GRIPS Discussion Paper 22-06

Quantifying the Impacts of Sanctions Following Russia's Invasion of Ukraine

By

Nobuhiro Hosoe

May 2022

National Graduate Institute for Policy Studies
7-22-1 Roppongi, Minato-ku,
Tokyo, Japan 106-8677

Quantifying the Impacts of Sanctions Following Russia's Invasion of Ukraine*

May 1, 2022

Nobuhiro Hosoe†

Abstract

We use a computable general equilibrium model of world trade to quantify the possible impact of economic sanctions imposed by the Western and other countries in response to Russia's invasion of Ukraine. If senders chose 100% import tariffs and export taxes on trade with Russia, Russia's GDP would decline by 3–7% due to a significant reduction in exports. By contrast, the GDP loss for those countries would be the largest for Europe but only about 0.2%, and 0.05% for Japan. The effect of China's participation in the sanctions is more significant than that of India. There are concerns about food and energy crises due to economic sanctions against Russia, but food supplies would not be a serious problem for either senders or third parties. The impact on energy supplies would affect all senders to some extent, for example with a reduction of energy consumption by 3% in and a rise in electricity and town gas prices by 3–4% in Japan.

Keywords: Russian invasion; Ukraine; economic sanctions; energy security; food security; simulation

* The author gratefully acknowledges that this research was supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (No. 19K01622).
† National Graduate Institute for Policy Studies, 7-22-1 Roppongi, Minato, Tokyo 106-8677, Japan. E-mail: nhosoe@grips.ac.jp.

1. Introduction

In response to Russia's invasion of Ukraine, which began in February 2022, countries—especially those in Europe plus the United States—demanded an immediate halt to the military invasion. Although military intervention is often taken as a countermeasure to such military aggression, it is difficult to intervene against Russia, a nuclear power, considering the possibility that it could trigger another world war. In addition, as a permanent member of the United Nations Security Council, Russia makes the United Nations dysfunctional in managing the Russia–Ukraine war. Instead, the United States, Europe, and Japan have taken the lead in imposing economic sanctions. The main measures were to block Russia's fuel exports (natural gas, oil, and coal) to prevent it from earning foreign currency, and to restrict imports to impede domestic economic activity. The decision was also made to block access to financial markets and freeze the foreign currency and gold reserves of government agencies and the personal assets of key government and business officials.

As the Russian veto has crippled the Security Council, it cannot to impose the same economic sanctions on Russia that it has imposed on Iran and North Korea. The UN General Assembly passed the withdrawal resolution by a majority vote. While it is not surprising that Russia and five other countries, including Belarus and North Korea, opposed the vote, the fact that 35 countries, including China and India, abstained shows that there are many countries in the world whose attitudes toward Russia differ significantly from those of the Western countries. In fact, those imposing economic sanctions are mainly the Western countries plus Japan. The "list of unfriendly countries" designated by Russia (dated March 5, 2022) indicates that only 48 countries and regions are participating in some form of sanctions.

In assessing the impacts of economic sanctions against Russia, we have not yet established common assumptions and analytical frameworks, because the full scope of the sanctions—sanction measures and countries involved—is still in flux, and the military invasion operation is still ongoing. With a similar motivation to ours, Kumagai et al. (2022) use a

computable general equilibrium (CGE) model that incorporates economies of agglomeration, à la Krugman (1991), and simulate prohibitively high transportation costs at the Russian border as an economic sanction. The results show that Russia's GDP would decline by 15.8% if logistics at all Russian borders were impeded and by 4.6% if logistics were affected at all Russian borders except that with China. The authors report that these logistical impediments would impact Japan with a 1.7% decline in automobiles and a 2% decline in production in the textile, clothing, and food processing sectors, while Japan's GDP would decline by only 0.1%. Chepeliev et al. (2022) use a world trade dynamic CGE model based on the Global Trade Analysis Project (GTAP) 10 Power Database (Chepeliev, 2020), to simulate that if the European Union (EU) and other high-income countries were to restrict fossil fuel imports from Russia (natural gas, oil, coal, and petroleum products), this would reduce the imports by half in the short run and by 70–90% in the long run. This would reduce Russia's annual real income by about 4–8%, while the EU's loss would be limited to about 0.04% per year.

Economic sanctions were imposed on Russia after the invasion of Ukraine and the annexation of the Crimean Peninsula in 2014. The sanctions targeted specific sectors (especially oil), companies, and individuals, rather than trade in general. Ahn and Ludema (2020) measure the impacts of these sanctions using firm- and individual-level data. Financial sanctions isolated Russia from global financial markets (Nivorozhkin and Castagneto-Gissey, 2016). However, impacts of the sanctions were not as large as that of oil price fluctuations observed in the same period (Dreger et al., 2016). If sanctions were imposed on a broader range of trade, Russia would not be able to sustain its business activities with only natural resource exports; firm exit would be accelerated by declining trade (Iwasaki et al., 2016).

Iran provides a similar case, with sanctions on exports of fossil fuels to deter it from developing nuclear weapons. Gharibnavaz and Waschik (2018) use a world trade CGE model to simulate economic sanctions, focusing on Iran's oil exports and imports of investment goods for oil production, which reduced Iran's oil exports to the senders by one fourth. They show that

while these strong sanctions would have significant negative impacts on Iran's welfare, the welfare losses suffered by the senders would be quite small: at most 1% of Iran's loss. Although a reduction of Iranian oil supply was anticipated to increase international oil prices, extra supply by other countries offset this impact (Farzanegan and Raeisian Parvari, 2014). Felbermayr et al. (2020) use a structural gravity model to show that impacts of the sanctions against Iran varied widely among senders and across sectors in each country. Russia is a large supplier of natural gas to Europe and Japan (17% global share in 2020; BP, 2021) and is also a major supplier of crude oil (12%) and coal (5%). Particularly, as Europe depends on Russia for one third of its natural gas supply, the supply disruption of Russian fossil fuels would have a far greater impact on energy markets than that of sanctions on Iranian oil, whose share of global crude oil production is only 4%. In fact, at the time of the invasion of Ukraine, Germany—heavily dependent on Russia for natural gas supplies—had to take a very negative attitude toward sanctions against Russia and support for Ukraine due to gas supply concerns.

As well as the disruption of fossil fuel supplies from Russia, food supply is also at stake globally (Dalheimer et al., 2021).[1] This is a problem crucial for countries, especially low-income countries in Africa, which are reluctant to confront Russia with economic sanctions. Therefore, analyses of sanctions on Russia need to address the problem of food security, and especially wheat supply. Because Ukraine, a breadbasket country, has been damaged by the war, food supplies from Russia have a larger significance. As Kumagai et al. (2022) carefully consider, China's participation would be crucial for the success of sanctions. No matter how strict the sanctions imposed are, loopholes in sanctions against Russia would undermine their effectiveness and increase burdens on those affected by them. Belarus is likely to engage in reexports for Russia to evade sanctions. How effective would the sanctions be, with and without China and India? How

[1] In addition to agricultural products, Russia's presence in developing countries is significant in terms of weapons supply. However, the arms trade will be omitted here.

much collateral damage would be imposed on third parties, such as African developing countries? How much damage would they have to incur in participating in the sanctions?

Economic sanctions can be seen as a reversal of economic integration, if we focus on the trade aspect, such as Brexit (Dhingra et al., 2017; Hosoe, 2018; Ortiz Valverde & Latorre, 2020) and the United States (US)–Mexico–Canada Agreement (Burfisher et al., 2019; Hosoe, 2022; United States International Trade Commission, 2019) . Brexit is self-sanctioning by the United Kingdom (UK), allowing the EU 27 to impose higher tariffs and other trade barriers in exchange for the UK's economic sovereignty. Export controls share the same political goals to prevent and/or stop warfare with economic sanctions and can be analyzed with similar approaches (Hosoe, 2020; Shin and Balistreri, 2022).

While the political science literature judges whether sanctions are effective by changes in the target country's behavior, the economics literature judges whether they cause damage (Felbermayr et al., 2021). In this study, setting aside whether economic sanctions would effectively force Russia to give up its military invasion, we examine whether and how much the economic sanctions could damage the Russian economy and how much the impact would be enhanced with the addition of two major economic powers, China and India, which have not yet participated (as of April 2022). Countries imposing sanctions cannot avoid incurring losses. We examine the impacts on the world economy and the Japanese economy.

To these ends, we use a static world trade CGE model, as shown in Section 2, and assume (1) that the senders impose 100% export taxes and import duties on Russia and additionally Belarus, and (2) that the war halves the endowments of primary factors in Ukraine. We examine changes caused by these shocks in various macro and micro economic variables. That is, we measure changes in bilateral trade, fossil fuel trade, sectoral production, and macroeconomy indicators of GDP and welfare (i.e., household consumption). Section 3 shows that Russia's GDP would decrease by about 3–7% due to the significant decline of exports. The more countries participate in the sanctions, the more losses Russia would incur. China's

participation is more important than India's. For senders, GDP losses would be 0.2% in Europe and 0.05% in Japan. Similar results are obtained when household consumption is used as a welfare indicator instead of GDP. The senders' GDP loss to achieve a 1-USD loss of GDP for Russia would be about 0.6 USD if the Western countries, Japan, India, and China participated in the sanctions. If the entire world participated, Russia's losses would be the largest among the six cases we consider. However, the efficiency of sanctions would deteriorate considerably; the senders' loss would increase to 0.9 USD for a 1-USD loss of GDP for Russia. Sanctions against Russia and destructions of the Ukrainian economy are expected to cause food and energy crises. We find that while food supplies would be little affected even in developing countries, energy supplies would be negatively affected to some extent. Japan's energy consumption would decrease by about 3% and raise electricity and town gas prices by 3–4%. Japan's domestic production in the energy and food sectors would be adversely affected, while manufacturing would expand slightly. After presenting the above, Section 4 provides a summary and future issues.

2. World Trade CGE Model

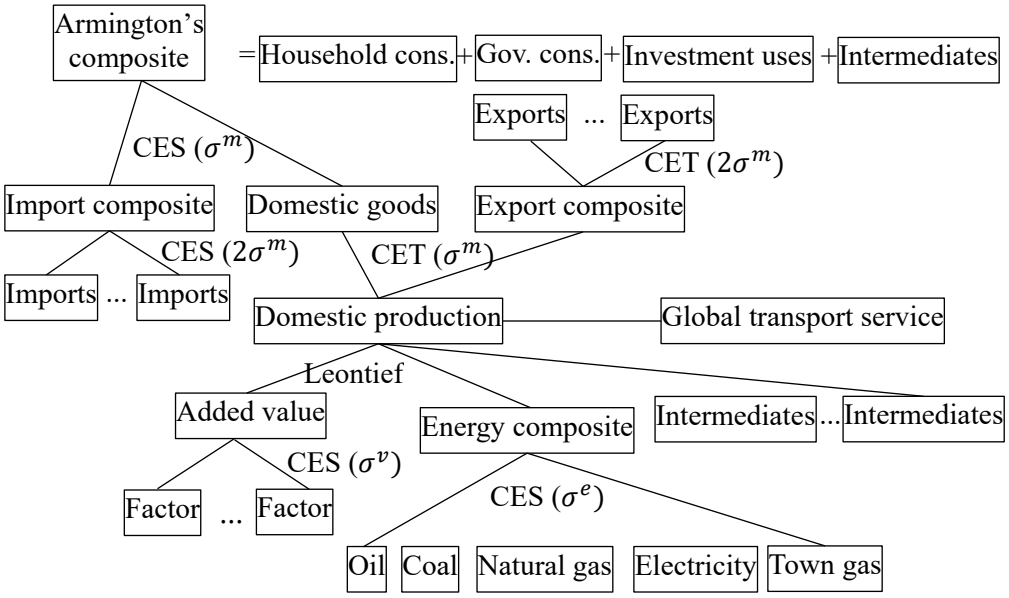
2.1 Basic Structure of the Model

We develop a static world trade CGE model based on the standard model by Hosoe et al. (2010). Starting from the bottom of Figure 1, value added is produced from various primary factors with a constant elasticity of substitution (CES) production function. Value added and various intermediate inputs (including energy composites, explained later) are combined to produce domestic output with a Leontief-type production function, as assumed in input–output models. Domestic production is allocated to domestic goods and export composites with a constant elasticity of transformation production function.[2] Export composites are further

[2] If this sector is the transportation sector, it exports ordinal service and supply to a global transport service sector. The latter is combined with other countries' exports in a Cobb–Douglas

disaggregated into exports to individual countries/regions in a similar manner. Symmetrically, imports from individual countries/regions are aggregated with a CES production function to produce import composites, which are then combined with domestic goods to produce Armington's (1969) composite goods. Armington's composite goods are used for household consumption, government consumption, investment demand, and intermediate inputs.

Figure 1: Production Structure



Note: CES/CET stands for constant elasticity of substitution/transformation.

Our model distinguishes 14 sectors and goods (Table 1)[3]. Three of these are agri-food products; five types of energy goods are distinguished. We extend the standard model to describe substitution among these goods separately for detailed analysis of food and energy issues (Figure 1). If a household consumption good comprises agri-food or energy goods, they are first

production function to supply global transport services, which are required for shipping of various goods and services. For more details, see Hertel (1997) .

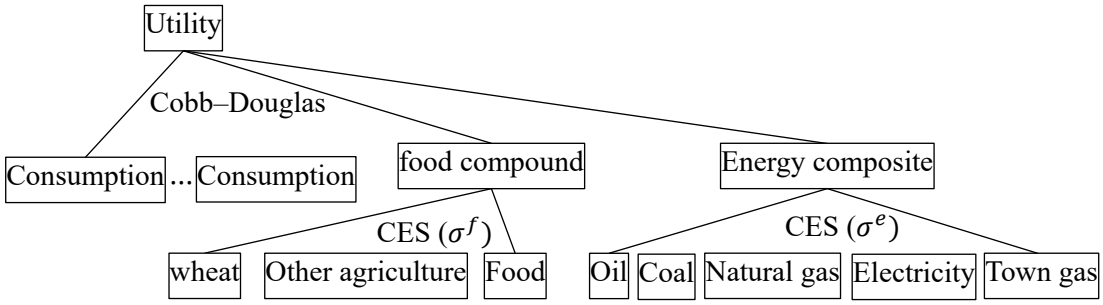
[3] See the Appendix for details of sectoral and regional aggregation.

aggregated into food composite goods or energy composite goods using a CES production function (Figure 2) and then placed in the household utility function. The other consumption goods are immediately placed in the household utility function. For this utility function, we assume a Cobb–Douglas function. For intermediate inputs of energy goods, we consider a similar energy composite (Figure 1).

Table 1: Sectoral Aggregation and Goods used for Food Composites and Energy Composites

	Food composite	Energy composite
Wheat	X	
Other agriculture	X	
Coal		X
Oil		X
Natural gas		X
Other mining		
Food	X	
Petroleum and coal products		
Light manufacturing		
Heavy manufacturing		
Electricity		X
Town gas		X
Transportation		
Other services		

Figure 2: Household Utility Function



Five types of primary factors are considered: land, capital, natural resources, skilled labor, and unskilled labor; the first three are not mobile across sectors. None of the factors are internationally mobile. The government earns revenues from direct taxes, production taxes, factor

input taxes, import duties, and export taxes. Indirect taxes are all ad valorem taxes. The revenue is proportionately allocated among consumption of goods and savings. Household and government savings plus foreign savings (i.e., current account deficits) are used to finance domestic investment. Demand for investment goods for each good is assumed to be determined proportionally. Foreign savings is fixed in US dollar terms.[4] We distinguish 14 countries and regions in the world economy (Table 2). All markets are assumed to be perfectly competitive, and general equilibrium is achieved by flexible adjustment of prices in each market.

Table 2: Regional Aggregation and Sender and Target Countries in Simulation Scenarios

	Scenario					
Country/Region	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Japan	X	X	X	X	X	X
North America (including Mexico)	X	X	X	X	X	X
Europe (EU, UK, EFTA)	X	X	X	X	X	X
Oceania	X	X	X	X	X	X
Russia	Y	Y	Y	Y	Y	Y
Belarus					Y	Y
Ukraine						X
China (including Hong Kong)			X	X	X	X
India		X		X	X	X
Other Asia						X
Middle East and North Africa						X
Sub-Saharan Africa						X
South America						X
Rest of the world (Central Asia, Former Soviet Union)						X

X: sender, Y: target. EFTA: European Free Trade Association.

[4] In a static model where the "next period" never arrives, foreign savings (current account deficits) become debt that does not need to be repaid, i.e., transfers from abroad (Hosoe et al., 2010). Thus, changes in foreign savings directly impact welfare, making fair evaluation difficult.

We calibrate the model to the GTAP Database version 11 (prerelease 2), whose base year is 2017. Armington's (1969) elasticity of substitution σ^m and the elasticity of substitution between factors of production σ^v are obtained from the GTAP Database. The elasticities of substitution in the food composite production function σ^f and the energy composite production function σ^e are assumed to be 1.1 and 0.5, respectively, due to the lack of reliable elasticity estimates globally. Sensitivity analysis is conducted to verify the robustness of our simulation results by alternatively assuming 30% larger or smaller values for these elasticities.

We choose land service used in the other agriculture sector as our numeraire; this is an effective reference for measuring relative prices. Because the model is homogeneous of degree zero in prices, we can freely choose a numeraire without affecting the solution in quantity while expressing prices relative to the chosen numeraire price. When we alternatively use unskilled or skilled labor as a numeraire, the changes in agri-food and energy prices are only 0.3–0.4 percentage points higher in Scenarios 1–5 and 0.2–0.3 percentage points lower in Scenario 6.

2.2 Simulation Scenarios

We prepare six scenarios, made with three types of shock: (1) 100% import and export tariffs, (2) on trade with target countries (Russia and Belarus), and (3) destruction of the Ukrainian economy (Table 2). (1) As for the membership of the senders, Scenario 1 includes only the Western countries (North America, Europe, and Oceania) and Japan. Scenario 2 adds India to this list, and Scenario 3 adds China instead. Scenarios 4 and 5 add both India and China. In Scenario 6, all countries except the targets, Russia and Belarus, participate. (2) In Scenarios 1–4, Russia is the target; in Scenarios 5–6, Belarus is added. In all scenarios, (3) Ukraine's primary factors (land, capital, natural resources, skilled and unskilled labor) are assumed to be uniformly reduced by half.

As the situation is ongoing and fluid, we consider the simplistic scenario factors to grasp the overall changes expected in the global economy and perhaps the largest economic losses that

would be achieved through trade restrictions, while actual sanctions may occur in various forms and magnitude and differ by sector and country. In fact, restrictions have been imposed on Russia's fossil fuel exports, and the G7 trade ministers confirmed sanction policies to restrict their exports of luxury goods on top of high-tech products and machine tools with potential military applications (Takahara, 2022). However, there are several hurdles with regard to Japan's fossil fuel trade. The Sakhalin natural gas development project will not be abandoned (Nikkei Asia, 2022). Japan is dependent on Russia for only 15% of coal supply, but nearly half of the coal used for cement production is imported from Russia. While trade bans and quotas rather than tariffs and taxes are presupposed in planning such sanctions, both have the same effect. In our simulation experiments, we focus on the effects of sanctions through trade restrictions with import tariffs and export taxes, while ignoring effects of other measures, such as asset freezing, sanctions through financial markets, and entry restrictions on key government officials and business executives.

3. Simulation Results

3.1 Impacts on Russia's Trade

In Scenario 1, sanctions by the smallest sender group would reduce Russia's imports and exports by 115 billion USD (37% of the baseline value) and 52 billion USD (16%), respectively (Table 3).[5] The reason for the larger decline in imports than in exports can be attributed to the deterioration in the terms of trade (i.e., depreciation of the Russian ruble). Export taxes and import tariffs imposed by senders raise import prices and lower export prices for Russia, respectively. Fossil fuel exports account for 7% of the total decrease in exports of the three types of fuel. Coal and oil exports would decrease significantly. Natural gas exports would decrease in a much smaller magnitude because Russian natural gas is exported mostly to continental Europe and Asia by pipeline, and to Japan in the form of liquefied natural gas. The result does not support the concern that sanctions by the Western countries and Japan alone cannot effectively harm Russian gas exports but only have its destinations shifted to third parties.

Table 3: Impacts on Russia's Trade [Unit: changes from the baseline equilibrium, mill. USD].

	Scenario					
	1 (West + Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Imports	−114,930	−119,588	−151,913	−157,386	−155,830	−245,252
Exports	−52,376	−54,581	−67,082	−69,211	−68,059	−83,462
Coal	*−1,801*	*−1,904*	*−3,190*	*−3,341*	*−3,346*	*−5,064*
Oil	*−1,395*	*−1,591*	*−8,827*	*−9,298*	*−9,802*	*−6,241*
Natural gas	*−554*	*−521*	*−735*	*−699*	*−694*	*−3,186*
Subtotal of fossil fuel exports	−3,750	−4,016	−12,752	−13,338	−13,842	−14,491
Fossil fuel contribution [%]	7.2	7.4	19.0	19.3	20.3	17.4

Note: Aggregated with Laspeyres prices. Excluding import tariffs, export taxes, and global transport services.

[5] Bilateral trade between Russia and senders would be reduced by 74–93% for Russian imports and 17–84% for Russian exports through the sanctions. See the Appendix for details.

With the addition of more senders, particularly India and China, the coalition would increase the impact of the sanctions. If India participated (Scenario 2), Russia's trade would be further reduced by about 4%. Alternatively, if China joined (Scenario 3), Russia's trade would be impeded by 30% more than in Scenario 1. Fossil fuel trade with China, which represents a huge volume in the status quo, would fall sharply. This increases the contribution of the decline in fossil fuels for export to 19%. China's participation has more impact than that of India partly because China's GDP is five times that of India and partly because China's import tariffs are lower initially and thus raised more sharply to 100%.[6] Their impacts would be combined in Scenario 4.

As Russia may trade through Belarus to avoid sanctions, Belarus is also assumed to be subject to sanctions (Scenario 5). Contrary to our concern, Russia's trade volume would remain virtually unchanged. If all countries and regions except Russia and Belarus were to join the sanctions (Scenario 6), the impact would increase significantly. Compared to the trade impact in Scenario 1, the reduction would double in total imports and increase by 60% in total exports. Notably, the reduction in fossil fuel exports would nearly triple. Compared to the baseline equilibrium, exports and imports are then reduced by 25% and 79%, respectively.

3.2 Impact on Sectoral Production

Sanctions would adversely affect the coal, oil, and petroleum and coal products sectors in Russia as well as food and other services sectors, which are mainly for domestic consumption (Table 4). The light and heavy manufacturing sectors would increase production by mobilizing labor from these declining sectors. This is the opposite of the Dutch disease. Comparing the results

[6] According to the GTAP 11 database, China set import tariffs of about 6% on imports from Russia, while India sets higher rates of 8–55%. By contrast, as China set higher export tax rates but most on fossil fuel exports, export tax hikes would not have much impact on Russia.

of the six scenarios, we find that the participation of China would crucially affect changes in sectoral output. If China joined the sanctions, Russia would decrease coal and oil exports for China and shift their sales destination to domestic users to increase production of petroleum and coal products. The disruption of Chinese exports would allow Russian domestic producers to increase light and heavy manufacturing goods markedly.

Table 4: Impacts on Domestic Production in Russia [Unit: changes from the baseline equilibrium, %].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Wheat	3.4	3.4	3.8	3.9	3.8	−1.6
Other agriculture	0.7	0.8	0.3	0.4	0.3	3.8
Coal	−3.1	−3.3	−5.8	−6.2	−6.2	−10.9
Oil	−0.2	−0.2	−0.5	−0.6	−0.6	−0.5
Natural gas	0.2	0.2	0.4	0.4	0.4	−0.2
Other mining	1.5	0.9	2.4	2.0	2.0	6.0
Food	−0.7	−0.7	−2.2	−2.2	−2.3	−4.5
Petroleum and coal products	−5.3	−5.2	0.1	0.5	0.9	4.0
Light manufacturing	7.2	7.2	15.0	15.3	15.1	28.8
Heavy manufacturing	9.6	9.8	15.7	16.1	16.2	22.1
Electricity	0.5	0.5	1.4	1.5	1.4	3.2
Town gas	−9.5	−9.5	−8.7	−8.7	−8.3	−2.4
Transportation	0.3	0.3	0.2	0.2	0.2	4.7
Other services	−1.3	−1.3	−2.3	−2.4	−2.4	−4.4

It is noteworthy in Scenario 6 that wheat production by Russia would be negative only when it faces global sanctions. In other words, even if the Western countries, Japan, India, and China reduced wheat imports from Russia, as assumed in Scenarios 1–5, wheat production would be encouraged by 3–4% to earn hard currency by exporting wheat to third parties.

The sanctions against Russia would mainly affect Japan's industrial exports and material imports. Japan's domestic production would increase slightly in the wheat, coal, and petroleum sectors, facing less competition with imports (Table 5). However, their increase has little significance because their domestic production is negligible in Japan. Food, oil and coal products,

electricity, and town gas sectors depend on imports of fossil fuels and raw materials and thus would be negatively affected. Light and heavy manufacturing sectors, less affected by the sanctions, would increase production slightly. Overall, the impact on domestic production would be very moderate and little affected by the scale of the sanctions.

Table 5: Impacts on Domestic Production in Japan [Unit: changes from the baseline equilibrium, %].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Wheat	1.1	1.1	1.2	1.2	1.2	1.3
Other agriculture	0.0	0.0	0.0	0.0	0.0	0.0
Coal	0.3	0.3	0.4	0.4	0.4	0.3
Oil	0.3	0.3	0.4	0.4	0.4	0.2
Natural gas	0.3	0.3	0.4	0.3	0.4	0.6
Other mining	0.5	0.6	0.6	0.7	0.7	0.5
Food	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
Petroleum and coal products	−1.7	−1.7	−2.2	−2.3	−2.3	−0.9
Light manufacturing	0.2	0.2	0.2	0.2	0.2	−0.1
Heavy manufacturing	0.2	0.2	0.2	0.2	0.2	0.1
Electricity	−0.2	−0.1	−0.2	−0.2	−0.2	−0.5
Town gas	−1.5	−1.6	−2.1	−2.1	−2.2	−1.9
Transportation	−0.1	−0.1	−0.2	−0.2	−0.2	−0.4
Other services	0.0	0.0	0.0	0.0	0.0	0.0

3.3 Macroeconomic Impacts

Sanctions only by Western countries and Japan (Scenario 1) would reduce Russia's GDP by 3.2%. If China and India joined (Scenario 4), Russia's GDP loss would reach 4.5% (Table 6). Sanctions against Belarus (Scenario 5) would have little impact on trade and GDP of Russia, but would, of course, result in significant, even greater losses for Belarus than for Russia. If the sanctions were imposed worldwide, Russia's GDP loss would exceed 7%. Note that the devastating loss of Ukraine, halving its GDP, is almost immediately brought about by the assumption that the war halves factor endowments.

Table 6: GDP Impacts [Unit: changes from the baseline equilibrium, %].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.03**
Russia	−3.24	−3.35	−4.41	−4.53	−4.54	−7.40
Belarus	−0.48	−0.51	−0.94	−1.01	−5.01	−9.82
Ukraine	−50.97	−50.98	−51.14	−51.16	−51.18	**−51.12**
China	−0.02	−0.02	**−0.06**	**−0.06**	**−0.06**	**−0.05**
India	−0.01	**−0.05**	−0.04	**−0.05**	**−0.05**	**−0.03**
Other Asia	−0.03	−0.04	−0.08	−0.09	−0.09	**−0.06**
North America	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.01**
Europe	**−0.17**	**−0.17**	**−0.16**	**−0.15**	**−0.16**	**−0.11**
Middle East and North Africa	−0.07	−0.08	−0.12	−0.13	−0.13	**−0.08**
Sub-Saharan Africa	−0.03	−0.03	−0.03	−0.03	−0.03	**−0.02**
Latin America	−0.01	−0.01	−0.03	−0.03	−0.03	**−0.04**
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
Rest of the world	−0.12	−0.13	−0.20	−0.21	−0.21	**−0.51**
World total	−0.19	−0.19	−0.22	−0.23	−0.23	−0.27
Sanction efficiency	0.76	0.75	0.63	0.62	0.64	0.86

Note: Percentage changes in expenditure-side GDP (private and government consumption, investment, and net exports) aggregated with Laspeyres prices. Bolded figures are for senders; underlined figures are for targets. Sanction efficiency is total GDP decreases for senders divided by the GDP decrease for Russia.

The sanctions inflict losses not only on targets but also on senders, which discourage their participation. A free rider problem also discourages them—sanctions by other senders impact targets even if one country does not join. Among the senders, Europe has strong economic ties to Russia and thus would suffer the largest losses by 0.2% in GDP, followed by Japan (0.05%), North America (0.02%), and Oceania (0.02%). The losses in the Western countries and Japan would change marginally if India and China participated or if the sanctions were also imposed on Belarus. China and India would suffer small collateral losses from contraction of global trade even if they did not join. By joining the sanctions, they would lose just as much as Japan would. If the entire world participated in the sanctions (Scenario 6), the losses for incumbent senders in Scenario 5, particularly Europe, would decrease. While third parties would suffer collateral damage from shrinking world trade in Scenario 5, some would gain and others would lose in Scenario 6 by participating. Among them, the rest of the world (ROW), which consists mostly of Central Asia

and Former Soviet Union countries, would significantly lose owing to negative impacts from Russia through their strong economic ties.

Senders may well want to minimize their own losses and maximize losses for targets. The bottom row of Table 6 shows the ratio of senders' GDP losses to those of Russia. The smaller this ratio is, the more efficiently the sanctions are implemented. Note that the senders differ among the scenarios and that the losses suffered by Belarus are not considered as targets' losses consistently in this sanction efficiency index, presuming that the goal of the sanctions is only to damage the Russian economy. When the Western countries and Japan alone impose the sanctions on Russia (Scenario 1), they would have to sacrifice 0.8 USD of their GDP to inflict 1 USD of GDP losses on the Russian economy. India's participation (Scenario 2) does not have much impact, as discussed above. By contrast, China's participation (Scenario 3) would not only exacerbate Russia's losses but also improve the sanction efficiency considerably. The sanctions against Belarus (Scenario 5) would not effectively inflict Russia's trade, and thus would worsen the sanction efficiency slightly. As Russia's losses would be maximized by worldwide sanctions (Scenario 6) but outpaced by the increase of senders' losses, the sanction efficiency would deteriorate significantly.

Table 7 provides welfare impacts with Hicksian equivalent variations (EVs), which measure changes in household consumption, and shows a similar tendency to impacts measured in GDP. A larger sanction coalition would inflict larger losses on Russia. As long as Belarus is a third party (Scenarios 1–4), it would benefit from Russia's trade diversion from senders. Being a target (Scenario 5), Belarus would lose a large part of this benefit but still be better than Russia

in EV, unlike GDP.[7] If the entire world joined the sanctions (Scenario 6), Russia would trade with no countries but Belarus. This trade diversion effect would favor Belarus slightly again.

Table 7: Welfare Impacts [Unit: Hicksian equivalent variations, % of baseline GDP].

	Scenario					
	1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
Japan	**−0.18**	**−0.18**	**−0.21**	**−0.22**	**−0.22**	**−0.16**
Russia	−3.69	−3.84	−5.06	−5.25	−5.21	−8.28
Belarus	2.42	2.55	4.32	4.53	−1.34	0.25
Ukraine	−26.47	−26.45	−26.20	−26.16	−26.12	**−27.74**
China	0.00	0.00	**−0.17**	**−0.17**	**−0.17**	**−0.08**
India	−0.13	**−0.24**	−0.17	**−0.31**	**−0.31**	**−0.20**
Other Asia	−0.03	−0.02	0.00	0.01	0.01	**−0.14**
North America	**−0.03**	**−0.03**	**−0.03**	**−0.02**	**−0.03**	**−0.02**
Europe	**−0.31**	**−0.31**	**−0.31**	**−0.31**	**−0.32**	**−0.18**
Middle East and North Africa	0.44	0.46	0.66	0.69	0.70	**0.23**
Sub-Saharan Africa	0.19	0.20	0.33	0.34	0.35	**0.13**
Latin America	0.05	0.06	0.09	0.09	0.10	**−0.01**
Oceania	**0.10**	**0.11**	**0.15**	**0.16**	**0.16**	**0.26**
Rest of the world	0.93	0.95	1.26	1.29	1.30	**−0.43**
World total	−0.16	−0.17	−0.19	−0.20	−0.21	−0.26
Sanction efficiency	1.21	1.26	1.16	1.21	1.26	0.64

Note: Senders are in bold, and targets are underlined. Sanction efficiency is computed by dividing the total welfare loss of senders by Russia's welfare loss. The world total is the simple sum of welfare gains/losses in individual countries and regions, expressed as its ratio to the world total baseline GDP.

Notably, EVs—compared with GDP—show some contrasting results with positive gains from the sanctions in some countries. Third parties can free-ride senders' sanction efforts and exploit trade diversion effects, because the sanctions make them alternative trade partners both for senders and targets, to improve welfare. Free riders, such as Middle East and North Africa,

[7] The welfare impacts on Belarus are complex and dependent on elasticity assumptions, especially the Armington elasticity. For more details, see the results of the sensitivity analysis in the Appendix.

Sub-Saharan Africa, Latin America, and the ROW, would gain. The first two would enjoy positive gains, although their participation would reduce their gains as third parties in Scenario 5.

Worldwide sanctions (Scenario 6) would be welfare-deteriorating in total but improve sanction efficiency, contrary to the GDP-based sanction efficiency, thanks to trade diversion effects among senders. Joining the sanctions, the new senders would relinquish gains from trade diversion effects with Russia but still benefit from those with the incumbent senders. The incumbents would also benefit from trade diversion effects with the new senders. Therefore, senders' sanction costs in EV, as much as 1.3 USD to harm Russia's EV by 1 USD loss in Scenario 1–5, would be halved in Scenario 6.

3.4 Impacts on Food and Energy Supply

There is concern that global trade restrictions could undermine food and energy security. We examine these incidences with Scenario 6, which assumes worldwide sanctions (Table 8). Consumption of food composites, made of agri-food products, would be affected little in all but Russia and Ukraine. Consumer prices, especially for wheat, would rise by up to 10%. This is not so severe in light of the assumed 100% import tariffs. Moreover, tariff and tax revenues would be reimbursed to affected households to mitigate impacts on their income. The other two goods would show moderate price changes.

Table 8: Impacts on Food Consumption and Prices in Scenario 6 [Unit: changes from the baseline equilibrium, %].

	Household consumption	Consumer price		
	Food composites	Wheat	Other agriculture	Food
Japan	−0.2	3.9	0.5	0.5
Russia	−19.0	−27.0	−7.2	−15.0
Belarus	−2.5	−26.9	−10.6	−13.7
Ukraine	−42.5	−6.9	−7.2	−11.5
China	−0.1	0.8	0.2	0.3
India	−0.2	1.2	0.1	0.3
Other Asia	−0.1	6.0	0.2	0.4
North America	0.0	4.7	0.0	0.0
Europe	−0.3	3.0	0.6	0.6
Middle East and North Africa	0.6	2.1	1.2	1.2
Sub-Saharan Africa	0.2	4.3	0.0	0.0
South America	0.2	4.9	1.0	1.3
Oceania	0.8	6.3	2.7	3.2
Rest of the world	−0.6	10.2	3.0	5.7

Unlike food, household consumption of energy composites, made of six energy goods, would decrease in all senders. The decrease would be larger than that of consumption of food composites but still only about 3% (Table 9). Primary energy prices would rise noticeably in Europe, which is heavily dependent on Russia for energy supply. Other countries and regions face comparable price rises. In Japan, primary energy prices would rise by 4–14%. As alternative natural gas suppliers are limited, a gas price rise is particularly significant; the rises of oil prices and coal are about one-third and half of the gas price rise, respectively. The price of electricity, produced partly from these fossil fuels, would inevitably rise but in a smaller magnitude than the rises of primary energy prices. The rise in electricity prices would be 2% in Europe and 3% in Japan.

Table 9: Impacts on Energy Consumption and Price in Scenario 6 [Unit: changes from the baseline equilibrium, %].

	Household consumption	Consumer price					
	Energy composites	Coal	Oil	Natural gas	Petroleum and coal products	Electricity	Town gas
Japan	−3.3	6.5	4.1	13.7	4.1	2.9	3.9
Russia	−8.8	−22.4	−33.9	−24.9	−27.0	−22.3	−22.2
Belarus	9.3	−36.3	−48.9	−38.3	−39.2	−18.3	−11.3
Ukraine	−42.9	−18.0	−20.2	−11.2	−18.6	−5.4	−19.3
China	−1.7	3.3	3.1	11.9	2.7	1.2	4.4
India	−1.9	4.8	3.9	12.1	2.7	1.2	2.8
Other Asia	−2.7	6.3	3.6	12.5	3.2	2.2	2.3
North America	−1.7	4.3	3.1	9.7	2.9	0.8	1.1
Europe	−3.2	7.5	4.9	13.2	4.7	2.0	4.5
Middle East and North Africa	−2.4	7.8	3.5	11.6	3.7	4.3	3.0
Sub-Saharan Africa	−1.6	4.1	2.7	11.3	2.5	0.9	2.2
South America	−1.6	6.9	4.4	11.8	4.0	2.3	3.5
Oceania	−1.2	7.7	5.2	14.6	5.3	4.7	4.0
Rest of the world	−0.6	−4.8	6.3	14.8	6.5	3.6	5.1

4. Conclusion

We quantified the impacts of economic sanctions as a countermeasure using import tariffs and export taxes as weapons against the Russia's invasion of Ukraine. While trade measures would reduce Russia's GDP by 3–7%, senders' GDP losses would be at most 0.2% in Europe and 0.05% or less in the other Western countries and Japan. The more countries/regions that would participate, the more impactful the sanctions would be. Among non-Western senders, China would play a significant role, inflicting an additional one percentage point of GDP loss on Russia and improving the sanction efficiency. Even if the sanctions were also imposed against Belarus to block trade by Russia through Belarus, the damage to Russia would change little. These damages measured in GDP and welfare (i.e., household consumption) show similar sanction

outcomes. While there are some differences in models and shocks assumed as sanction measures between this study and a few earlier studies, the estimates of Russia's losses are generally at the same level. Although there are some differences in the estimates of senders' losses, they report only a small loss for senders concurrently. As the crisis broke out in Europe, natural gas has attracted much attention. However, the simulation results demonstrate the importance of sanctions generally imposed on trade, rather than the natural gas trade alone, whose trade is geographically confined mostly to the countries adjacent to Russia and is smaller than the coal and oil trades. There would be some price hikes in primary energies, particularly in natural gas, while food security would not be a serious concern for all countries, including developing countries.

In this study, we examined impacts of the sanctions with a standard static CGE model, where prices and quantities were assumed to be smoothly adjusted in the markets while assuming immobility of land, natural resources, and capital across sectors. This frictionless market assumption may make our estimates of sanction impacts small, like in other trade impact analyses with similar CGE models, which tend to yield conservative estimates. Socioeconomic indicators that we observe daily amid the storm originating from Ukraine show overwhelmingly extreme changes in directions and magnitude. Policy-making should not depend on indictors rising and falling every day but rather on more representative ones aggregated on a monthly or yearly basis, free from various noises. Even before this crisis created by Russia's invasion, the Japanese economy has suffered from many shocks—the outbreak of the new coronavirus, supply disruptions of liquefied natural gas (not owing to this crisis), electricity shortages due to natural disasters, and the commodity price bubbles caused by prolonged monetary easing. Nevertheless, when making policy decisions, such as economic sanctions, which would cause serious damage to a macro and world economy, it is necessary to quantify its impacts by controlling for the other factors.

Our analysis has several limitations. While we considered trade restrictions as sanction devices, there are other sanction measures, such as asset freezing, blocking Russian banks, travel

bans, and so on. As we omitted these, our analysis provides lower bound estimates of losses in targets and senders. For Japan, the supply of natural gas will depend crucially on the fate of the Sakhalin natural gas development project. In trade, we need to consider dynamic effects of sanctions on investment goods trades as Gharibnavaz and Waschik (2018) analyzed for Iran. Our macroeconomic model, even with elaborations for food and energy security issues, can capture aggregate impacts of the sanctions. By contrast, there are a wide variety of agents in an economy. Ahn and Ludema (2020) analyzed so-called smart sanctions targeted to strategically important companies and individuals after the Crimean crisis and found their impacts had been neutralized by the Russian government. Sanction analysis needs to consider heterogeneity of agents in a macroeconomy.

References

Ahn, D. P., & Ludema, R. D. (2020). The sword and the shield: The economics of targeted sanctions. *European Economic Review*, *130*, 103587. https://doi.org/https://doi.org/10.1016/j.euroecorev.2020.103587

Armington, P. S. (1969). A Theory of Demand for Products Distinguished by Place of Production. *IMF Staff Papers*. https://doi.org/10.2307/3866403

BP. (2021). *Statistical Review of World Energy 2021*. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Burfisher, M. E., Lambert, F., & Matheson, T. (2019). NAFTA to USMCA: What is Gained? *IMF Working Papers*. https://doi.org/10.5089/9781498303286.001

Chepeliev, M. (2020). GTAP- Power Database: Version 10. *Journal of Global Economic Analysis*, *5*(2), 110–137. https://doi.org/10.21642/JGEA.050203AF

Chepeliev, M., Hertel, T., & van der Mensbrugghe, D. (2022, March 9). *Cutting Russia's fossil fuel exports: Short-term pain for long-term gain*. VOX. https://voxeu.org/article/cutting-russia-s-fossil-fuel-exports-short-term-pain-long-term-gain

Dalheimer, B., Herwartz, H., & Lange, A. (2021). The threat of oil market turmoils to food price stability in Sub-Saharan Africa. *Energy Economics*, *93*, 105029. https://doi.org/https://doi.org/10.1016/j.eneco.2020.105029

Dhingra, S., Huang, H., Ottaviano, G., Paulo Pessoa, J., Sampson, T., & van Reenen, J. (2017). The costs and benefits of leaving the EU: trade effects. *Economic Policy*, *32*(92), 651–705. https://doi.org/10.1093/epolic/eix015

Dreger, C., Kholodilin, K. A., Ulbricht, D., & Fidrmuc, J. (2016). Between the hammer and the anvil: The impact of economic sanctions and oil prices on Russia's ruble. *Journal*

of Comparative Economics, *44*(2), 295–308. https://doi.org/10.1016/J.JCE.2015.12.010

Farzanegan, M. R., & Raeisian Parvari, M. (2014). Iranian-Oil-Free Zone and international oil prices. *Energy Economics*, *45*, 364–372. https://doi.org/https://doi.org/10.1016/j.eneco.2014.08.004

Felbermayr, G., Morgan, T. C., Syropoulos, C., & Yotov, Y. V. (2021). Understanding economic sanctions: Interdisciplinary perspectives on theory and evidence. *European Economic Review*, *135*, 103720. https://doi.org/https://doi.org/10.1016/j.euroecorev.2021.103720

Felbermayr, G., Syropoulos, C., Yalcin, E., & Yotov, Y. V. (2020). On the Heterogeneous Effects of Sanctions on Trade and Welfare: Evidence from the Sanctions on Iran and a New Database. *School of Economics Working Paper Series, LeBow College of Business, Drexel University.*, *2020–4*.

Gharibnavaz, M. R., & Waschik, R. (2018). A computable general equilibrium model of international sanctions in Iran. *The World Economy*, *41*(1), 287–307. https://doi.org/10.1111/twec.12528

Hertel, T. W. (1997). *Global Trade Analysis: Modeling and Applications Cambridge University Press*.

Hosoe, N. (2018). Impact of border barriers, returning migrants, and trade diversion in Brexit: Firm exit and loss of variety. *Economic Modelling*, *69*, 193–204. https://doi.org/10.1016/j.econmod.2017.09.018

Hosoe, N. (2020). Impact of tighter controls on Japanese chemical exports to Korea. *Economic Modelling*, *94*, 631–648. https://doi.org/10.1016/j.econmod.2020.02.006

Hosoe, N. (2022). Economic de-integration in North America and foreign direct investment from Japan. *Japan and the World Economy*, *61*, 101114. https://doi.org/10.1016/J.JAPWOR.2021.101114

Hosoe, N., Gasawa, K., & Hashimoto, H. (2010). *Textbook of Computable General Equilibrium Modelling: Programming and Simulations*. Palgrave Macmillan. https://doi.org/10.1017/CBO9781107415324.004

Iwasaki, I., Maurel, M., & Meunier, B. (2016). Firm entry and exit during a crisis period: Evidence from Russian regions. *Russian Journal of Economics*, *2*(2), 162–191. https://doi.org/10.1016/J.RUJE.2016.06.005

Kumagai, S., Hayakawa, K., Gokan, T., Isono, I., Keola, S., & Tsubota, K. (2022). Impact of Economic Sanctions against Russia on the Global Economy Using the IDE-GSM. *IDE Policy Brief*, *148*.

Nikkei Asia. (2022, March 31). *Japan will not abandon Sakhalin-2 LNG stake, Kishida says*.

Nivorozhkin, E., & Castagneto-Gissey, G. (2016). Russian stock market in the aftermath of the Ukrainian crisis. *Russian Journal of Economics*, *2*(1), 23–40. https://doi.org/10.1016/J.RUJE.2016.04.002

Ortiz Valverde, G., & Latorre, M. C. (2020). A computable general equilibrium analysis of Brexit: Barriers to trade and immigration restrictions. *The World Economy*, *43*(3), 705–728. https://doi.org/https://doi.org/10.1111/twec.12881

Shin, S., & Balistreri, E. J. (2022). The other trade war: Quantifying the Korea–Japan trade dispute. *Journal of Asian Economics*, *79*, 101442. https://doi.org/10.1016/J.ASIECO.2022.101442

Takahara, K. (2022, March 16). Japan to revoke Russia's most favored nation trade status. *The Japan Times*. https://www.japantimes.co.jp/news/2022/03/16/national/russia-most-favored-nation-status-revoke/

United States International Trade Commission (USITC). (2019). *U.S.-Mexico-Canada Trade Agreement: Likely Impact on the U.S. Economy and on Specific Industry Sectors*. *Investigation Number: TPA 105-003*. https://www.usitc.gov/publications/332/pub4889.pdf

Appendix

A.1 Sensitivity Analysis

Our CGE model is a standard world trade model. Therefore, we can apply the same standard methodology to examine the robustness of our results. There are four key elasticities: Armington's elasticity σ^m, the elasticity of substitution between primary factor input σ^v, the elasticity of substitution between agri-food products σ^f, and the elasticity of substitution between energy sources σ^e. The same simulations are run with 30% larger or smaller values for these elasticities. Note that for Armington's elasticity in Scenario 6, we assume only 25% larger (instead of 30% larger) because of numerical problems.[8]

In terms of the changes in GDP, none of the four parameters is very important except for Armington's elasticity (Table A. 1). When a country participated in the sanctions, trade to Russia would be diverted to other countries and regions. A larger Armington elasticity allows more flexible adjustment to shocks and thus makes losses smaller. GDP losses are found consistently negative in all elasticity cases. Quantitatively, we should expect that Russia's GDP impacts would be about 0.3–1.2 percentage points larger or smaller than the point estimates shown in Table 6. For Belarus and the rest of the world (Central Asia and Former Soviet Union countries), GDP may be positively or negatively affected depending on their elasticity, because they would be impacted by the Russian economy through their tight linkages as well as by the senders.

We find that the results are mostly robust in welfare (household consumption) and show mostly similar patterns of differences given the assumed elasticity values (Table A. 2). There are some differences in the welfare results compared with the GDP results, with a few exceptions. The elasticity of substitution between energy sources seems to be more important for EV impacts

[8] There are some very large elasticity values in the GTAP database. For example, Armington's elasticity of substitution is 34.4 for natural gas. Assuming a far larger value for this elasticity could lead to numerical difficulties.

than GDP impacts. This is intuitively reasonable as the energy composite production function is incorporated as a sub-utility in the utility function. In some cases, alternative elasticity values flip the sign of welfare changes. They are mostly in countries/regions that do not participate in the sanctions and have marginal collateral impacts from the sanctions. Belarus is a unique case where alternative Armington elasticity values sometimes bring significant and qualitatively different welfare impacts when it is a target (Scenarios 5 and 6), because it faces several strong effects from both Russia and senders through trade simultaneously. It would be enough to expect about one percentage point larger or smaller values for Russia's welfare losses.

For food composites, the elasticity of substitution between agri-food goods σ^f is less crucial than the Armington elasticity σ^m (Table A. 3). Simulation results for food consumption, both in developed or developing countries, are generally robust qualitatively, except for North America and Belarus. The former would be only marginally affected. The latter is, for the same reason explained above, about Belarus's reversing welfare impacts as a target.

For energy composites, the elasticity of substitution between energy sources σ^e as well as the Armington elasticity σ^m is indeed important (Table A. 4). Smaller elasticity leads to smaller energy composite consumption because the smaller elasticity makes it more difficult to switch an energy good affected by the sanctions to others. The results are qualitatively consistent, except for a few cases for China, Middle East and North Africa, Belarus, and the ROW.

Table A. 1: GDP Impacts under Alternative Elasticity Assumptions [Unit: change from the baseline equilibrium, %].

	σ^e		σ^f		σ^m		σ^v	
	+30%	−30%	+30%	−30%	+30%	−30%	+30%	−30%
	Scenario 1							
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.04**	**−0.05**	**−0.05**	**−0.05**
Russia	−3.23	−3.25	−3.24	−3.24	−2.96	−2.94	−3.25	−3.22
Belarus	−0.47	−0.49	−0.48	−0.48	−0.37	−0.63	−0.47	−0.49
Ukraine	−50.97	−50.96	−50.97	−50.97	−50.54	−52.37	−50.96	−50.98
China	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
India	−0.01	−0.01	−0.01	−0.01	−0.01	−0.02	−0.01	−0.01
Other Asia	−0.03	−0.03	−0.03	−0.03	−0.03	−0.04	−0.03	−0.03
North America	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
Europe	**−0.17**	**−0.17**	**−0.17**	**−0.17**	**−0.16**	**−0.15**	**−0.17**	**−0.17**
MENA	−0.07	−0.08	−0.07	−0.07	−0.06	−0.08	−0.07	−0.07
Sub-Saharan A.	−0.03	−0.03	−0.03	−0.03	−0.02	−0.03	−0.03	−0.03
South America	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
ROW	−0.12	−0.12	−0.12	−0.12	−0.09	−0.18	−0.12	−0.12
	Scenario 2							
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.04**	**−0.05**	**−0.05**	**−0.05**
Russia	−3.34	−3.36	−3.35	−3.35	−3.08	−3.03	−3.36	−3.34
Belarus	−0.50	−0.52	−0.51	−0.51	−0.40	−0.66	−0.50	−0.52
Ukraine	−50.98	−50.98	−50.98	−50.98	−50.55	−52.39	−50.97	−50.99
China	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
India	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.04**	**−0.05**	**−0.05**	**−0.05**
Other Asia	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
North America	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
Europe	**−0.17**	**−0.17**	**−0.17**	**−0.17**	**−0.15**	**−0.15**	**−0.17**	**−0.17**
MENA	−0.08	−0.08	−0.08	−0.08	−0.07	−0.08	−0.08	−0.08
Sub-Saharan A.	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03
South America	−0.01	−0.02	−0.01	−0.02	−0.02	−0.01	−0.01	−0.01
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
ROW	−0.12	−0.13	−0.13	−0.13	−0.09	−0.19	−0.13	−0.12

	Scenario 3							
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**
Russia	−4.39	−4.43	−4.41	−4.41	−4.23	−3.82	−4.43	−4.37
Belarus	−0.94	−0.94	−0.94	−0.94	−0.90	−0.90	−0.93	−0.97
Ukraine	−51.15	−51.13	−51.14	−51.14	−50.74	−52.54	−51.13	−51.15
China	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**
India	−0.04	−0.04	−0.04	−0.04	−0.04	−0.03	−0.04	−0.04
Other Asia	−0.08	−0.08	−0.08	−0.08	−0.10	−0.06	−0.08	−0.08
North America	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
Europe	**−0.16**	**−0.16**	**−0.16**	**−0.16**	**−0.15**	**−0.14**	**−0.16**	**−0.15**
MENA	**−0.12**	**−0.13**	**−0.12**	**−0.12**	**−0.12**	**−0.10**	**−0.12**	**−0.12**
Sub-Saharan A.	−0.03	−0.03	−0.03	−0.03	−0.03	−0.02	−0.03	−0.03
South America	−0.03	−0.03	−0.03	−0.03	−0.03	−0.02	−0.03	−0.03
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
ROW	−0.20	−0.21	−0.20	−0.20	−0.20	−0.24	−0.20	−0.20
	Scenario 4							
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**
Russia	−4.51	−4.56	−4.53	−4.54	−4.38	−3.92	−4.56	−4.50
Belarus	−1.01	−1.02	−1.01	−1.01	−1.00	−0.95	−1.00	−1.04
Ukraine	−51.17	−51.16	−51.16	−51.17	−50.77	−52.57	−51.16	−51.18
China	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**
India	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.04**	**−0.05**	**−0.05**
Other Asia	−0.09	−0.09	−0.09	−0.09	−0.12	−0.06	−0.09	−0.09
North America	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
Europe	**−0.15**	**−0.15**	**−0.15**	**−0.15**	**−0.15**	**−0.14**	**−0.15**	**−0.15**
MENA	−0.13	−0.13	−0.13	−0.13	−0.14	−0.10	−0.13	−0.13
Sub-Saharan A.	−0.03	−0.03	−0.03	−0.03	−0.03	−0.02	−0.03	−0.03
South America	−0.03	−0.03	−0.03	−0.03	−0.04	−0.02	−0.03	−0.03
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
ROW	−0.21	−0.22	−0.21	−0.22	−0.22	−0.26	−0.22	−0.21

	Scenario 5							
Japan	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**
Russia	−4.52	−4.56	−4.54	−4.54	−4.39	−3.92	−4.56	−4.50
Belarus	−5.03	−4.99	−5.01	−5.01	−4.84	−4.38	−5.01	−5.01
Ukraine	−51.19	−51.17	−51.18	−51.18	−50.79	−52.58	−51.17	−51.19
China	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**
India	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**	**−0.05**
Other Asia	−0.09	−0.09	−0.09	−0.09	−0.12	−0.07	−0.09	−0.10
North America	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
Europe	**−0.16**	**−0.16**	**−0.16**	**−0.16**	**−0.16**	**−0.14**	**−0.16**	**−0.16**
MENA	−0.13	−0.14	−0.13	−0.13	−0.14	−0.11	−0.13	−0.13
Sub-Saharan A.	−0.03	−0.03	−0.03	−0.03	−0.03	−0.02	−0.03	−0.03
South America	−0.03	−0.03	−0.03	−0.03	−0.04	−0.02	−0.03	−0.03
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
ROW	−0.21	−0.22	−0.21	−0.21	−0.22	−0.26	−0.22	−0.21
	Scenario 6							
Japan	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**
Russia	−7.45	−7.33	−7.40	−7.40	−7.80	−6.23	−7.44	−7.34
Belarus	−9.85	−9.79	−9.81	−9.82	−10.86	−7.96	−9.82	−9.81
Ukraine	**−51.12**	**−51.12**	**−51.12**	**−51.12**	**−50.79**	**−52.45**	**−51.10**	**−51.14**
China	**−0.05**	**−0.05**	**−0.05**	**−0.06**	**−0.05**	**−0.07**	**−0.05**	**−0.05**
India	**−0.03**	**−0.04**	**−0.03**	**−0.03**	**−0.03**	**−0.04**	**−0.03**	**−0.04**
Other Asia	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.06**	**−0.07**	**−0.06**	**−0.06**
North America	**−0.01**	**−0.01**	**−0.01**	**−0.01**	**−0.01**	**−0.02**	**−0.01**	**−0.01**
Europe	**−0.11**	**−0.11**	**−0.11**	**−0.11**	**−0.10**	**−0.14**	**−0.11**	**−0.11**
MENA	**−0.08**	**−0.08**	**−0.08**	**−0.08**	**−0.08**	**−0.08**	**−0.08**	**−0.07**
Sub-Saharan A.	**−0.02**	**−0.03**	**−0.03**	**−0.02**	**−0.02**	**−0.03**	**−0.02**	**−0.02**
South America	**−0.04**	**−0.04**	**−0.04**	**−0.03**	**−0.03**	**−0.04**	**−0.03**	**−0.04**
Oceania	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**	**−0.02**
ROW	**−0.51**	**−0.51**	**−0.51**	**−0.51**	**−0.51**	**−0.48**	**−0.50**	**−0.51**

Note: NENA stands for Middle East and North Africa. GDP is expenditure-side GDP aggregated with Laspeyres prices. Coloring indicates relative magnitude for each scenario and for each country. In Scenario 6, we assume 25%, instead of 30%, larger elasticity values for σ^m due to numerical problems. Senders are in bold, and targets are underlined.

Table A. 2: Welfare Impacts under Alternative Elasticity Assumptions [Unit: Hicksian equivalent variations, % of the baseline GDP].

	σ^e		σ^f		σ^m		σ^v	
	+30%	−30%	+30%	−30%	+30%	−30%	+30%	−30%
	Scenario 1							
Japan	**−0.17**	**−0.19**	**−0.18**	**−0.18**	**−0.14**	**−0.18**	**−0.18**	**−0.18**
Russia	−3.70	−3.66	−3.69	−3.68	−2.81	−4.50	−3.68	−3.70
Belarus	2.44	2.39	2.42	2.42	2.22	1.72	2.41	2.44
Ukraine	−26.47	−26.48	−26.48	−26.46	−28.30	−22.55	−26.49	−26.44
China	0.00	−0.01	0.00	0.00	0.00	0.01	0.00	−0.01
India	−0.12	−0.15	−0.13	−0.13	−0.11	−0.11	−0.13	−0.14
Other Asia	−0.02	−0.04	−0.03	−0.03	−0.02	−0.01	−0.02	−0.03
North America	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**
Europe	**−0.30**	**−0.32**	**−0.31**	**−0.31**	**−0.23**	**−0.36**	**−0.31**	**−0.31**
MENA	0.41	0.50	0.44	0.44	0.39	0.32	0.44	0.45
Sub-Saharan A.	0.17	0.21	0.19	0.19	0.17	0.14	0.18	0.20
South America	0.05	0.05	0.05	0.05	0.06	0.04	0.05	0.06
Oceania	**0.10**	**0.11**	**0.10**	**0.10**	**0.09**	**0.10**	**0.09**	**0.11**
ROW	0.89	0.98	0.93	0.93	0.76	0.88	0.92	0.94
	Scenario 2							
Japan	**−0.17**	**−0.19**	**−0.18**	**−0.18**	**−0.14**	**−0.18**	**−0.18**	**−0.18**
Russia	−3.85	−3.82	−3.84	−3.84	−2.94	−4.67	−3.83	−3.86
Belarus	2.56	2.52	2.55	2.54	2.35	1.81	2.53	2.57
Ukraine	−26.45	−26.46	−26.46	−26.44	−28.28	−22.53	−26.47	−26.42
China	0.01	−0.01	0.00	0.00	0.00	0.01	0.00	0.00
India	**−0.23**	**−0.27**	**−0.25**	**−0.24**	**−0.21**	**−0.22**	**−0.24**	**−0.25**
Other Asia	−0.01	−0.04	−0.02	−0.02	−0.01	−0.01	−0.02	−0.02
North America	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.02**	**−0.03**	**−0.03**	**−0.03**
Europe	**−0.30**	**−0.32**	**−0.31**	**−0.31**	**−0.23**	**−0.36**	**−0.31**	**−0.31**
MENA	0.42	0.52	0.46	0.46	0.41	0.33	0.45	0.47
Sub-Saharan A.	0.19	0.22	0.20	0.20	0.18	0.14	0.19	0.21
South America	0.06	0.06	0.06	0.06	0.06	0.04	0.05	0.07
Oceania	**0.10**	**0.11**	**0.11**	**0.11**	**0.10**	**0.10**	**0.10**	**0.12**
ROW	0.91	1.01	0.95	0.95	0.79	0.89	0.94	0.96

	Scenario 3							
Japan	**−0.20**	**−0.24**	**−0.21**	**−0.22**	**−0.20**	**−0.18**	**−0.21**	**−0.22**
Russia	−5.07	−5.03	−5.06	−5.06	−3.93	−5.98	−5.03	−5.10
Belarus	4.35	4.27	4.32	4.32	4.24	2.97	4.29	4.38
Ukraine	−26.19	−26.21	−26.20	−26.19	−28.02	−22.31	−26.21	−26.17
China	**−0.16**	**−0.18**	**−0.17**	**−0.17**	**−0.16**	**−0.13**	**−0.16**	**−0.17**
India	−0.15	−0.20	−0.17	−0.17	−0.17	−0.12	−0.17	−0.18
Other Asia	0.02	−0.02	0.00	0.00	0.00	0.02	0.00	0.00
North America	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**
Europe	**−0.30**	**−0.33**	**−0.32**	**−0.31**	**−0.26**	**−0.33**	**−0.31**	**−0.31**
MENA	0.61	0.75	0.66	0.66	0.67	0.40	0.65	0.67
Sub-Saharan A.	0.31	0.36	0.33	0.33	0.32	0.22	0.32	0.35
South America	0.09	0.09	0.09	0.09	0.09	0.06	0.08	0.10
Oceania	**0.14**	**0.16**	**0.15**	**0.15**	**0.15**	**0.11**	**0.14**	**0.17**
ROW	1.20	1.34	1.26	1.26	1.18	1.03	1.25	1.26
	Scenario 4							
Japan	**−0.20**	**−0.24**	**−0.22**	**−0.22**	**−0.20**	**−0.18**	**−0.21**	**−0.22**
Russia	−5.26	−5.23	−5.25	−5.25	−4.11	−6.17	−5.22	−5.29
Belarus	4.56	4.48	4.53	4.52	4.50	3.09	4.49	4.60
Ukraine	−26.16	−26.17	−26.17	−26.16	−27.98	−22.29	−26.18	−26.14
China	**−0.16**	**−0.18**	**−0.17**	**−0.17**	**−0.16**	**−0.13**	**−0.16**	**−0.17**
India	**−0.29**	**−0.34**	**−0.31**	**−0.31**	**−0.31**	**−0.23**	**−0.30**	**−0.32**
Other Asia	0.03	−0.01	0.01	0.01	0.01	0.03	0.01	0.01
North America	**−0.02**	**−0.03**	**−0.03**	**−0.02**	**−0.03**	**−0.03**	**−0.03**	**−0.02**
Europe	**−0.30**	**−0.33**	**−0.31**	**−0.31**	**−0.26**	**−0.32**	**−0.31**	**−0.31**
MENA	0.63	0.77	0.69	0.69	0.72	0.41	0.68	0.70
Sub-Saharan A.	0.32	0.38	0.34	0.34	0.34	0.23	0.33	0.36
South America	0.09	0.10	0.09	0.09	0.10	0.06	0.09	0.11
Oceania	**0.15**	**0.16**	**0.15**	**0.16**	**0.16**	**0.11**	**0.14**	**0.17**
ROW	1.23	1.36	1.29	1.29	1.24	1.04	1.28	1.29

	Scenario 5							
Japan	**−0.20**	**−0.24**	**−0.22**	**−0.22**	**−0.21**	**−0.18**	**−0.22**	**−0.22**
Russia	−5.23	−5.19	−5.22	−5.21	−4.09	−6.13	−5.19	−5.26
Belarus	−1.29	−1.41	−1.34	−1.34	0.00	−4.55	−1.33	−1.34
Ukraine	−26.11	−26.13	−26.13	−26.11	−27.92	−22.26	−26.14	−26.09
China	**−0.16**	**−0.18**	**−0.17**	**−0.17**	**−0.17**	**−0.13**	**−0.16**	**−0.18**
India	**−0.29**	**−0.34**	**−0.31**	**−0.31**	**−0.32**	**−0.23**	**−0.31**	**−0.32**
Other Asia	0.03	−0.01	0.01	0.01	0.01	0.03	0.01	0.01
North America	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**	**−0.03**
Europe	**−0.31**	**−0.34**	**−0.33**	**−0.33**	**−0.28**	**−0.34**	**−0.32**	**−0.32**
MENA	0.64	0.79	0.70	0.70	0.74	0.41	0.69	0.71
Sub-Saharan A.	0.33	0.38	0.35	0.35	0.35	0.23	0.34	0.37
South America	0.10	0.10	0.10	0.10	0.10	0.06	0.09	0.11
Oceania	**0.15**	**0.17**	**0.16**	**0.16**	**0.16**	**0.10**	**0.14**	**0.17**
ROW	1.24	1.38	1.30	1.30	1.25	1.06	1.29	1.30
	Scenario 6							
Japan	**−0.15**	**−0.17**	**−0.16**	**−0.16**	**−0.19**	**−0.09**	**−0.16**	**−0.15**
Russia	−8.27	−8.30	−8.28	−8.29	−7.62	−8.91	−8.21	−8.40
Belarus	0.30	0.20	0.25	0.26	5.46	−7.81	0.20	0.34
Ukraine	**−27.73**	**−27.74**	**−27.74**	**−27.73**	**−29.28**	**−23.64**	**−27.77**	**−27.69**
China	**−0.08**	**−0.08**	**−0.08**	**−0.08**	**−0.09**	**−0.06**	**−0.08**	**−0.08**
India	**−0.20**	**−0.21**	**−0.20**	**−0.21**	**−0.24**	**−0.15**	**−0.20**	**−0.21**
Other Asia	**−0.14**	**−0.14**	**−0.14**	**−0.14**	**−0.16**	**−0.11**	**−0.14**	**−0.14**
North America	**−0.02**	**−0.01**	**−0.01**	**−0.02**	**−0.01**	**−0.02**	**−0.02**	**−0.01**
Europe	**−0.17**	**−0.18**	**−0.18**	**−0.18**	**−0.17**	**−0.18**	**−0.18**	**−0.17**
MENA	**0.22**	**0.24**	**0.23**	**0.23**	**0.34**	**0.02**	**0.23**	**0.23**
Sub-Saharan A.	**0.13**	**0.13**	**0.13**	**0.13**	**0.17**	**0.04**	**0.12**	**0.14**
South America	**−0.01**	**−0.01**	**−0.01**	**−0.01**	**0.00**	**−0.03**	**−0.01**	**0.01**
Oceania	**0.24**	**0.29**	**0.26**	**0.26**	**0.33**	**0.12**	**0.25**	**0.27**
ROW	**−0.44**	**−0.43**	**−0.43**	**−0.44**	**−0.27**	**−0.53**	**−0.44**	**−0.43**

Note: NENA stands for Middle East and North Africa. Coloring indicates relative magnitude for each scenario and for each country. In Scenario 6, we assume 25%, instead of 30%, larger elasticity values for σ^m due to numerical problems. Senders are in bold, and targets are underlined.

Table A. 3: Changes in Food Consumption under Alternative Elasticity Assumptions [Unit: changes from the baseline equilibrium, %].

	σ^e		σ^f		σ^m		σ^v	
	+30%	−30%	+30%	−30%	+30%	−30%	+30%	−30%
	Scenario 1							
Japan	**-0.38**	**-0.43**	**-0.40**	**-0.40**	**-0.35**	**-0.37**	**-0.39**	**-0.41**
Russia	-7.03	-6.94	-6.99	-7.00	-5.26	-8.61	-6.90	-7.12
Belarus	3.55	3.53	3.55	3.54	3.46	1.81	3.47	3.67
Ukraine	-40.80	-40.72	-40.74	-40.78	-43.79	-34.82	-40.81	-40.69
China	-0.01	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	-0.03
India	-0.19	-0.22	-0.21	-0.20	-0.17	-0.24	-0.19	-0.23
Other Asia	-0.09	-0.13	-0.11	-0.12	-0.09	-0.11	-0.09	-0.13
North America	**0.00**	**0.00**	**0.00**	**0.00**	**-0.03**	**0.01**	**0.00**	**0.01**
Europe	**-0.65**	**-0.69**	**-0.66**	**-0.67**	**-0.58**	**-0.68**	**-0.66**	**-0.68**
MENA	0.61	0.80	0.70	0.68	0.64	0.31	0.68	0.70
Sub-Saharan A.	0.21	0.25	0.23	0.22	0.19	0.15	0.22	0.23
South America	0.10	0.11	0.10	0.10	0.08	0.08	0.09	0.11
Oceania	**0.26**	**0.29**	**0.28**	**0.28**	**0.20**	**0.29**	**0.24**	**0.33**
ROW	1.18	1.32	1.25	1.23	1.00	1.10	1.23	1.26
	Scenario 2							
Japan	**-0.38**	**-0.43**	**-0.40**	**-0.40**	**-0.35**	**-0.36**	**-0.39**	**-0.41**
Russia	-7.40	-7.31	-7.36	-7.37	-5.56	-9.01	-7.26	-7.50
Belarus	3.72	3.71	3.72	3.72	3.64	1.94	3.64	3.85
Ukraine	-40.77	-40.69	-40.71	-40.75	-43.75	-34.80	-40.78	-40.66
China	-0.01	-0.03	-0.01	-0.02	-0.02	-0.01	-0.01	-0.03
India	**-0.29**	**-0.32**	**-0.30**	**-0.30**	**-0.28**	**-0.30**	**-0.29**	**-0.32**
Other Asia	-0.08	-0.12	-0.10	-0.10	-0.08	-0.10	-0.08	-0.12
North America	**0.00**	**0.01**	**0.00**	**0.01**	**-0.02**	**0.01**	**0.00**	**0.01**
Europe	**-0.64**	**-0.69**	**-0.65**	**-0.67**	**-0.58**	**-0.67**	**-0.65**	**-0.67**
MENA	0.65	0.85	0.74	0.72	0.69	0.33	0.72	0.75
Sub-Saharan A.	0.22	0.27	0.24	0.24	0.21	0.16	0.24	0.25
South America	0.10	0.11	0.11	0.11	0.09	0.08	0.10	0.12
Oceania	**0.27**	**0.31**	**0.29**	**0.29**	**0.22**	**0.29**	**0.25**	**0.35**
ROW	1.21	1.35	1.28	1.26	1.03	1.13	1.26	1.29

	Scenario 3							
Japan	**−0.43**	**−0.51**	**−0.46**	**−0.47**	**−0.47**	**−0.35**	**−0.46**	**−0.47**
Russia	−9.16	−9.05	−9.11	−9.12	−6.82	−11.06	−9.06	−9.19
Belarus	7.01	7.00	7.01	7.01	7.54	3.75	6.79	7.36
Ukraine	−40.27	−40.19	−40.21	−40.24	−43.13	−34.49	−40.30	−40.13
China	**−0.31**	**−0.35**	**−0.32**	**−0.33**	**−0.35**	**−0.22**	**−0.31**	**−0.35**
India	−0.22	−0.26	−0.24	−0.23	−0.21	−0.25	−0.22	−0.26
Other Asia	−0.05	−0.11	−0.07	−0.08	−0.06	−0.05	−0.06	−0.09
North America	**0.02**	**0.03**	**0.02**	**0.02**	**−0.01**	**0.02**	**0.02**	**0.03**
Europe	**−0.66**	**−0.72**	**−0.68**	**−0.69**	**−0.66**	**−0.62**	**−0.68**	**−0.70**
MENA	1.00	1.30	1.13	1.11	1.23	0.48	1.10	1.15
Sub-Saharan A.	0.35	0.42	0.38	0.37	0.38	0.23	0.37	0.38
South America	0.16	0.18	0.17	0.17	0.16	0.12	0.16	0.19
Oceania	**0.38**	**0.43**	**0.41**	**0.41**	**0.36**	**0.33**	**0.36**	**0.48**
ROW	1.67	1.87	1.76	1.74	1.69	1.36	1.72	1.80
	Scenario 4							
Japan	**−0.43**	**−0.51**	**−0.46**	**−0.47**	**−0.47**	**−0.34**	**−0.46**	**−0.47**
Russia	−9.60	−9.50	−9.56	−9.57	−7.21	−11.50	−9.50	−9.65
Belarus	7.31	7.30	7.31	7.31	7.96	3.91	7.09	7.68
Ukraine	−40.22	−40.14	−40.16	−40.19	−43.05	−34.46	−40.25	−40.08
China	**−0.31**	**−0.35**	**−0.32**	**−0.33**	**−0.36**	**−0.21**	**−0.31**	**−0.35**
India	**−0.33**	**−0.38**	**−0.36**	**−0.35**	**−0.37**	**−0.32**	**−0.33**	**−0.38**
Other Asia	−0.03	−0.09	−0.05	−0.06	−0.03	−0.04	−0.04	−0.07
North America	**0.02**	**0.03**	**0.02**	**0.03**	**−0.01**	**0.02**	**0.02**	**0.03**
Europe	**−0.65**	**−0.71**	**−0.67**	**−0.69**	**−0.66**	**−0.61**	**−0.67**	**−0.69**
MENA	1.05	1.36	1.19	1.17	1.32	0.50	1.16	1.20
Sub-Saharan A.	0.37	0.44	0.40	0.39	0.41	0.24	0.39	0.40
South America	0.17	0.19	0.18	0.18	0.17	0.12	0.17	0.20
Oceania	**0.40**	**0.45**	**0.42**	**0.42**	**0.39**	**0.33**	**0.37**	**0.50**
ROW	1.70	1.90	1.80	1.77	1.76	1.39	1.76	1.83

	Scenario 5							
Japan	**−0.43**	**−0.51**	**−0.46**	**−0.47**	**−0.48**	**−0.34**	**−0.46**	**−0.47**
Russia	−9.49	−9.38	−9.44	−9.45	−7.15	−11.31	−9.39	−9.52
Belarus	−3.58	−3.68	−3.61	−3.64	−0.90	−8.89	−3.63	−3.59
Ukraine	−40.16	−40.07	−40.10	−40.13	−42.97	−34.41	−40.19	−40.00
China	**−0.31**	**−0.35**	**−0.32**	**−0.33**	**−0.36**	**−0.21**	**−0.31**	**−0.35**
India	**−0.33**	**−0.38**	**−0.36**	**−0.35**	**−0.37**	**−0.31**	**−0.33**	**−0.38**
Other Asia	−0.03	−0.08	−0.05	−0.06	−0.03	−0.03	−0.04	−0.07
North America	**0.03**	**0.03**	**0.03**	**0.03**	**0.00**	**0.02**	**0.02**	**0.04**
Europe	**−0.66**	**−0.72**	**−0.68**	**−0.69**	**−0.67**	**−0.61**	**−0.68**	**−0.69**
MENA	1.07	1.39	1.21	1.19	1.37	0.51	1.18	1.23
Sub-Saharan A.	0.37	0.45	0.41	0.40	0.42	0.24	0.40	0.41
South America	0.17	0.19	0.18	0.18	0.18	0.12	0.17	0.20
Oceania	**0.40**	**0.45**	**0.43**	**0.43**	**0.40**	**0.32**	**0.38**	**0.50**
ROW	1.73	1.94	1.83	1.80	1.78	1.45	1.79	1.86
	Scenario 6							
Japan	**−0.22**	**−0.26**	**−0.24**	**−0.24**	**−0.32**	**−0.09**	**−0.25**	**−0.22**
Russia	−19.06	−19.02	−18.95	−19.14	−18.30	−19.48	−18.73	−19.40
Belarus	−2.47	−2.50	−2.44	−2.54	7.12	−14.82	−2.57	−2.26
Ukraine	**−42.47**	**−42.45**	**−42.44**	**−42.48**	**−45.24**	**−35.71**	**−42.56**	**−42.32**
China	**−0.07**	**−0.08**	**−0.08**	**−0.07**	**−0.10**	**−0.03**	**−0.07**	**−0.07**
India	**−0.23**	**−0.24**	**−0.23**	**−0.23**	**−0.25**	**−0.24**	**−0.22**	**−0.25**
Other Asia	**−0.13**	**−0.14**	**−0.15**	**−0.12**	**−0.19**	**−0.08**	**−0.14**	**−0.13**
North America	**−0.03**	**−0.03**	**−0.02**	**−0.04**	**−0.01**	**−0.05**	**−0.02**	**−0.03**
Europe	**−0.27**	**−0.29**	**−0.28**	**−0.28**	**−0.29**	**−0.31**	**−0.29**	**−0.26**
MENA	**0.55**	**0.60**	**0.58**	**0.57**	**0.82**	**0.06**	**0.58**	**0.57**
Sub-Saharan A.	**0.17**	**0.17**	**0.17**	**0.16**	**0.23**	**0.05**	**0.17**	**0.18**
South America	**0.15**	**0.15**	**0.15**	**0.15**	**0.16**	**0.11**	**0.12**	**0.19**
Oceania	**0.76**	**0.92**	**0.81**	**0.84**	**1.02**	**0.42**	**0.75**	**0.93**
ROW	**−0.63**	**−0.63**	**−0.64**	**−0.61**	**−0.58**	**−0.42**	**−0.68**	**−0.57**

Note: NENA stands for Middle East and North Africa. Coloring indicates relative magnitude for each scenario and for each country. In Scenario 6, we assume 25%, instead of 30%, larger elasticity values for σ^m due to numerical problems. Senders are in bold, and targets are underlined.

Table A. 4: Changes in Energy Consumption under Alternative Elasticity Assumptions [Unit: changes from the baseline equilibrium, %].

	σ^e		σ^f		σ^m		σ^v	
	+30%	−30%	+30%	−30%	+30%	−30%	+30%	−30%
	Scenario 1							
Japan	**−2.97**	**−3.51**	**−3.19**	**−3.20**	**−2.52**	**−3.25**	**−3.18**	**−3.19**
Russia	−4.25	−4.39	−4.31	−4.31	−2.72	−6.19	−4.38	−4.19
Belarus	8.81	8.41	8.64	8.63	7.30	7.78	8.65	8.64
Ukraine	−39.68	−39.99	−39.84	−39.80	−43.50	−31.72	−39.92	−39.69
China	−0.18	−0.59	−0.35	−0.36	−0.46	0.30	−0.31	−0.41
India	−1.27	−1.69	−1.45	−1.44	−1.27	−0.97	−1.42	−1.46
Other Asia	−0.96	−1.45	−1.17	−1.17	−1.06	−0.47	−1.13	−1.20
North America	**−1.97**	**−2.26**	**−2.09**	**−2.09**	**−1.91**	**−1.53**	**−2.04**	**−2.13**
Europe	**−5.77**	**−5.94**	**−5.83**	**−5.83**	**−4.64**	**−6.02**	**−5.76**	**−5.90**
MENA	−0.39	−0.62	−0.49	−0.49	−0.39	−0.37	−0.50	−0.45
Sub-Saharan A.	−1.74	−2.03	−1.86	−1.86	−1.62	−1.43	−1.86	−1.83
South America	−1.23	−1.53	−1.35	−1.35	−1.26	−0.88	−1.33	−1.37
Oceania	**−1.14**	**−1.44**	**−1.27**	**−1.26**	**−1.15**	**−0.78**	**−1.28**	**−1.20**
ROW	1.38	1.33	1.35	1.37	1.16	1.61	1.30	1.45
	Scenario 2							
Japan	**−3.00**	**−3.54**	**−3.22**	**−3.23**	**−2.57**	**−3.23**	**−3.20**	**−3.22**
Russia	−4.43	−4.57	−4.49	−4.49	−2.84	−6.44	−4.56	−4.37
Belarus	9.21	8.79	9.03	9.02	7.66	8.09	9.04	9.03
Ukraine	−39.61	−39.92	−39.78	−39.74	−43.45	−31.64	−39.85	−39.62
China	−0.14	−0.56	−0.31	−0.32	−0.44	0.36	−0.27	−0.37
India	**−1.86**	**−2.32**	**−2.05**	**−2.05**	**−1.85**	**−1.48**	**−2.03**	**−2.06**
Other Asia	−0.94	−1.45	−1.15	−1.16	−1.06	−0.42	−1.12	−1.19
North America	**−1.99**	**−2.28**	**−2.11**	**−2.10**	**−1.94**	**−1.52**	**−2.06**	**−2.15**
Europe	**−5.76**	**−5.93**	**−5.82**	**−5.82**	**−4.66**	**−5.94**	**−5.75**	**−5.88**
MENA	−0.33	−0.56	−0.42	−0.42	−0.34	−0.29	−0.43	−0.38
Sub-Saharan A.	−1.75	−2.05	−1.88	−1.87	−1.65	−1.43	−1.88	−1.85
South America	−1.23	−1.53	−1.35	−1.35	−1.27	−0.86	−1.33	−1.37
Oceania	**−1.14**	**−1.45**	**−1.27**	**−1.27**	**−1.16**	**−0.77**	**−1.29**	**−1.21**
ROW	1.46	1.40	1.43	1.44	1.22	1.68	1.38	1.53

	Scenario 3							
Japan	**−3.74**	**−4.55**	**−4.07**	**−4.08**	**−3.81**	**−3.28**	**−4.05**	**−4.05**
Russia	−5.56	−5.84	−5.68	−5.69	−3.85	−7.78	−5.65	−5.70
Belarus	15.04	14.30	14.72	14.70	12.89	12.65	14.74	14.66
Ukraine	−38.95	−39.35	−39.16	−39.12	−43.02	−30.86	−39.23	−39.02
China	**−3.87**	**−4.42**	**−4.10**	**−4.11**	**−4.00**	**−2.76**	**−3.99**	**−4.21**
India	−1.75	−2.34	−2.00	−2.00	−2.09	−1.07	−1.98	−1.99
Other Asia	−1.16	−1.90	−1.47	−1.48	−1.70	−0.21	−1.43	−1.49
North America	**−2.49**	**−2.93**	**−2.68**	**−2.67**	**−2.85**	**−1.57**	**−2.63**	**−2.71**
Europe	**−6.01**	**−6.37**	**−6.15**	**−6.15**	**−5.56**	**−5.24**	**−6.08**	**−6.20**
MENA	0.04	−0.35	−0.12	−0.12	−0.36	0.28	−0.14	−0.06
Sub-Saharan A.	−1.96	−2.36	−2.14	−2.12	−2.27	−1.17	−2.15	−2.07
South America	−1.63	−2.10	−1.83	−1.83	−2.01	−0.94	−1.81	−1.82
Oceania	**−1.65**	**−2.10**	**−1.83**	**−1.83**	**−1.95**	**−0.95**	**−1.87**	**−1.74**
ROW	2.07	1.96	2.01	2.04	1.69	2.31	1.95	2.14
	Scenario 4							
Japan	**−3.75**	**−4.58**	**−4.09**	**−4.10**	**−3.92**	**−3.22**	**−4.07**	**−4.07**
Russia	−5.76	−6.04	−5.88	−5.89	−3.99	−8.05	−5.84	−5.91
Belarus	15.74	14.97	15.41	15.39	13.68	13.08	15.43	15.35
Ukraine	−38.83	−39.24	−39.05	−39.00	−42.93	−30.75	−39.11	−38.91
China	**−3.89**	**−4.45**	**−4.12**	**−4.13**	**−4.13**	**−2.70**	**−4.02**	**−4.23**
India	**−2.52**	**−3.16**	**−2.80**	**−2.79**	**−2.95**	**−1.64**	**−2.78**	**−2.78**
Other Asia	−1.07	−1.83	−1.38	−1.40	−1.66	−0.10	−1.35	−1.41
North America	**−2.50**	**−2.95**	**−2.70**	**−2.68**	**−2.93**	**−1.55**	**−2.64**	**−2.72**
Europe	**−5.95**	**−6.32**	**−6.09**	**−6.10**	**−5.62**	**−5.10**	**−6.03**	**−6.14**
MENA	0.17	−0.22	0.01	0.02	−0.25	0.40	−0.01	0.08
Sub-Saharan A.	−1.95	−2.37	−2.14	−2.12	−2.33	−1.13	−2.15	−2.06
South America	−1.60	−2.07	−1.80	−1.80	−2.03	−0.90	−1.78	−1.79
Oceania	**−1.63**	**−2.09**	**−1.82**	**−1.82**	**−1.99**	**−0.92**	**−1.86**	**−1.72**
ROW	2.20	2.09	2.13	2.16	1.82	2.41	2.07	2.26

	Scenario 5							
Japan	**−3.78**	**−4.61**	**−4.12**	**−4.13**	**−4.01**	**−3.17**	**−4.10**	**−4.10**
Russia	−5.68	−5.97	−5.80	−5.81	−3.92	−8.01	−5.76	−5.84
Belarus	3.11	2.37	2.79	2.78	5.00	−5.92	2.63	3.07
Ukraine	−38.70	−39.12	−38.92	−38.87	−42.71	−30.73	−39.00	−38.74
China	**−3.91**	**−4.48**	**−4.15**	**−4.16**	**−4.22**	**−2.66**	**−4.04**	**−4.26**
India	**−2.55**	**−3.20**	**−2.83**	**−2.83**	**−3.04**	**−1.61**	**−2.81**	**−2.82**
Other Asia	−1.07	−1.84	−1.39	−1.40	−1.72	−0.04	−1.35	−1.42
North America	**−2.53**	**−2.98**	**−2.72**	**−2.71**	**−3.00**	**−1.53**	**−2.67**	**−2.74**
Europe	**−6.15**	**−6.53**	**−6.30**	**−6.30**	**−5.87**	**−5.21**	**−6.23**	**−6.34**
MENA	0.17	−0.23	0.01	0.01	−0.30	0.44	−0.01	0.06
Sub-Saharan A.	−1.98	−2.40	−2.17	−2.15	−2.42	−1.10	−2.18	−2.10
South America	−1.61	−2.09	−1.81	−1.81	−2.09	−0.87	−1.79	−1.81
Oceania	**−1.63**	**−2.09**	**−1.82**	**−1.82**	**−2.03**	**−0.87**	**−1.86**	**−1.72**
ROW	2.22	2.10	2.15	2.19	1.84	2.45	2.09	2.29
	Scenario 6							
Japan	**−3.07**	**−3.51**	**−3.25**	**−3.26**	**−4.03**	**−1.63**	**−3.35**	**−3.07**
Russia	−8.73	−8.88	−8.83	−8.73	−6.38	−12.25	−8.65	−9.01
Belarus	9.72	8.80	9.23	9.35	24.10	−15.94	8.67	10.19
Ukraine	**−42.83**	**−43.01**	**−42.92**	**−42.91**	**−46.29**	**−34.01**	**−43.13**	**−42.59**
China	**−1.71**	**−1.75**	**−1.75**	**−1.73**	**−2.42**	**−0.57**	**−1.75**	**−1.68**
India	**−1.81**	**−1.93**	**−1.86**	**−1.90**	**−2.49**	**−0.81**	**−1.89**	**−1.82**
Other Asia	**−2.61**	**−2.79**	**−2.70**	**−2.67**	**−3.48**	**−1.15**	**−2.78**	**−2.51**
North America	**−1.65**	**−1.67**	**−1.64**	**−1.70**	**−2.23**	**−0.69**	**−1.68**	**−1.61**
Europe	**−3.14**	**−3.29**	**−3.19**	**−3.20**	**−3.93**	**−1.59**	**−3.27**	**−3.05**
MENA	**−2.18**	**−2.63**	**−2.34**	**−2.38**	**−3.19**	**−0.79**	**−2.49**	**−2.13**
Sub-Saharan A.	**−1.54**	**−1.55**	**−1.52**	**−1.59**	**−2.17**	**−0.55**	**−1.63**	**−1.41**
South America	**−1.60**	**−1.64**	**−1.61**	**−1.63**	**−2.20**	**−0.62**	**−1.69**	**−1.50**
Oceania	**−1.21**	**−1.23**	**−1.23**	**−1.21**	**−1.80**	**−0.28**	**−1.35**	**−1.00**
ROW	**−0.58**	**−0.55**	**−0.51**	**−0.61**	**−1.34**	**0.82**	**−0.70**	**−0.35**

Note: NENA stands for Middle East and North Africa. Coloring indicates relative magnitude for each scenario and for each country. In Scenario 6, we assume 25%, instead of 30%, larger elasticity values for σ^m due to numerical problems. Senders are in bold, and targets are underlined.

A.2 Supplementary Tables

While Table 3 shows Russia's total imports and exports, Table A.5 provides their breakdowns by its trade partners. Russia's imports from the senders would decrease by more than 70% by the sanctions and be replaced with imports from third parties. Russia's exports to the senders would also decrease similarly. However, in Scenario 6, the magnitude of export reduction would become smaller because of the export drive induced by the significant depreciation of the Russian ruble.

Table A.5: Impacts on Russia's Bilateral Trade [Unit: changes from the baseline equilibrium, %].

Trading partner	Scenario 1 (West +Japan)	2 (+India)	3 (+China)	4 (+India, China)	5 (+Belarus)	6 (Worldwide)
			Imports by Russia			
Japan	**−82.5**	**−82.4**	**−79.9**	**−79.8**	**−79.9**	**−86.7**
Belarus	13.0	13.2	24.0	24.4	43.3	62.3
Ukraine	−35.8	−35.6	−19.7	−19.1	−19.9	**−92.8**
China	27.5	28.0	**−81.1**	**−81.0**	**−81.1**	**−87.4**
India	19.2	**−77.1**	36.5	**−75.4**	**−75.5**	**−82.8**
Other Asia	23.5	24.1	47.7	48.6	47.6	**−84.5**
North America	**−74.7**	**−74.5**	**−73.8**	**−73.6**	**−73.7**	**−81.4**
Europe	**−80.9**	**−80.8**	**−78.7**	**−78.5**	**−78.6**	**−85.4**
MENA	12.5	13.0	24.1	24.7	24.1	**−81.4**
Sub-Saharan Africa	8.8	9.1	14.5	14.7	14.3	**−74.8**
Latin America	6.1	6.5	11.3	11.6	11.1	**−81.6**
Oceania	**−74.2**	**−74.0**	**−73.8**	**−73.7**	**−73.7**	**−81.4**
ROW	9.1	9.2	27.3	27.8	26.9	**−79.5**
			Exports from Russia			
Japan	**−83.6**	**−83.2**	**−80.5**	**−79.8**	**−79.8**	**−37.0**
Belarus	26.3	27.7	38.7	41.0	39.9	87.2
Ukraine	−18.1	−16.8	−12.8	−11.0	−12.0	**−61.0**
China	80.6	85.1	**−76.0**	**−74.9**	**−74.6**	**−17.4**
India	51.3	**−65.4**	89.8	**−63.1**	**−63.1**	**−26.9**
Other Asia	72.7	76.7	122.1	131.3	133.4	**−30.7**
North America	**−75.1**	**−74.7**	**−72.6**	**−72.0**	**−72.0**	**−36.4**
Europe	**−75.9**	**−75.4**	**−71.4**	**−70.5**	**−70.1**	**−27.4**
MENA	52.4	55.5	79.6	85.3	86.1	**−24.8**
Sub-Saharan Africa	32.6	34.5	41.2	43.9	43.6	**−27.1**
Latin America	57.0	60.7	91.4	98.8	99.7	**−40.2**
Oceania	**−69.3**	**−68.9**	**−66.9**	**−66.3**	**−66.4**	**−27.1**
ROW	35.9	38.4	45.9	49.2	48.5	**−50.1**

Note: NENA stands for Middle East and North Africa. Aggregated with Laspeyres prices. Excluding import tariffs, export taxes, and global transport services.

Table A. 6: Details of Sectoral Aggregation

Sectors	GTAP11 Sector
Wheat	wht
Other agriculture	pdr, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh
Coal	coa
Oil	oil
Natural gas	gas
Other mining	oxt
Food	cmt, omt, vol, mil, pcr, sgr, ofd, b_t
Petroleum and coal products	p_c
Light manufacturing	tex, wap, lea, lum, ppp
Heavy manufacturing	chm, bph, rpp, nmm, i_s, nfm, fmp, ele, eeq, ome, mvh, otn, omf
Electricity	Ely
Town gas	gdt
Transportation	otp, wtp, atp, whs
Other services	wtr, cns, trd, afs, cmn, ofi, ins, rsa, obs, ros, osg, edu, hht, dwe

Table A.1: Details of Regional Aggregation

Country/Region	GTAP11 Country/Region Classification
Japan	jpn
Russia	rus
Belarus	blr
Ukraine	ukr
China (including Hong Kong)	chn, hkg
India	ind
Other Asia	kor, mng, twn, xea, brn, khm, idn, lao, mys, phl, sgp, tha, vnm, xse, bgd, npl, pak, lka, xsa
North America (including Mexico)	can, usa, mex, xna
Europe (EU, UK, EFTA)	aut, bel, bgr, hrv, cyp, cze, dnk, est, fin, fra, deu, grc, hun, irl, ita, lva, ltu, lux, mlt, nld, pol, prt, rou, svk, svn, esp, swe, gbr, che, nor, xef
Middle East and North Africa (MENA)	bhr, irn, irq, isr, jor, kwt, lbn, omn, pse, qat, sau, syr, tur, are, xws, egy, mar, tun, xnf
Sub-Saharan Africa	ben, bfa, cmr, civ, gha, gin, nga, sen, tgo, xwf, tcd, cog, gab, xcf, xac, com, eth, ken, mdg, mwi, mus, moz, rwa, sdn, tza, uga, zmb, zwe, xec, bwa, nam, zaf, xsc
South America	arg, bol, bra, chl, col, ecu, pry, per, ury, ven, xsm, cri, gtm, hnd, nic, pan, slv, xca, dom, jam, pri, tto, xcb
Oceania	aus, nzl, xoc
Rest of the world (Central Asia, Former Soviet Union)	srb, alb, xee, xer, kaz, kgz, tjk, xsu, arm, aze, geo, xtw