bmatrix}$, as a row vector it is denoted by $\mathbf{i}'$, $\mathbf{i}'=\begin{bmatrix}1 & 1 & \dots & 1\end{bmatrix}$. The apostrophe is a sign of transpose. Multiplying from the right by the column vector i with the corresponding number of elements can be used to sum a matrix row by row, $\mathbf{i}'$ and multiplying by the row vector from the left, we can sum up a matrix by column, and we get the column or row vector of the former row or column totals.

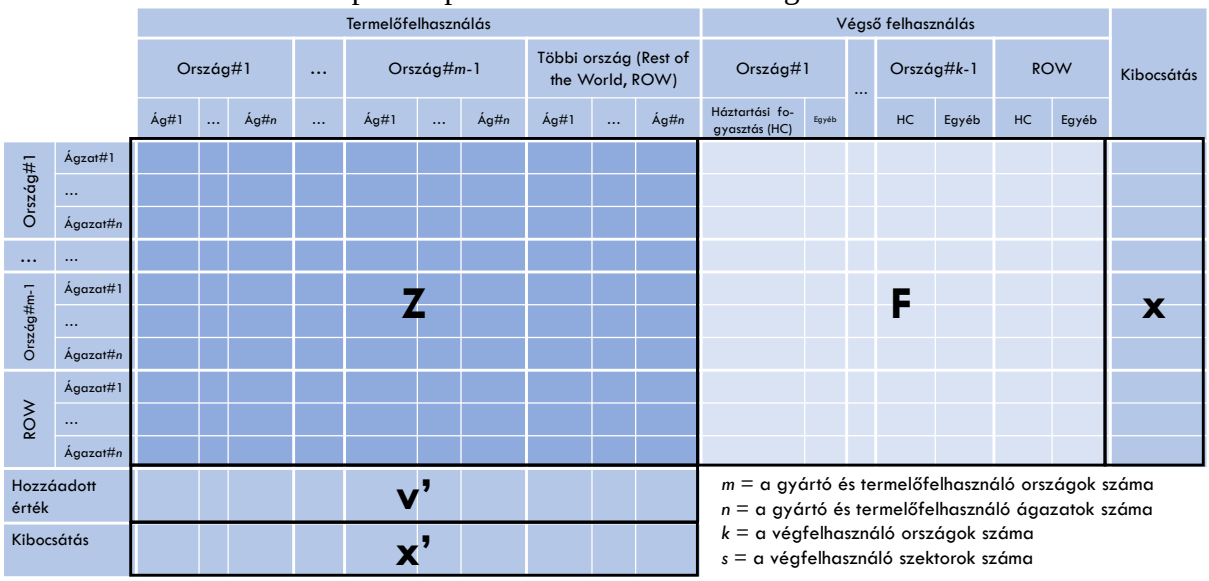
The unit matrix, which contains 1 elements on its main diagonal and 0 elsewhere**,** is denoted by $\mathbf{I}$, $\mathbf{I}=\hat{\mathbf{i}}=\begin{bmatrix}1 & 0 & \dots & 0\\0 & 1 & \dots & 0\\\vdots & \vdots & \ddots & \vdots\\0 & 0 & \dots & 1\end{bmatrix}$, that is, $\mathbf{I}$ is the diagonal matrix of vector i, where the hat is a sign of diagonalization.

To summarize the elements of the world input-output table by country, row or column, we need the $\underset{(mn\times m)}{\mathbf{I}_{cntry}}=\begin{bmatrix}\mathbf{i} & \mathbf{0} & \dots & \mathbf{0}\\\mathbf{0} & \mathbf{i} & \dots & \mathbf{0}\\\vdots & \vdots & \ddots & \vdots\\\mathbf{0} & \mathbf{0} & \dots & \mathbf{i}\end{bmatrix}$, $\underset{(m\times mn)}{\mathbf{I}'_{cntry}}=\begin{bmatrix}\mathbf{i}' & \mathbf{0} & \dots & \mathbf{0}\\\mathbf{0} & \mathbf{i}' & \dots & \mathbf{0}\\\vdots & \vdots & \ddots & \vdots\\\mathbf{0} & \mathbf{0} & \dots & \mathbf{i}'\end{bmatrix}$, and $\underset{(ms\times m)}{\mathbf{I}_{cntry,f}}=\begin{bmatrix}\mathbf{i}_f & \mathbf{0} & \dots & \mathbf{0}\\\mathbf{0} & \mathbf{i}_f & \dots & \mathbf{0}\\\vdots & \vdots & \ddots & \vdots\\\mathbf{0} & \mathbf{0} & \dots & \mathbf{i}_f\end{bmatrix}$ block matrices, where $\mathbf{i}$ $n\times 1$, $\mathbf{i}'$ $1\times n$, $\mathbf{i}_f$ $s\times 1$, $\mathbf{I}_{cntry}$ $mn\times m$, $\mathbf{I}'_{cntry}$ $m\times mn$, $\mathbf{I}_{cntry,f}$ is $ms\times m$ sized, m countries distinguished in the world input-output table, n denotes the number of sectors *and* the number of end-user sectors.

For columnar summation by sector $n\times mn$, $\underset{n\times mn}{\mathbf{I}_{ind}}=\begin{bmatrix}\mathbf{I} & \mathbf{I} & \dots & \mathbf{I}\end{bmatrix}=\begin{bmatrix}1 & 0 & \dots & 0 & 1 & 0 & \dots & 0 & \dots & 1 & 0 & \dots & 0\\0 & 1 & \dots & 0 & 0 & 1 & \dots & 0 & \dots & 0 & 1 & \dots & 0\\\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots\\0 & 0 & \dots & 1 & 0 & 0 & \dots & 1 & \dots & 0 & 0 & \dots & 1\end{bmatrix}$ A special block matrix can be used.

World input-output table segments and coefficients

The schema of the world input-output table is shown in the figure below.



The interregional flow of intermediate goods (intra-industrial transactions) has a bloc matrix $\underset{(mn\times mn)}{\mathbf{Z}}=\begin{bmatrix}\mathbf{Z}^{11} & \mathbf{Z}^{12} & \dots & \mathbf{Z}^{1m}\\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \dots & \mathbf{Z}^{2m}\\ \vdots & \vdots & \ddots & \vdots\\ \mathbf{Z}^{m1} & \mathbf{Z}^{m2} & \dots & \mathbf{Z}^{mm}\end{bmatrix}$, where i_c (tow-) and j_c (column)country ($i_c, j_c = 1,2,\dots,m$) is the transaction block matrix $\underset{(n\times n)}{\mathbf{Z}^{i_c,j_c}}=\begin{bmatrix}z_{11}^{i_cj_c} & z_{12}^{i_cj_c} & \dots & z_{1n}^{i_cj_c}\\ z_{21}^{i_cj_c} & z_{22}^{i_cj_c} & \dots & z_{2n}^{i_cj_c}\\ \vdots & \vdots & \ddots & \vdots\\ z_{n1}^{i_cj_c} & z_{n2}^{i_cj_c} & \dots & z_{nn}^{i_cj_c}\end{bmatrix}$. The symmetrical Z matrix (so called global inside square) show the flow of intermediate goods from i_c (row)country i_i (row)industry to j_c (column)country j_i (column)industry, $\mathbf{Z}=\left[z_{i_ij_i}^{i_cj_c}\right]$, $i_i, j_i = 1,2,\dots,n$.

Matrix F has a similar structure, however its size is different. It contains flow of final goods from producers to final users:

$$\underset{(mn\times ks)}{\mathbf{F}}=\begin{bmatrix}\mathbf{F}^{11} & \mathbf{F}^{12} & \dots & \mathbf{F}^{1k}\\ \mathbf{F}^{21} & \mathbf{F}^{22} & \dots & \mathbf{F}^{2k}\\ \vdots & \vdots & \ddots & \vdots\\ \mathbf{F}^{m1} & \mathbf{F}^{m2} & \dots & \mathbf{F}^{mk}\end{bmatrix},\ \underset{(n\times s)}{\mathbf{F}^{i_c,j_c}}=\begin{bmatrix}f_{11}^{i_cj_c} & f_{12}^{i_cj_c} & \dots & f_{1s}^{i_cj_c}\\ f_{21}^{i_cj_c} & f_{22}^{i_cj_c} & \dots & f_{2s}^{i_cj_c}\\ \vdots & \vdots & \ddots & \vdots\\ f_{n1}^{i_cj_c} & f_{n2}^{i_cj_c} & \dots & f_{ns}^{i_cj_c}\end{bmatrix},\ i_c = 1,2,\dots,m,\ j_c = 1,2,\dots,k$$

$\mathbf{F}=\left[f_{i_ij_i}^{i_cj_c}\right]$, $i_i = 1,2,\dots,n$, $j_s = 1,2,\dots,s$, where k the number of final users.

Value-added are denoted by (v), below that total output can be found. It structure and notation is the following:

$$\underset{(1\times mn)}{\mathbf{v}'}=\begin{bmatrix}\mathbf{v}^1 & \mathbf{v}^2 & \dots & \mathbf{v}^m\end{bmatrix},\ \underset{(1\times n)}{\mathbf{v}'^{j_c}}=\begin{bmatrix}v_1^{j_c} & v_2^{j_c} & \dots & v_n^{j_c}\end{bmatrix},\ \underset{(1\times mn)}{\mathbf{v}'}=\begin{bmatrix}v_{j_i}^{j_c}\end{bmatrix},\text{ and}$$

$$\underset{(1\times mn)}{\mathbf{x}'}=\begin{bmatrix}\mathbf{x}^1 & \mathbf{x}^2 & \dots & \mathbf{x}^m\end{bmatrix},\ \underset{(1\times n)}{\mathbf{x}'^{j_c}}=\begin{bmatrix}x_1^{j_c} & x_2^{j_c} & \dots & x_n^{j_c}\end{bmatrix},\ \underset{(1\times mn)}{\mathbf{x}'}=\begin{bmatrix}x_{j_i}^{j_c}\end{bmatrix}.$$

Outputs are also represented on the right side of the table as a column vector.

Value added by countries is $\mathbf{v}'_{cntry} = \mathbf{v}'\mathbf{I}_{cntry}$, the final demand by countries is $\mathbf{f}'_{cntry} = \mathbf{i}'\mathbf{F}\mathbf{I}_{cntry,f}$.

Value added shares are denoted by $\mathbf{v}'_c$, $\mathbf{v}'_c = \mathbf{v}'\langle\mathbf{x}\rangle^{-1}$. Matrix of intermediate consumption from the same industries, irrespective of country of origin (summed up worldwide by supplying industry) $\underset{(nxmn)}{\mathbf{Z}^{\square}} = \mathbf{I}_{ind}\mathbf{Z} = \left[z_{i_i j_i}^{\square j_c} \right]$, technical/technological coefficients are $\underset{(nxmn)}{\mathbf{A}^{\square}} = \mathbf{Z}^{\square}\langle\mathbf{x}\rangle^{-1} = \left[a_{i_i j_i}^{\square j_c} \right]$, $a_{i_i j_i}^{\square j_c} = z_{i_i j_i}^{\square j_c} / x_{j_i}^{j_c}$. Based on the Leontief production function, outputs from the country sectors included in each column $x_{j_i}^{j_c} = \min_{i_i=1}^{n} z_{i_i j_i}^{\square j_c} / a_{i_i j_i}^{\square j_c}$.

Measuring the impact of sanctions on the economy

The estimation of sanction impact is based on the partial hypothetical extraction method in which $z_{\cdot m}$ row elements of **Z** and $f_{\cdot k}$ row elements of **F** are decreased by $r_{\%}^{z} = \frac{z_{\cdot m}^{s}}{\sum_{i=1}^{n} z_{im}} \times 100$ where $z_{\cdot m}^{s}$ denotes the value of sanctioned intermediate use in partner industry *m* and by $r_{\%}^{f} = \frac{f_{\cdot m}^{s}}{\sum_{i=1}^{n} f_{im}} \times 100$ where $f_{\cdot m}^{s}$ is the value of final use of sanctioned products. The matrices containing the reduced use values are denoted respectively by $\mathbf{Z^s}$ and $\mathbf{F^s}$.

Both export and import sanctions are implemented to gauge the total impact. The estimation relies on the identity of $\bar{\mathbf{x}}_{(j)} = \left(\mathbf{I} - \bar{\mathbf{A}}_{(j)}\right)^{-1}\bar{\mathbf{f}}_{(j)}$, where $\bar{\mathbf{a}}_{\cdot(j)} = \mathbf{r}_{\%j}^{z}\boldsymbol{a}_{\cdot j}$ and $\bar{\mathbf{f}}_{\cdot(j)} = \mathbf{r}_{\%j}^{f}\mathbf{f}_{\cdot j}$ are the corresponding reduced technological coefficients and final use elements. The total impact can be calculated by $\mathbf{i}'\bar{\mathbf{x}}_{(j)}/\mathbf{i}'\mathbf{x}$. Change in value-added can be calculated by $\mathbf{i}'\bar{\mathbf{x}}_{(j)}\mathbf{v}'_c/\mathbf{i}'\mathbf{x}\mathbf{v}'_c$ (assuming constant value-added shares).